SUPPLEMENT

TO THE

ENCYCLOPÆDIA,

OR

DICTIONARY

OF

ARTS, SCIENCES,

AND

MISCELLANEOUS LITERATURE.

IN THREE VOLUMES.

ILLUSTRATED WITH COPPERPLATES.

NON IGNORO QUÆ BONA SINT, FIERI MELIORA POSSE DOCTRINA, ET QUÆ NON OPTIMA, ALIQUO MODO ACUI TAMEN, ET CORRIGI POSSE.—*CICERO.*

VOL. I.

A———ELE

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ADVERTISEMENT

By the Rev. Dr GLEIG *to the* EDINBURGH EDITION.

It would ill become me to dismiss these Volumes from my hands without acknowledging that, from many of the most valuable disquisitions which they contain, I can claim no other merit than that of having ushered them into the world.

Those who have read, and who understand, the articles in the Encyclopædia Britannica, which were furnished by Professor Robison of Edinburgh, can hardly need to be informed, that to the same eminent philosopher I am indebted for the valuable articles Arch, Astronomy, Carpentry, Centre, Dynamics, Electricity, Impulsion, Involution, *and* Evolution *of Curves*, Machinery, Magnetism, Mechanics, Percussion, Piano-*Forte*, *Centre of* Position, Temperament *in Music*, Thunder, *Musical* Trumpet, Tschirnhaus, and Watchwork, in this Supplement. Of a friend and co-adjutor, whose reputation is so well established as Dr Robison's, I am proud to say, that, while I looked up to him, during the progress of this Work, as to my master in mathematical and physical science, I found him ever ready to support, with all his abilities, those great principles of religion, morality, and social order, which I felt it my own duty to maintain.

To Thomas Thomson, M. D. of Edinburgh, a man of like principles, I am indebted for the beautiful articles Chemistry, Mineralogy, and *Vegetable*, *Animal*, and *Dyeing* Substances ; of which it is needless for me to say any thing, since the Public seems to be fully satisfied that they prove their author eminently qualified to teach the science of chemistry.

The account of the French Revolution, and of the wars which it has occasioned, has been continued in this Supplement by the same Gentlemen by whom that account was begun in the Encyclopædia ; and, owing to the cause assigned in the article, probably with the same merits and the same defects.

My thanks are due to Dr William Wright for his continued kindness in communicating much curious botanical information: and to Mr Professor Playfair of the university of Edinburgh, for lending his assistance, occasionally, in the mathematical department; and for writing one beautiful article in that science, which is noticed as his in the order of the alphabet.

In compiling this Supplement, I have made very liberal use of the most respectable literary and scientific journals, both foreign and domestic; of all the late accounts of travels and voyages of discovery, which have obtained, or seem indeed to deserve, the regard of the Public; of different and opposite works on the French revolution, and what are emphatically called *French principles;* and even of the most approved Dictionaries, scientific and biographical. From no Dictionary, however, have I taken, without acknowledgment, any articles, except such as are floating everywhere on the surface of science, and are the property, therefore, of no living author.

After all my labour and industry, which, whatever be thought of my other merits, I am conscious have been great, no man can be more sensible than myself, that the Encyclopædia Britannica, even with the addition of this Supplement, is still imperfect. It would continue to be so, were another Supplement added to this by the most learned and laborious man on earth; for perfection seems to be incompatible with the nature of works constructed on such a plan, and embracing such a variety of subjects.

No candid reader will suppose that, by expressing myself thus, I mean to censure the plan of the Encyclopædia Britannica in particular; for, to the general excellence of that plan I have elsewhere borne my testimony, which I have yet seen no reason to retract. Experience has indeed led me to think, that it is susceptible of such improvements as would enable the principal Editor to carry the work *nearer* to perfection, even with less trouble to himself; but the purchasers of the third edition and this Supplement need not regret the want of those improvements, for they are such as few would discern, who have not paid the same attention that I have done to dictionaries of arts, sciences, and literature.

Before I take leave of the reader, I must account for the omission of one or two articles (chiefly biographical) which I had given him reason to expect

pect in these volumes. It was my intention at first to introduce into the Supplement articles on every subject which had been admitted into the Encyclopædia itself; and hence in the first supplementary volume will be found biographical sketches of men whose characters, though in some respects remarkable, have very little connection with science, arts, or literature. From this part of the original plan I was soon obliged to deviate. So many applications were made to me to insert accounts of persons who, whatever may have been their private virtues, were never heard of in the republic of letters, that I was under the necessity of excluding from the second volume the lives of *all* such as had not either been themselves eminent in literature, or in some liberal art or science, or been conspicuous as the *patrons* of science, arts, and literature, in others. Hence the omission of the life referred to from AUBIGNE in the first volume, and of one or two others, to which references are made in the same way. The life of Mr James Hay Beattie of Aberdeen, whose originality of genius, ardent love of virtue, and early and extensive attainments in science and literature; raise him almost to the eminence of BARRETIER, of whom we have so pathetic an account from the pen of Johnson, I omitted with regret; but I thought not myself authorized to publish what his father had then only distributed among a few particular friends. For the omission of the life of Soame Jenyns I can make no apology: it was the consequence of forgetfulness.

FOR the *errors* of these two volumes, whether typographical or of a nature more important, I have perhaps no occasion to solicit greater indulgence than will be voluntarily extended to me by a generous public. The progress, however, of science, and of the revolutionary events in Europe, has been such, since great part of them was printed, that I must request the reader, in justice to myself, to proceed directly from the article GALVANISM to TORPEDO, and from REVOLUTION to the life of Marshal SUWOROW.

UNDER the title TRANSLATION, both in the Encyclopædia and in the Supplement, expressions are made use of, which may lead the reader to suppose that Mr Fraser Tytler was indebted for the general laws of the art, which he so ably illustrates, to Dr Campbell's Preliminary Dissertations to his Translation of the Gospels. It is but justice to declare my perfect

perfect conviction, as it was that of Dr Campbell himself, that Mr Tytler and he were equally intitled to the merit of having discovered those laws; and that however coincident in opinion, neither of them, when composing their separate works, had the smallest suspicion that the other had ever employed his thoughts on the subject. The only difference seems to have been in the mode of their discovery: Mr Tytler having deduced the laws of the art by regular analytical inference from his own description of a perfect translation; whereas Dr Campbell appears to have fortunately discovered them without that process of deduction.

The publisher begs leave to add to the foregoing, that the different Geographical articles so far as relate to America are taken from the Rev. Dr Morse's American Gazetteer. The article *United States* is extracted from the new Edition of Dr Morse's Universal Geography, and the article *New England* was written by the same author on purpose for this Supplement. The account of the Lucernal Microscope under the head of *Optics* was furnished by the Rev. Dr John Prince, the author of the improvements. The description of the *American Air Pump* in the article *Pneumatics*, was likewise inserted by permission of Dr Prince, the inventor. The corrections of the account of this Pump which was published in the Encyclopædia, are original. The observations on Vision by Dr Hosack of New York were published by his permission. The two articles of *Artificial Horizon*, and the *New Log* are published in an appendix by permission of Mr Gould the Patentee.

SUPPLEMENT

TO THE

ENCYCLOPÆDIA.

AARONSBURG, a poſt town in Northumberland county, Pennſylvania, lies near the head of Penn's creek, it is chiefly a German ſettlement, about 30 miles weſterly from Lewiſburg and 40 W. by N. from Sunbury, 160 miles W. N. W. from Philadelphia.—*Morse.*

ABACISCUS, in architecture, the ſame with ABACUS; for which, ſee *Encyclopædia.*

ABACOOCHEE, or *Cooſee*, a large river riſing in the S. W. Territory, paſſing into Georgia, through the Cherokee into the Creek country, where it unites with the Oakfuſkee, and forms the Alibama.—*Morse.*

ABATIS, or ABATTIS, is, in military language, the name of a kind of retrenchment made of felled trees. When the emergency is ſudden, the trees are merely laid lengthwiſe beſide each other, with their branches pointed towards the enemy, to prevent his approach, whilſt the trunks ſerve as a breaſtwork before thoſe by whom the abatis is raiſed. When the abatis is meant for the defence of a paſs or entrance, the boughs of the trees are generally ſtripped of their leaves and pointed; the trunks are planted in the ground; and the boughs are interwoven with each other. It is needleſs to add that the cloſer the trees are laid or planted together, the more ſecure is the defence which they afford; and if, when they are planted, a ſmall ditch be dug towards the enemy, and the earth thrown up properly againſt the lower part of the abatis, it will be very difficult to paſs it if well defended.—*Simes's Military Guide.*

ABBEVILLE *County*, in Ninety-ſix diſtrict, S. Carolina, bounded on the N. E. by the Saluda, and on the S. W. by the Savannah, is 35 miles in length and 21 in breadth; contains 9197 inhabitants, including 1665 ſlaves. The ſoil is rich and well watered. —*Morse.*

ABBREVIATION OF FRACTIONS, in arithmetic and algebra, is the reducing of them to lower terms; which is done by dividing the numerator and denominator by ſome number or quantity which will divide both without leaving a remainder of either.

ABERRATION, in optics (in Encycl.), refers the reader to the article OPTICS, n° 17, 136, 173. It ſhould have referred him to OPTICS, n° 17, and 251—256.

ABERRATION of the Viſual Ray, is a phenomenon, of which, though ſome account of it has been given in the Encyclopædia (ſee ABERRATION, in aſtronomy; and the article ASTRONOMY, n° 337.), one of the moſt candid of our correſpondents requires a fuller explanation. If ſuch an explanation be requiſite to him, it muſt be much more ſo to many others; and we know not where to find, or how to deviſe, one which would be more ſatisfactory, or more familiar, than the following by Dr. Hutton.

"This effect (ſays he) may be explained and familiarized by the motion of a line parallel to itſelf, much after the manner that the compoſition and reſolution of forces are explained. If light have a progreſſive motion, let the proportion of its velocity to that of the earth in her orbit be as the line BC to the line AC; then, by the compoſition of theſe two motions, the particle of light will ſeem to deſcribe the line BA or DC, inſtead of its real courſe BC; and will appear in the direction AB or CD, inſtead of its true direction CB. So that if AB repreſent a tube, carried with a parallel motion by an obſerver along the line AC, in the time that a particle of light would move over the ſpace BC, the different places of the tube being AB, *ab*, *cd*, CD; and when the eye, or end of the tube, is at A, let a particle of light enter the other end at B; then when the tube is at *ab*, the particle of light will be at *e*, exactly in the axis of the tube; and when the tube is at *cd*, the particle of light will arrive at *f*, ſtill in the axis of the tube; and, laſtly, when the tube arrives at CD, the particle of light will arrive at the eye or point C, and conſequently will appear to come in the direction DC of the tube, inſtead of the true direction BC: and ſo on, one particle ſucceeding another, and forming a continued ſtream or ray of light in the apparent direction DC. So that the apparent angle made by the ray of light with the line AE is the angle DCE, inſtead of the true angle BCE; and the difference BCD, or ABC, is the quantity of the aberration." Plate II. fig. 1.

ABERRATION of the Planets, is equal to their geocentric motion, or, in other words, to the ſpace which each appears to move as ſeen from the earth, during the time that light employs in paſſing from the planet to the eye of the obſerver. Thus the ſun's aberration in longitude is conſtantly 20″, that being the ſpace actually moved by the earth; but apparently by the ſun in 8 minutes and 7 ſeconds, the time in which light paſſes from the ſun to the earth. If then the diſtance of any ter, at all distances, tending towards each other by a fixed law, we might be led to consider mutual attraction as an *essential* property of that substance, and think no more of inquiring into its cause, than we think of inquiring into the cause of extension. But when we find that the same particles, which at one distance seem to attract each other, are at a different distance kept asunder by a power of repulsion, which no force, with which we are acquainted, is able to overcome, we cannot attribute the *principle* or *cause* of these changes to brute matter, but must refer it to some other agent exciting power according to a fixed law.

It is the fashion at present to despise all metaphysical inquiries as abstruse and useless; and on this account we doubt not but some of our readers will turn away from this disquisition with affected disgust, whilst the petulant and unthinking chemist, proud of possessing the secrets of his science, will deem it superfluous to inquire after any other natural agents than those of which he has been accustomed to talk. But with the utmost respect for the discoveries made by modern chemists, which we acknowledge to be both numerous and important, we beg leave to observe, that though these gentlemen have brought to light many events and operations of nature formerly unknown, and have shown that those operations are carried on by established laws, none of them can say with certainty that he has discovered a single agent. The most enlightened of them indeed pretend not to have discovered in one department of science more than Newton discovered in another; for they well know that agents and agency cannot be subjected to any kind of physical experiments. Our very notions of these things are derived wholly from our own consciousness and reflection; and when it is considered what dreadful consequences have in another country resulted from that pretended philosophy which excludes the agency of mind from the universe, it is surely time to inquire whether our consciousness and reflection do not lead us to refer real agency to mind alone. Let this be our apology both to the real and to the affected enemies of metaphysics for endeavouring to draw their attention to the present question. It is a question of the utmost importance, as well to science as to religion, and if the laws of human thought decide it, as we have endeavoured to show that they do, we may without hesitation affirm, that the impious philosophy of France can never gain ground but among men incapable of patient thinking.

ACTON, a township in Middlesex county, Massachusetts, containing 853 inhabitants; 24 miles N. W. of Boston.—*Morse.*

ACWORTH, a township in Cheshire county, New-Hampshire, incorporated in 1766, and contains 704 inhabitants; 8 miles E. by N. from Charlestown, and 73 N. W. by W. from Portsmouth.—*ib.*

ADAMAS, a name given, in astrology, to the moon.

ADAMS, a township in Berkshire county, Massachusetts, containing 2040 inhabitants, is about 140 miles N. W. of Boston. In the northern part of this town, is a great natural curiosity. A pretty mill stream, called Hudson's Brook, which rises in Vermont, and falls into the north branch of Hoosuck river, has, for 30 or 40 rods, formed a very deep channel, in some places 60 feet deep, through a quarry of white marble. Over this channel, where deepest, some of the rocks remain, and form a natural bridge. From the top of this bridge to the water, is 62 feet; its length is about 12 or 15, and its breadth about 10. Partly under this bridge, and about 10 or 12 feet below it, is another, which is wider, but not so long; for at the east end they form one body of rock, 12 or 14 feet thick, and under this the water flows. The rocks here are mostly white, and in other places clouded, like the coarse marble common at Lanesborough, and in other towns in Berkshire county.—*Morse.*

ADDISON *County*, in Vermont, is on the east side of Lake Champlain, and is divided nearly into equal parts by Otter creek; has Chittenden county on the N. and Rutland county on the S. and contains 6449 inhabitants, dispersed in 21 townships. It is about 30 miles by 27: a range of the green mountains passes through it. Chief town Middlebury, granted Nov. 1761.—*ib.*

ADSON's *Town*, lies near the N. E. line of New-Jersey, and S. E. of the Drowned Lands; 27 miles N. of Morristown, and 24 N. W. of Patterson.—*ib.*

ÆOLUS, in mechanics, a small machine invented by Mr. Tidd for refreshing or changing the air in rooms when it becomes too hot or otherwise unfit for respiration. The æolus is so contrived as to supply the place of a square of glass in the window, where it works, with very little noise, like the sails of a wind-mill or a smoke-jack.

AEROLOGY is a branch of science which was detailed in the Encyclopædia at sufficient length, and according to the principles which were then generally admitted by chemists. Subsequent experiments, however, have shown, that some of those principles are erroneous, and of course that some of the opinions advanced in the article AEROLOGY are inconsistent with facts. These opinions must be corrected; but instead of swelling this volume with a new article AEROLOGY, we apprehend that it will be more acceptable to our scientific readers to refer them for those corrections to the article CHEMISTRY in this Supplement.

AFFUERA, one of the islands of Juan Fernandes, on the South Sea coast, in the kingdom of Chili. Long. from the meridian of Callao, 30. 20. about 400 leagues to the N. of Cape Horn. This coast swarms with sea lions and wolves.—*Morse.*

AFGHANS, are a people in India who inhabit a province of CABUL or CABULISTAN (see Encycl.), and have always been connected with the kingdoms of Persia and Hindostan. They boast of being descended of Saul the first king of Israel; of whose advancement to the royal dignity they give an account which deviates not very widely from the truth. They say indeed, that their great ancestor was raised from the rank of a shepherd, not for any princely qualities which he possessed, but because his stature was exactly equal to the length of a rod which the angel Gabriel had given to the prophet Samuel as the measure of the stature of him whom God had destined to fill the throne of Israel.

SAUL, whose descent, according to some of them, was of Judah, and according to others of Benjamin, had, they say, two sons, BERKIA and IRMIA, who served David, and were beloved by him. The sons of Berkia and Irmia were AFGHAN and USBEC, who, during the

the reigns of David and Solomon, diſtinguiſhed themſelves, the one for his corporeal ſtrength, and the other for his learning. So great indeed was the ſtrength of *Afghan*, that we are told it ſtruck terror even into demons and genii.

This hero uſed frequently to make excurſions to the mountains; where his progeny, after his death, eſtabliſhed themſelves, lived in a ſtate of independence, built forts, and exterminated infidels. When the ſelect of creatures (the appellation which this people give to *Mahomet)* appeared upon earth, his fame reached the *Afghans*, who ſought him in multitudes under their leaders *Khalid* and *Abdul Reſpid*, ſons of *Walid;* and the prophet honouring them with this reception—"Come, O *Muluc*, or Kings!" they aſſumed the title of *Melic*, which they retain to this day.

The hiſtory, from which this abſtract is taken, gives a long and unintereſting detail of the exploits of the Afghans, and of their zeal in overthrowing the temples of idols. It boaſts of the following monarchs of their race who have ſat upon the throne of *Dehli:* Sultan Behlole, *Afghan* Lodi, Sultan Secander, Sultan Ibrahim, Shir Shah, Islam Shah, Adil Shah Sur. It alſo numbers the following kings of *Gaur* deſcended of the Afghan chiefs: Solaiman *Shah Gurzani*, Beyazid *Shah*, and Kutb *Shah;* beſides whom, their nation, we are told, has produced many conquerors of provinces. The Afghans are ſometimes called *Solaimani*, either becauſe they were formerly the ſubjects of Solomon king of Iſrael, or becauſe they inhabit the mountains of Solomon. They are likewiſe called Patans, a name derived from the *Hindi* verb *Paitna* "to ruſh" which was given to them by one of the Sultans whom they ſerved, in conſequence of the alacrity with which they had attacked and conquered his enemies. The province which they occupy at preſent was formerly called *Roh*; and hence is derived the name of the *Rohillas*. The city which was eſtabliſhed in it by the *Afghans* was called by them *Paiſhwer* or *Paiſher*, and is now the name of the whole diſtrict. The ſects of the Afghans are very numerous; of which the principal are, *Lodi, Lohouni, Sur, Serwani, Yuſufzihi, Bangiſh, Dilazaui, Khetti, Yaſin, Khail*, and *Beloje*. They are *Muſulmans*, partly of the *Sunni*, and partly of the *Shiek* perſuaſion.

Though they are great boaſters, as we have ſeen, of the antiquity of their origin, and the reputation of their race, other *Muſulmans* reject their claim, and conſider them as of modern, and even of baſe extraction.

This is probably a calumny; for it ſeems inconſiſtent with their attention to the purity of their deſcent—an attention which would hardly be paid by a people not convinced of their own antiquity. They are divided into four claſſes. The firſt is the *pure* claſs, conſiſting of thoſe whoſe fathers and mothers were *Afghans*. The ſecond claſs conſiſts of thoſe whoſe fathers were *Afghans* and mothers of another nation. The third claſs contains thoſe whoſe mothers were *Afghans* and fathers of another nation. The fourth claſs is compoſed of the children of women whoſe mothers were *Afghans* and fathers and huſbands of a different nation. Perſons who do not belong to one of theſe claſſes are not called *Afghans*.

This people have at all times diſtinguiſhed themſelves by their courage, both ſingly and unitedly, as principals and auxiliaries. They have conquered for their own princes and for foreigners, and have always been conſidered as the main ſtrength of the army in which they ſerved. As they have been applauded for virtues, they have alſo been reproached for vices, having ſometimes been guilty of treachery, and of acting the baſe part even of aſſaſſins.

Such is the account of the Afghans publiſhed in the ſecond volume of the Aſiatic Reſearches. It was tranſlated from a Perſian abridgment of a book written in the Puſhto language, and called *The Secrets of the Afghans*, and communicated by Henry Vanſittart, Eſq; to Sir William Jones, then Preſident of the Aſiatic Society. Their claim to a deſcent from Saul king of Iſrael, whom they call Melic Talut, is probably of not a very ancient date; for the introduction of the angel Gabriel with his rod, gives to the whole ſtory the air of one of thoſe many fictions which Mahomet borrowed from the later rabbins. Sir William Jones, however, though he ſurely gave no credit to this fable, ſeems to have had no doubt but the Afghans are deſcendants of Iſrael. "We learn (ſays he) from Esdras, that the ten tribes, after a wandering journey, came to a country called *Arſareth*, where we may ſuppoſe they ſettled: now the *Afghans* are ſaid by the beſt *Perſian* hiſtorians to be deſcended from the *Jews*. They have traditions among themſelves of ſuch a deſcent; and it is even aſſerted, that their families are diſtinguiſhed by the names of *Jewiſh* tribes, although, ſince their converſion to *Iſlam*, they ſtudiouſly conceal their origin from all whom they admit not to their *ſecrets*. The *Puſhto* language, of which I have ſeen a dictionary, has a maniſeſt reſemblance to the *Chaldaick;* and a conſiderable diſtrict under their dominion is called *Hazareh* or *Hazaret*, which might eaſily have been changed into the word uſed by Esdras. I ſtrongly recommend an inquiry into the literature and hiſtory of the *Afghans*."

It is to co-operate with this accompliſhed ſcholar that we have inſerted into our Work this ſhort account of that ſingular people; and it is with pleaſure that, upon the authority of Mr Vanſittart, we can add, that a very particular account of the *Afghans* has been written by the late Hafiz Rahmat *Khan*, a chief of the *Rohillahs*, from which ſuch of our readers as are oriental ſcholars may derive much curious information.

AGAMENTICUS, a mountain of conſiderable elevation in the diſtrict of Maine, diſtant about ſix miles from Bald Head, and eight from York harbor. Lat. 43. 16. N. and 70. 39. W. long. from Greenwich. It is a noted land-mark for ſeamen, and is a good directory for the entry of Paſcataqua harbor, as it lies very nearly in the ſame meridian with it, and with Pigeon Hill, on Cape Ann. The mountain is covered with wood and ſhrubs, and affords paſture up to its ſummit, where there is an enchanting proſpect. The cultivated parts of the country, eſpecially on the S. and S. W. appear as a beautiful garden, interſected by the majeſtic river Paſcataqua, its bays and branches. The immenſe ranges of mountains on the N. and N. W. afford a ſublime ſpectacle; and on the ſea ſide, the various indentings of the coaſt, from Cape Ann to Cape Elizabeth, are plainly in view in a clear day; and the Atlantic ſtretches to the E. as far as the power of viſion extends. At this ſpot the bearings of the following objects were taken, with a good ſurveying inſtrument, October 11, 1780.

Submit of the White Mountains, N. 15. W.
Cape Porpoise, N. 63. E.
Rochester Hill, N. 64. W.
Tuckaway South Peak, S. 80. W.
Frost's Hill, Kittery, S. 57. W.
Saddle of Bonabeag, N. 14. W.
Isle of Shoals Meeting-house, S. 6. E.
Varney's Hill, in Dover, distant 10¼ miles by mensuration, N. 89. W. Variation of the Needle, 6. W.—*Morse.*

ALABAMA, an Indian village, delightfully situated on the banks of the Mississippi, on several swelling green hills, gradually ascending from the verge of the river. These Indians are the remains of the ancient Alabama nation, who inhabited the east arm of the *Great Mobile river*, which still bears their name, now possessed by the Creeks, or Muscogulges, who conquered the former.—*ib.*

ALABAMA *River*, is formed by the junction of the *Coosa* or *Coosee*, or *High Town river*, and Tallapoosee river, at Little Tallasee, and runs in a S. W. direction, until it meets Tombigbee river from the N. W. at the great island which it there forms, 90 miles from the mouth of Mobile bay, in the gulf of Mexico. This beautiful river has a gentle current, pure waters, and excellent fish. It runs about 2 miles an hour, is 70 or 80 rods wide at its head, and from 15 to 18 feet deep, in the driest season. The banks are about 50 feet high, and seldom, if ever, overflowed. Travellers have gone down in large boats, in the month of May, in 9 days from Little Tallasee to Mobile bay, which is about 350 miles by water. Its banks abound with valuable productions in the vegetable and mineral kingdoms.—*ib.*

ALABASTER, or *Eleuthera*, one of the Bahama or Lucayo islands, on which is a small fort and garrison. It is on the Great Bahama Bank. The soil of this island, and Harbor Island, which lies at the north end of it, is better than Providence Island, and produces the greatest part of the pine-apples that are exported; the climate is very healthy. N. lat. 25. to 26. W. long. 75. to 76. 5.—*ib.*

ALACHUA SAVANNAH, is a level green plain, in the country of the Indians of that name, in E. Florida, situated about 75 miles west from St. Augustine. It is above 15 miles over, and 50 in circumference; and scarcely a tree or bush of any kind to be seen on it. It is encircled with high sloping hills, covered with waving forests, and fragrant orange groves, rising from an exuberantly fertile soil. The ancient *Alachua* town stood on the borders of this savannah; but the Indians removed to *Cuscowilla*, 2 miles distant, on account of the unhealthiness of the former scite, occasioned by the stench of the putrid fish and reptiles, in the summer and autumn, driven on shore by the alligators, and the noxious exhalations from the marshes of the savannah. Though the horned cattle and horses bred in these meadows are large, sleek, sprightly, and fat, yet they are subject to mortal diseases; such as the water rot, or scald, occasioned by the warm water of the savannah; while those which range in the high forests are clear of this disorder.—*ib.*

ALACRANES, LOS, a long range of shoals, banks, and rocks, on the south side of the gulph of Mexico, opposite the peninsula of Yucatan, east from Stone Bank, and west from Cape St. Antonio; within the 23d deg. of N. lat. and between the 89th and 91st degrees of W. long.—*Morse.*

ALASKA, a long peninsula on the N. W. coast of America, formed by Bristol bay and the ocean on the N. W. and N. and by the ocean and the waters of Cook's river on the S. and S. E. At its extremity are a number of islands, the chief of which, in their order westward, are, Oonemak, Oonalasha, and Ocumnak, which form part of the chain or cluster of islands called the Northern Archipelago. Capt. Cook, on his return in 1779, passed through the channel east of Oonemak island. See *N. W. Coast of America.*—*ib.*

ALATAMAHA, a navigable river of Georgia. It rises in the Cherokee mountains, near the head of a western branch of Savannah river, called Tugulo. In its descent through the mountains it receives several auxiliary streams; thence it winds, with considerable rapidity, through the hilly country 250 miles, from whence it throws itself into the open, flat country, by the name of *Oakmulgee*. Thence, after meandering for 150 miles, it is joined by the *Oconee*, which likewise has its source in the mountains. After this junction, it assumes the name of Alatamaha, when it becomes a large majestic river; and flowing with a gentle current through forests and plains 100 miles, discharges itself into the Atlantic by several mouths. The north channel glides by the heights of Darien, about 10 miles above the bar, and after several turnings, enters the ocean between Sapelo and Wolf islands. The south channel, which is esteemed the largest and deepest, after its separation from the north, descends gently, taking its course between M'Intosh and Broughton islands; and at last by the west coast of St. Simon's sound, between the south end of the island of that name, and the north end of Jekyl island. At its confluence with the Atlantic, it is 500 yards wide.—*ib.*

ALBAN's St. a township in Franklin county, Vermont, on Lake Champlain, opposite N. Hero island, 256 inhabitants.—*ib.*

ALBANY *County*, on Hudson's river, in the state of New-York, lies between Ulster and Saratoga; its extent 46 miles by 28. By the state census, Jan. 20, 1796, the number of electors in this county were 6087, and the number of towns 11.—*ib.*

ALBANY, the chief town of the above county, is situated on the west bank of Hudson's river, 160 miles north of the city of New-York, to which it is next in rank, and 340 S. of Quebec. N. lat. 42. 39. W. long. 73. 30. This city and suburbs, by enumeration in 1797, contained 1263 buildings, of which 863 were dwelling-houses, and 6021 inhabitants. Many of them are in the Gothic style, with the gable end to the street, which custom the first settlers brought from Holland; the new houses are built in the modern style. Its inhabitants are collected from various parts of the world, and speak a great variety of languages, but the English predominates; and the use of every other is gradually lessening. Albany is unrivalled for situation, being nearly at the head of sloop navigation, on one of the noblest rivers in the world. It enjoys a salubrious air, and is the natural emporium of the increasing trade of a large extent of country W. and N.—a country of an excellent soil, abounding in every article

article for the W. India market; plentifully watered with navigable lakes, creeks and rivers, settling with almost unexampled rapidity, and capable of affording subsistence to millions of inhabitants: and when the contemplated locks and canals are completed, and convenient roads opened into every part of the country, all which will, it is expected, be accomplished in the course of a few years, Albany will probably increase and flourish beyond almost any other city or town in the United States. The public buildings are, a Low Dutch church, of ancient and very curious construction, one for Episcopalians, two for Presbyterians, one for Germans, or High Dutch, and one for Methodists; an hospital, city hall, and a handsome brick jail. The corporation consists of a mayor, recorder, six aldermen, and as many assistants. In the year 1609, Henry Hudson, whose name the river bears, ascended it in his boat to *Aurania*, the spot on which Albany now stands.

The improvements in this city, within 5 or 6 years past, have been very great in almost all respects. Wharves have been built on the river, the streets have been paved, a bank instituted, a new and handsome style of building introduced, and now excellent water (an article in which this city has hitherto been extremely deficient, having been obliged to use the dirty water of the river) is about to be conducted into the various parts of the city, from a fine spring 5 miles west of the city. For these improvements the inhabitants are indebted to the patriotic exertions of a very few gentlemen.

One mile north of this city, in its suburbs, near the manor house of lieutenant governor Van Renssalaer, are very ingeniously constructed, extensive and useful works, for the manufacture of Scotch and rappee snuff, roll and cut tobacco of different kinds, chocolate, mustard, starch, hair powder, split pease, and hulled barley. These valuable works are the property of Mr. James Caldwell, who unfortunately lost a complete set of similar works, by fire, in July, 1794, with the stock, valued at 37,500 dollars. It is a circumstance worthy of remark, and is evincive of the industry and enterprize of the proprietor, that the whole of the present buildings and machinery were begun and completed in the short space of eleven months. These works are decidedly superior to any of the kind in America. All the articles above enumerated, even to the spinning of tobacco, are manufactured by the aid of water machinery. For the invention of this machinery the proprietor has obtained a patent. These works give employment and subsistence to 40 poor boys, and a number of workmen. Men who make such efforts to advance American manufactures, deserve well of their country.—*Morse*.

Albany, a British fortress in New South Wales, in N. America, situated on the river of the same name. N. lat. 53. 10. W. long. 87. 20.—*ib*.

Albany *River*, falls into James's bay, in N. America, in N. lat. 51. 30. W. long. 84. 30. This river runs in a N. E. direction, and has communication with a vast chain of small lakes, in a line S. W. to the S. end of Winnipeg lake, a body of water next in size to Lake Superior.—*ib*.

ALBATEGNI, an Arabic prince of Batan in Mesopotamia, was a celebrated astronomer, about the year of Christ 880, as appears by his observations. He is also called *Muhammed ben Geber Albatani*, *Mahomet the son of Geber*, and *Muhamedes Aractensis*. He made astronomical observations at Antioch, and at Racah or Aracta, a town of Chaldea, which some authors call a town of Syria or of Mesopotamia. He is highly spoken of by Dr Halley, as *vir admirandi acuminis, ac in administrandis observationibus exercitatissimus*.

Finding that the tables of Ptolemy were imperfect, he computed new ones, which were long used as the best among the Arabs: these were adapted to the meridian of Aracta or Racah. Albategni composed in Arabic a work under the title of *The Science of the Stars*, comprising all parts of astronomy, according to his own observations and those of Ptolemy. This work, translated into Latin by Plato of Tibur, was published at Nuremberg in 1537, with some additions and demonstrations of Regiomontanus; and the same was reprinted at Bologna in 1645, with this author's notes. Dr Halley detected many faults in these editions.—*Phil. Trans.* for 1693, N° 204.

In this work Albategni gives the motion of the sun's apogee since Ptolemy's time, as well as the motion of the stars, which he makes one degree in 70 years. He made the longitude of the first star of Aries to be 18° 2′; and the obliquity of the ecliptic 23° 35′. And upon Albategni's observations were founded the Alphonsine tables of the moon's motions; as is observed by Nic. Muler, in the *Tab. Frisicæ*, p. 248.

ALBEMARLE *County*, in Virginia, lies between the Blue ridge and the tide waters, and contains 12,585 inhabitants, including 5579 slaves. Its extent about 35 miles square.—*Morse*.

Albemarle Sound, on the coast of North-Carolina, is a kind of inland sea, 60 miles in length, and from 8 to 12 in breadth. It lies north of Pamplico Sound, and communicates with it; as it likewise does with Currituck Inlet. It receives Roanoke and Meherrin rivers; and the passage into it from the sea is called Roanoke Inlet.—*ib*.

ALDERAIMIN, a star of the third magnitude, in the right shoulder of the constellation Cepheus.

ALEXANDRIA, a township in Grafton county, New-Hampshire, containing 298 inhabitants; incorporated in 1782.—*Morse*.

Alexandria, a township in Hunterdon county, New-Jersey, containing 1503 inhabitants, inclusive of 40 slaves.—*ib*.

Alexandria, a small town in Huntingdon county, Pennsylvania, on the Frankstown branch of Juniata river; 192 miles N. W. of Philadelphia.—*ib*.

Alexandria, formerly called *Belhaven*, a city in Virginia, situated on the southern bank of the Patowmac river, in Fairfax county, about 5 miles S. W. from the Federal City, 60 S. W. from Baltimore, 60 N. from Fredericksburgh, 168 N. of Williamsburgh, and 290 from the sea; 38. 45. N. lat. and 77. 10. W. long. Its situation is elevated and pleasant. The soil is clayey. The original settlers, anticipating its future growth and importance, laid out the streets on the plan of Philadelphia. It contains about 400 houses, many of which are handsomely built, and 2748 inhabitants. This city, upon opening the navigation of Patowmac river, and in consequence of its vicinity to the future seat of the federal government, bids fair to be one of the

the most thriving commercial places on the continent. —*Morse*.

ALFORD, a township in Berkshire county, Massachusetts, containing 577 inhabitants; 145 miles westward from Boston.—*ib*.

ALFRAGAN, Alferganı, or *Fargani*, a celebrated Arabic astronomer, who flourished about the year 800. He was so called from the place of his nativity, Fergan, in Sogdiana, now called Maracanda, or Samarcand, anciently a part of Bactria. He is also called *Ahmed* (or *Muhammed) ben Cothair*, or *Katir*. He wrote the Elements of Astronomy in 30 chapters or sections. In this work the author chiefly follows Ptolemy, using the same hypothesis, and the same terms, and frequently citing him. Of Alfragan's work there are three Latin translations, of which the last and best was made by Golius, professor of mathematics and oriental languages in the university of Leyden. This translation, which was published in 1669, after the death of Golius, is accompanied with the Arabic text, and with many learned notes on the first nine chapters, which would undoubtedly have been carried to the end, had the translator lived to complete his plan.

ALGORAB, a fixed star of the third magnitude, in the right wing of the constellation Corvus.

ALHAZEN, an Arabian astronomer, who flourished in Spain about the beginning of the 12th century. See Astronomy, n° 6. Encycl.

ALKANSAS, or *Arkansas*, an Indian nation in Louisiana, on the west side of Mississippi river, near the river of the same name, in N. lat. 34. See *Arkansas River*.—*Morse*.

ALLBURG, a township in Franklin county, Vermont, containing 446 inhabitants; situated on *Missisque Bay*.—*ib*.

ALLEGHANY *Mountains*. See Appalachian, *Encyclopædia*.

Alleghany *River*, in Pennsylvania, rises on the western side of the Alleghany Mountain, and after running about 200 miles in a S. W. direction, meets the Monongahela at Pittsburg, and both united, form the Ohio. The lands on each side of this river, for 150 miles above Pittsburg, consist of white oak and chesnut ridges, and, in many places, of poor pitch pines, interspersed with tracts of good land, and low meadows. This river, and the Ohio likewise, from its head waters until it enters the Mississippi, are known and called by the name of Alleghany River, by the Seneca, and other tribes of the Six Nations, who once inhabited it.—*Morse*.

Alleghany *County*, in Pennsylvania, extends from the junction of the river of that name with the Ohio, where its chief town, Pittsburg, is situated, to the New-York line. It contains 10,309 inhabitants, including 159 slaves.—*ib*.

Alleghany, is the most western county in Maryland, and has Pennsylvania on the north. The windings of the Potowmac River separate it from Virginia on the south, and Sideling hill Creek divides it from Washington county on the east. It contains 4809 inhabitants, including 258 slaves. Cumberland is its chief town.—*ib*.

ALLEMAND, a river which falls into the Mississippi from the S. E. about 43 miles S. of the Natches. —*ib*.

ALLENSTOWN, a town in New-Jersey, in Monmouth county, 15 miles N. E. from Burlington, and 13 S. by E. from Princeton.—*Morse*.

Allenstown, a township in Rockingham county, New-Hampshire, containing 254 inhabitants; situated on the E. side of Merrimack river, 25 miles N. W. of Exeter, and 40 from Portsmouth.—*ib*.

ALLEN-TOWN, in Pennsylvania, Northampton county, on the point of land formed by Jordan's creek, and the Little Lehiegh. It contains about 90 houses, and an academy.—*ib*.

ALLOWAY *Creek*, in Salem county, New-Jersey, empties into the Delaware. It is navigable 16 miles, interrupted, however, by several draw-bridges.—*ib*.

ALL-SAINTS, a parish in Georgetown district, South-Carolina, containing 2225 inhabitants, of whom 429 are whites, and 1795 slaves. It sends a member to each house of the state legislature.—*ib*.

All-Saints *Bay*, a captainship in the middle division of Brazil, so called from a large bay of that name, bounded N. by the Ria Real; on the S. by that of Las Ilheos; on the E. by the ocean; and on the W. by three unconquered nations of Indians. It is reckoned one of the richest and most fertile captainships in all Brazil, producing great quantities of cotton and sugar. The bay itself is about 2½ leagues over, interspersed with a number of small, but pleasant islands, and is of prodigious advantage to the whole country. It has several cities and towns, particularly St. Salvador, which is its capital. All-Saints Bay lies in lat. 12. 3. S. long. 40. 10. W. See *Salvador*.—*ib*.

ALMAMON, was a philosopher and astronomer, who, in the beginning of the 9th century, ascended the throne of the caliphs of Bagdat. He was the son of Harun Al-Rashid, and grandson of Almansor. His name is otherwise written, *Mamon*, *Almaon*, *Almamun*, *Alamoun*, or *Al-Maimon*. Having been educated with great care, and with a love for the liberal sciences, he applied himself to cultivate and encourage them in his own country. For this purpose he requested the Greek emperors to supply him with such books on philosophy as they had among them; and he collected skilful interpreters to translate them into the Arabic language. He also encouraged his subjects to study them; frequenting the meetings of the learned, and assisting at their exercises and deliberations. He caused Ptolemy's Almagest to be translated in 827, by Isaac Ben-honain, and Thabet Ben-korah according to Herbelot, but, according to others, by Sergius, and Alhazen the son of Joseph. In his reign, and doubtless by his encouragement, an astronomer of Bagdat, named Habash, composed three sets of astronomical tables.

Almamon himself made many astronomical observations, and determined the obliquity of the ecliptic to be then 23° 35′ (or 23° 33′ in some manuscripts), but Vossius says 23° 51′ or 23° 34′. He also caused skilful observers to procure proper instruments to be made, and to exercise themselves in astronomical observations; which they did accordingly at Shemasi in the province of Bagdat, and upon Mount Cassius near Damus.

Under the auspices of Almamon also a degree of the meridian was measured on the plains of Sinjar or Sindgiar (or, according to some, Fingar), upon the borders of the Red Sea; by which the degree was found to contain 56⅔ miles, of 4000 coudees each, the coudee being

being a foot and a half: but it is not known what foot is here meant, whether the Roman, the Alexandrian, or ſome other. Riccioli makes this meaſure of the degree amount to 81 ancient Roman miles, which value anſwers to 62,046 French toiſes; a quantity more than the true value of the degree by almoſt one third. Finally, Almamon revived the ſciences in the Eaſt to ſuch a degree, that many learned men were found, not only in his own time, but after him, in a country where the ſtudy of the ſciences had been long forgotten. This learned king died near Tarſus in Cilicia, by having eaten too freely of ſome dates, on his return from a military expedition, in the year 833.

ALMSBURY, commonly called *Ameſbury*, is a flouriſhing town in Eſſex county, Maſſachuſetts, on the north weſtern bank of Merrimack river, about five miles N. W. of Newburyport, containing 1801 inhabitants. Powaws river divides the townſhip from Saliſbury, over which a handſome bridge has lately been erected. A number of mills lie on this river round the lower falls. See *Powaws river*.—*Morse*.

ALOE DICHOTOMA, in botany, called by the Dutch *Kooker-boom* or *Quiver-tree*, is a native of the ſouthern parts of Africa, and ſeems to be a ſpecies of the AGAVE or *American aloe* (ſee AGAVE, Encycl.) It is thus deſcribed by LE VAILLANT in his *New Travels into the Interior Parts of Africa*: "The *aloe dichotoma* riſes to the height of 25 or 30 feet; its trunk is ſmooth, and the bark white. When young, and the trunk not more than four or five feet long, it terminates with a ſingle tuft of leaves, which, like thoſe of the ananas, ſpread and form a crown, from the midſt of which all its flowers iſſue. As it grows older, it puſhes out lateral branches, perfectly regular and ſymmetrical, each of which has at its extremity a crown ſimilar to that of the young plant. The kooker-boom thrives much better on mountains than in the plain. Inſtead of long roots penetrating deep into the earth, like thoſe of other trees, it has but a very ſlight one by which it is fixed to the ſoil. Accordingly, three inches of mould are ſufficient to enable it to grow upon the very rocks, and attain its utmoſt beauty; but its root is ſo feeble a ſupport, that I could throw down the largeſt with a ſingle kick of my foot. The hordes on the weſt make their quivers of the trunk of this tree when young, whence is derived the name given it by the planters."

It becomes not us, ſitting in our chamber, to controvert a fact in natural hiſtory, of the reality of which we never had an opportunity of judging; nor would it be proper, on account of our own ſcepticiſm, to ſuppreſs the narrative of a traveller, who corrects the narratives of former travellers in terms which nothing ſhould have dictated but the conſciouſneſs of his own invariable veracity. Yet we hope to be pardoned for expreſſing our ſurpriſe that, in any part of the world, trees ſhould be found in great numbers 25 or 30 feet high, and ſhooting out many branches, which have yet ſo looſe a hold of the ground, that the largeſt of them may be thrown down by the ſingle kick of a man's foot. The reader's ſurpriſe will probably equal ours, when he is informed that the author ſaw one of theſe trees of which the trunk was ten feet four inches in circumference, whilſt its branches overſhadowed a ſpace of more than 100 feet in diameter! This tree he aſſures that he could have *kicked* over. The country, according to his account, is not exempted from ſtorms. He is himſelf a French philoſopher. What a pity then is it that he did not explain to thoſe, who have not had the benefit of being enlightened in that ſchool, upon what principle of mechanics or ſtatics the tree could reſiſt the violence of the elements till it arrived at ſo enormous a ſize?

ALPHONSUS X. king of Leon and Caſtile (ſee *Encycl.*) This prince underſtood aſtronomy, philoſophy, and hiſtory, as if he had been only a man of letters; and compoſed books upon the motions of the heavens, and on the hiſtory of Spain, which are highly commended. "What can be more ſurpriſing (ſays Mariana), than that a prince, educated in a camp, and handling arms from his childhood, ſhould have ſuch a knowledge of the ſtars, of philoſophy, and the tranſactions of the world, as men of leiſure can ſcarcely acquire in their retirements? There are extant ſome books of Alphonſus on the motions of the ſtars, and the hiſtory of Spain, written with great ſkill and incredible care." In his aſtronomical purſuits he diſcovered that the tables of Ptolemy were full of errors; and thence he conceived the firſt of any the reſolution of correcting them. For this purpoſe, about the year 1240, and during the life of his father, he aſſembled at Toledo the moſt ſkilful aſtronomers of his time, Chriſtians, Moors, and Jews, when a plan was formed for conſtructing new tables. This taſk was accompliſhed about 1252, the firſt year of his reign; the tables being drawn up chiefly by the ſkill and pains of Rabbi Iſaac Hazan, a learned Jew, and the work called the *Alphonſine Tables*, in honour of the prince, who was at vaſt expenſes concerning them. He fixed the epoch of the tables to the 30th of May 1252, being the day of his acceſſion to the throne. They were printed for the firſt time in 1483, at Venice, by Radtoldt, who excelled in printing at that time. This edition is extremely rare: there are others of 1492, 1521, 1545, &c.

In the Encyclopædia it is ſaid, that the charge of impiety brought againſt this prince was *unjuſt*. This was ſaid too confidently, becauſe we know not of any direct proof of his innocence. All that has been ſaid for him by Dr. Hutton, one of his ableſt apologiſts, amounts to nothing more than a high degree of probability that the charge was carried by much too far. The charge itſelf was, that Alphonſus affirmed, "that if he had been of God's privy council when he made the world, he would have adviſed him better." Mariana, however, ſays only in general, that Alphonſus was ſo bold as to blame the works of Providence, and the conſtruction of our bodies; and he ſays that this ſtory concerning him reſted only upon a vulgar tradition. The Jeſuit's words are curious: "Emanuel, the uncle of Sanchez (the ſon of Alphonſus), in his own name, and in the name of other nobles, deprived Alphonſus of his kingdom by a public ſentence; which that prince merited, for daring ſeverely and boldly to cenſure the works of Divine Providence, and the conſtruction of the human body, as tradition ſays he did. Heaven moſt juſtly puniſhed the folly of his tongue." Though the ſilence of ſuch an hiſtorian as Mariana, in regard to Ptolemy's ſyſtem, ought to be of ſome weight, yet we cannot think it improbable, that if Alphonſus did paſs ſo bold a cenſure on any part of the univerſe, it was on the celeſtial ſphere, and meant to glance upon the contrivers and ſupporters of that ſyſtem. For, beſides

sides that he studied nothing more, it is certain that at that time astronomers explained the motions of the heavens by intricate and confused hypotheses, which did no honour to God, nor any wise answered the idea of an able workman. So that, from considering the multitude of spheres composing the system of Ptolemy, and those numerous eccentric cycles and epicycles with which it is embarrassed, if we suppose Alphonsus to have said, "that if God had asked his advice when he made the world, he would have given him better counsel," the boldness and impiety of the censure will be greatly diminished.

Such is the apology made by Dr Hutton for this royal astronomer of Spain; and we hope, for the honour of science, that it is well founded. Still it leaves Alphonsus guilty of great irreverence of language, which is to us wholly unaccountable, if it be really true that he read the Bible fourteen times. We have seen impiety indeed break out lately from very eminent astronomers of a neighbouring nation; but these men read not the Bible, nor any thing else, but the dreams of the eternal sleepers.

ALSTEAD, a township in Cheshire county, New-Hampshire, containing 1111 inhabitants; 8 miles S. from Charlestown.—*Morse.*

ALTERNATE ANGLES. See GEOMETRY (Encycl.), Part I. 35.

ALTERNATE Ratio, or *Proportion*, is the ratio of the one antecedent to the other, or of one consequent to the other, in any proportion, in which the quantities are of the same kind. So if $A : B :: C : D$, then alternately, or by alternation $A : C :: B : D$.

ALTITUDE, PARALLAX OF, is an arch of a vertical circle, by which the true altitude, observed at the centre of the earth, exceeds that which is observed on the surface. See PARALLAX (Encycl.) and ASTRONOMY *(Suppl.)*

ALTITUDE of the Nonagesimal, is the altitude of the 90th degree of the ecliptic, counted upon it from where it cuts the horizon, or of the middle or highest point of it which is above the horizon, at any time; and is equal to the angle made by the ecliptic and horizon where they intersect at that time.

ALTITUDE of the Cone of the Earth's or Moon's Shadow, the height of the shadow of the body made by the sun, and measured from the centre of the body. To find it say, As the tangent of the angle of the sun's apparent semidiameter is to radius; so is 1 to a fourth proportional, which will be the height of the shadow in semidiameters of the body.

ALUM is a salt so useful in commerce and the arts, that the knowledge of its component parts, and of the best method of preparing it, must be of importance. In the article CHEMISTRY (Encycl.), the opinions which were then held respecting its composition, and the practice which was generally followed in its preparation, have been detailed at full length; but some of these opinions have since been controverted, and if they be erroneous, it must be expedient to vary in some degree the mode of preparation. In particular, the opinion that it is merely an excess of acid which prevents the formation of alum by evaporation of the ley, has been shown to be false by Citizen *Vauquelin*, who contends, of course, that the addition of putrid urine to the ley is a very bad practice.

This eminent chemist had long suspected, that the crystallization of alum is not prevented by an excess of acid, and that pot-ash is not of use simply to saturate this acid, but to perform an office of more importance. To bring his suspicions to the test of experiment, he dissolved very pure ALUMINE in sulphuric acid of equal purity, and evaporated the solution to dryness, for the purpose of expelling the superabundant acid. He then redissolved the dry and pulverulent residue in water, and reduced the solution to different degrees of specific gravity, with a view to seize the point most favourable to crystallization; but with every possible precaution he could obtain nothing but a magma (see MAGMA), formed of saline plates, without consistence or solidity. This solution, however, though it constantly refused to afford crystallized alum alone, afforded it immediately by the addition of a few drops of the solution of pot-ash; and as he had employed these two substances in the requisite proportion, the rest of the solution, to the very end, afforded pure alum, without any mixture of sulphate of pot-ash.

Into another portion of the same solution of pure alumine he dropped the same quantity of carbonate of soda, as he had added of that of pot-ash to the former; but no crystallization was formed, even by the help of evaporation, nor did lime and barytes produce any better effect. But if the common opinion that pot-ash, in the formation of alum, is of use only to abstract the excess of acid, be true, soda, lime, barytes, and all the substances which by a more powerful force would take this acid from alum, ought to give the same result. Another argument presented itself, which seemed decisive: If the alkalis, pot-ash, and ammoniac, do nothing more than unite to the superabundant acid of the alum, the sulphates of pot-ash and of ammoniac ought not to occasion any change in pure alum in its acidulated state; whereas if these alkalis enter as a constituent part into the alum, and are necessary to its existence, they ought to produce the same effects as pure pot-ash or ammoniac. He therefore added to a third portion of the solution of sulphate of alumine before-mentioned some drops of the solution of sulphate of pot-ash; immediately upon which octahedral crystals of alum were formed. The sulphate of ammoniac presented the same effect.

This result gave still greater confirmation to his first notions, though it did not yet afford a demonstration perfectly without objection; for it might have happened that the two salts he made use of might determine the crystallization of the alum, simply by absorbing the superfluous acid, of which they are very greedy; but to determine this possible fact, he mixed in the uncrystallizable solution of alumine some sulphate of pot-ash with excess of acid, and obtained a crystallization no less abundant than with the neutral sulphate of pot-ash.

This last experiment leaves therefore no doubt with regard to the influence and mode of action of pot-ash and ammoniac in the fabrication of alum; and this action is still more strongly confirmed by the examination of the alums which have been formed by the processes above related; for in this manner it is proved that they contain considerable quantities of the sulphates of pot-ash and ammoniac.

These experiments led M. Vauquelin to an examination of the different alums of commerce, of which he found not one that did not afford sulphate of pot-ash, or of ammoniac, or of both. His methods of analyſis are very accurate; but to detail them at length would ſwell this article to little purpoſe. To ſuch of our readers as are not chemiſts they would hardly be intelligible; and the experienced chemiſt will deviſe methods of analyſis for himſelf. It may be proper, however, to obſerve, that M. Vauquelin proved, to his own ſatiſfaction, that the ſulphate of pot-aſh, or of ammoniac, is neceſſary to render alum capable of being precipitated by its earth, or to cauſe it to paſs, as it were, to the earthy ſtate (A). He proved likewiſe, that ſuch aluminous waters as do not contain pot-aſh, may remain, as long as may be deſired, on their materials, without being ſaturated with too great a quantity of earth, or ſuffering alum to precipitate.

From the whole of his experiments our author drew the following concluſions, which he conſiders as of importance to the arts, to chemiſtry, and to natural hiſtory.

1. It is not, at leaſt in the greateſt number of circumſtances, the exceſs of acid which impedes the cryſtallization of alum, but it is the want of pot-aſh or ammoniac: For it is difficult to imagine that the ſulphuric acid could remain diſengaged after ſo long remaining upon alumine in a ſtate of extreme diviſion, and always ſuperabundant. It is true that the aluminous waters redden the vegetable tinctures; but this property is not owing to a diſengaged acid. This portion of acid is a conſtituent part of theſe waters; and it appears to have more affinity with the neutral ſulphate of alumine than with a new quantity of this earth at the temperature of the atmoſphere.

2. The ſulphate of pot-aſh may be uſed, as well as pure pot-aſh, to cauſe the cryſtallization of alum. It even has the advantage over the latter ſalt, becauſe if the aluminous waters do not really contain a diſengaged acid, the pot-aſh, in its combination, will precipitate a portion of alumine, and diminiſh the product of the boiling; whereas the ſulphate of pot-aſh does not produce the ſame effect; but if the lixiviums contain diſengaged acid, which muſt very ſeldom be the caſe, it is not converted into alum by the ſulphate of pot-aſh, and is loſt with regard to the product. Our author therefore is of opinion, that when the waters really contain an exceſs of acid, or a very oxided ſulphate of iron, the uſe of pot-aſh is preferable to that of the ſulphate of pot-aſh. But when economy is an object, that in many places it would be profitable to uſe the ſulphate of pot-aſh; becauſe it is a ſalt indirectly produced in many manufactories, where of courſe it may be obtained for nothing. In particular, the reſidues of the diſtillation of aquafortis by the ſulphuric acid would be excellent for this operation, and much preferable to putrid urine, becauſe this fluid always contains phoſphoric ſalts, which decompoſe a portion of the ſulphate of alumine, and conſiderably diminiſh the product.

3. Alumine cannot be uſed in the treatment of mother waters, as Bergman propoſes. This earth is incapable of favouring the cryſtallization of alum, beſides which, it decompoſes a portion of alum by the aſſiſtance of ebullition; in which circumſtance it ſeizes the acid neceſſary to its ſolution, and precipitates it in the form of that powder which is called alum ſaturated with its earth.

4. Many alum ores muſt naturally contain pot-aſh, becauſe perfect alum is often obtained from the firſt cryſtallization of new alum waters without the addition of this alkali. It is true that an objection may be made with regard to the wood uſed in calcining theſe ores, which may be ſuppoſed to have furniſhed the alkali; but it is not probable that the ſmall quantity of wood employed, in compariſon to the quantity of ore and the alum it affords, could ſupply enough of pot-aſh for the cryſtallization.

5. All the earths and ſtones which have given, or ſhall hereafter afford, by analyſis with the ſulphuric acid, perfect alum without addition of pot-aſh, muſt contain this alkali naturally. For it is well proved, that alum cannot exiſt without pot-aſh or ammoniac; and as there is little probability that this laſt ſhould be found combined in earths or ſtones, unleſs perhaps in very rare caſes, we may almoſt conſtantly be aſſured, when alum is obtained from any of theſe ſubſtances, that its formation was effected by pot-aſh. The quantity of alum will immediately ſhow in what proportion this alkali exiſted in the ſubſtances analyſed.

6. The alum of commerce ought not to be conſidered as a ſimple ſalt, but as a combination in the ſtate of a tripple and ſometimes quadruple ſalt of ſulphate of alumine, ſulphate of pot-aſh, or of ammoniac. Among theſe laſt we may diſtinguiſh two ſpecies; the one without exceſs of acid, inſoluble in water and inſipid, being what is improperly called alum ſaturated with its own earth; and the other, which contains an exceſs of acid ſoluble in water, very ſapid and aſtringent, is the common alum.

There is likewiſe a pure ſulphate of alumine, very aſtringent, very difficult of cryſtallization, in the form of brilliant pearl-coloured plates without conſiſtence, and which cannot be rendered ſoluble by the addition of a new quantity of its baſe. This laſt ſalt may with the greateſt propriety be called the ſulphate of alumine.

7. It follows from the comparative analyſis, and the knowledge acquired reſpecting the different ſtates of the combination of alumine with the ſulphuric acid united at the ſame time with other baſes, that we muſt diſtinguiſh ſeven ſtates in this combination, and that it is neceſſary to expreſs them according to the rules of the methodical nomenclature. Here follow the ſeries, the nature, and the names of theſe ſeven ſulphates of alumine.

1. Sulphate of alumine, or the artificial combination of ſulphuric acid and alumine. This ſalt is aſtringent; it cryſtallizes in laminæ or flexible leaves, ſoluble in water. It has never been deſcribed nor named by chemiſts. 2. Acid ſulphate of alumine is the foregoing ſalt, with exceſs of acid, from which it differs by reddening blue vegetable colours. It is eaſily made by diſſolving that ſalt in the ſulphuric acid, but it is not eaſy to convert this into the neutral ſulphate of alumine but by boiling it a long time with its earth. This ſalt, like the firſt, has not been deſcribed. 3. Saturated

(A) It may be proper to notice, that Scheele ſeems to have known this long before, and that he mentions it expreſsly in his paper on *Pyrophorus*.

fulphate of alumine and of pot-afh is the alum of the chemifts faturated with its earth. It is pulverulent, infipid, infoluble, not cryftallizable, and is eafily converted into true alum by the addition of fulphuric acid. 4. The acid fulphate of alumine and of pot-afh greatly refembles common alum, and is eafily prepared chemically; but M. Vauquelin found no alum but that of La Tolfa which is exactly of the fame nature with it. 5. The acid fulphate of alumine and of ammoniac has all the properties of alum, and may be ufed for the fame purpofes; but though it is eafily made in the laboratories, our author never found it pure in commerce. 6. The acid fulphate of alumine, pot-afh, and ammoniac. It is remarkable enough, fays M. Vauquelin, that this fhould be the nature of the alum moft frequently made in the arts, and that to exprefs its combination fo many words fhould be neceffary. This, however, may be avoided, by referving the name of alum to this fubftance, which will be fufficient to diftinguifh it perfectly. 7. The acidulous fulphate of alumine and of pot-afh, our author fays, he is lefs acquainted with than with the preceding feries. The name by which he characterizes it was fuggefted to him, and he thinks it proper, becaufe by adding to the folution a fmall quantity of pot-afh more than is neceffary to obtain octahedral cryftals, it manifeftly paffes to the cubic form.

From thefe deductions, the phyfician, the chemift, and the manufacturer, with whom the ufes of alum are greatly multiplied, will hereafter poffefs a knowledge of the fubftance they employ, and may appreciate its effects on the animal economy, and other bodies to which it is fo frequently applied. See *Annales de Chimie*, xxii. 258, and *Nicholfon's Journal*, Vol. I. p. 318, &c.

ALUMINE, one of the fimple earths. See CHEMISTRY in this *Supplement*.

ALVARADO, a river in New Spain, which rifes in the mountains of the Zapotecas, and, after making a circuit through the province of Mazaltan, and receiving feveral fmaller rivers and ftreams, empties into the Gulf of Mexico, at 30 miles diftance from Vera-Cruz.—*Morse*.

AMBROSE, ST. an ifland in the S. Pacific ocean, on the coaft of Chili, 4 or 5 leagues due W. from St. Felix ifland. At firft view, it appears like two fmall iflands, but after a nearer approach, it is found they are joined by a reef. It lies in 26. 13. S. lat. and 80. 55. W. long. from Greenwich. There is a large rock 4 miles to the northward of the ifland, called, from its appearance, *Sail rock*. Capt. Roberts, who was here in 1792, found St. Felix ifland inacceffible. On St. Ambrofe ifland, his crew killed and cured 13,000 feal fkins of the beft quality, in feven weeks. The ifland has little elfe to recommend it. Fifh and crawfifh abound. The beft feafon for fealing is from the 1ft of April to the 1ft of Auguft. The ifland has the appearance of having had volcanic eruptions.—*ib.*

AMELIA, a county in Virginia, bounded N. by Appamatox river which feparates it from Powhatan and Chefterfield counties, N. W. by Prince Edward, E. by Dinwiddie, and S. by Nottaway. *Scott.* Amelia, including Nottaway, a new county, contains 18,097 inhabitants, of whom 11,037 are flaves.

AMELIA *Ifle*, on the coaft of E. Florida, lies about 7 leagues N. of St. Auguftine, and very near Talbot ifland on the S. at the mouth of St. John's river. It is 13 miles long and 2 broad, is very fertile, and has an excellent harbour. Its N. end lies oppofite Cumberland ifland, between which and Amelia Ifle is the entry into St. Mary's river, in N. lat. 30. 52. W. long. 67. 23.—*Morse*.

AMICABLE NUMBERS have been defined, and the firft pair of them given in the Encyclopædia. The fecond pair of amicable numbers are 17296 and 18416; and the third pair are 9363584 and 9437056.

Dr. Hutton informs us, that thefe three pairs of amicable numbers, with the properties from which they receive their name, were found out by F. Schooten, as appears from Sect. ix. of his *Exercitationes Mathematicæ*. To find the firft pair, he puts $4x$ and $4yz$, or a^2x and a^2yz for the two numbers where $a=2$; then making each of thefe equal to the fum of the aliquot parts of the other, gives two equations, from which are found the values of x and z, and confequently affuming a proper value for y, the two amicable numbers themfelves $4x$ and $4yz$.

In like manner for the other pairs of fuch numbers; in which he finds it neceffary to affume $16x$ and $16yz$, or a^4x and a^4yz for the fecond pair, and $128x$ and $128yz$ or a^7x and a^7yz for the third pair.

Schooten then gives this practical rule, from Defcartes, for finding amicable numbers, viz. affume the number 2, or fome power of the number 2, fuch that if unity or 1 be fubtracted from each of thefe three following quantities, viz. from 3 times the affumed number, alfo from 6 times the affumed number, and from 18 times the fquare of the affumed number, the three remainders may be all prime numbers; then the laft prime number being multiplied by double the affumed number, the product will be one of the amicable numbers fought, and the fum of its aliquot parts will be the other. That is, if a be put = the number 2, and n fome integer number, fuch that $3a^n - 1$, and $6a^n - 1$, and $18a^{2n} - 1$ be all three prime numbers; then is $\overline{18a^{2n} - 1} \times 2a^n$ one of the amicable numbers; and the fum of its aliquot parts is the other.

AMSTERDAM and ST PAUL, are two iflands in the South Sea, lying in the fame degree of longitude, and generally confounded with each other. The Dutch navigators have given the name of *Amfterdam* to the northern, and of *St Paul* to the fouthern ifland, and Captain Cook conforms to that appellation. Moft other Englifh navigators, and particularly Meffrs Cox and Mortimer, with Sir George Staunton, reverfe the names, calling the fouthern ifland Amfterdam, and the other St Paul. At this fouthern ifland the Lion man of war ftopped on her voyage to China with Lord Macartney, the late ambaffador to the court of Pekin, which gave an opportunity to the men of fcience in the train of the ambaffador to examine the ifland with more fkill and attention than probably it had ever been examined before.

Dr Gillan, who was appointed phyfician to the embaffy, as well for his knowledge of chemiftry as for his medical fkill, is confident that the ifland of Amfterdam is the product of fubterraneous fire, as it bears in every part of it evident marks of volcanic eruption. "On the weft and fouth-weft fides (fays he) there are four fmall cones regularly formed, with craters in their centres, in which the lava and other volcanic fubftances have

have every appearance of recent formation. The heat continues ftill fo great, and fuch a quantity of elaftic vapour iffues through numberlefs crevices, that there can be no doubt of their having been very lately in a ftate of eruption. In a thermometer placed upon the furface, the quickfilver rofe conftantly to 180 degrees, and when funk a little into the afhes, it advanced to 212 degrees. It certainly would have rifen ftill higher; but the fcale being graduated only to the point of boiling water, and the length of the tube proportioned to that extent, the thermometer was immediately withdrawn, left the increafing expanfion of the quickfilver fhould burft the glafs. The ground was felt tremulous under the feet; a ftone thrown violently upon it returned a hollow found; and the heat was fo intenfe for a confiderable diftance around, that the foot could not be kept for a quarter of a minute in the fame pofition without being fcorched. But the great crater on the eaftern fide, now full of water, is by far the largeft here, or perhaps elfewhere, and is of an aftonifhing fize, confiderably exceeding in diameter thofe of Etna or Vefuvius. The quantity of matter to be thrown up, which required fo wide an orifice for its paffage, and the force with which fuch matter was impelled, in order to overcome the refiftance of the fuperincumbent earth and fea, muft have been indeed prodigious.

"This vaft crater, according to the ufual method of computing the antiquity of volcanoes, muft have been formed at a very remote period. The lava all around its fides is much decompofed, and has mouldered into duft, which lies on the furface in many parts to a confiderable depth. The decompofition has fupplied a rich foil for the long grafs growing on the fides of the crater, and has even fpread over moft parts of the ifland. The fibrous roots of the grafs, extending in all directions through the decompofed lava and volcanic afhes, and mixed in a decaying ftate with the vegetable mould, produced from the annual putrefaction of the leaves and ftalks, have formed a layer of foil feveral feet deep all over the ifland. But as it has nothing except its own weight to comprefs it together, it is of a light fpongy texture, with very little cohefion, and in many places furrowed and interfected by the fummer rains, and the torrents occafioned by the melting of the fnow which lies upon it in the winter, from three to four feet thick, in all thofe places where the fubterraneous heat is not great enough to prevent its accumulation. In fome parts thefe furrows and cavities are deeper than the level of the common channel; hence they ferve the purpofe of fmall natural refervoirs. The water flows into them from all the neighbouring ground; and as their fides are fhaded, and almoft covered over by the leaves of the long grafs, growing from their edges in oppofite directions, the rays of the fun are excluded, and very little is loft by evaporation. Thefe refervoirs, however, are very fmall, and but few in number; the largeft could not contain more than three or four hogfheads of water; and there is none elfe to be found, except in the fprings on the fides of the large crater.

"The foil everywhere being light and fpongy, and full of holes, formed in it by fea-birds for nefts, is very troublefome to walk upon; the foot breaks through the furface, and finks deep at every ftep; a circumftance which renders the journey acrofs the ifland uncommonly fatiguing, although it be fcarcely three miles from the edge of the great crater to the oppofite weft fide. There is one place near the centre of the ifland, extending about 200 yards in length, and fomewhat lefs in breadth, where particular caution is neceffary in walking over it. From this fpot a hot frefh fpring is fuppofed to derive its fource, finding its way through the interftices of the lava to the great crater, and burfting out a little above the water covering its bottom. The heat in this upper fpot is too great to admit of vegetation. The furface is covered with a kind of mud or pafte formed from the afhes, moiftened by fteam conftantly rifing from below. When the mud is removed, the vapour iffues forth with violence, and in fome parts copioufly. This mud is fo hot, that a gentleman who inadvertently ftepped into it, had his foot feverely fcalded by it. The fame caufes which have prevented vegetation on this fpot, have had the fame effect on the four cones recently thrown up. Their furfaces are covered with afhes only; nor is there the leaft appearance even of mofs on the furrounding lava, for the production of which there does not appear to have elapfed a fufficient length of time fince the cones were formed: but this is not the cafe with the lava of the great primary crater; for in thofe parts of it where the edges are more perpendicular, and where confequently the mouldering decompofed earth, having no bafis to fupport it, flides down the fides of the rock, pretty long mofs was generally found growing upon it. All the fprings or refervoirs of hot water, except one only, were brackifh. One fpring derives its fource from the high ground and ridges of the crater. The water in it, inftead of boiling upwards through the ftones and mud, as in the other fprings, flows downward with a confiderable velocity, in a fmall collected ftream. Its temperature has been found not to exceed 112 degrees. The hand could be eafily kept in it for a confiderable time. It is a pretty ftrong chalybeate. The fides of the rock whence it iffues, and of the cavity into which it falls, are incrufted with ochre depofited from it.

"When the great crater is viewed from the high ground, it appears to have been originally a perfect circle, but to have been encroached upon by the fea on the eaftern fide, where the flood tide ftrikes violently. The rocks of lava which formed the edge of the crater on that fide have fallen down. The depth of the water in the crater is about 170 feet, rendering the whole height of the crater, from the bottom to its upper ridge, nearly if not quite 900 feet. The lofty rocks forming this ridge are the higheft parts of the ifland, which feems to have been originally produced by the melted lava flowing down on all fides from hence. Thus there is a gradual flope from the edges of the crater to the fea; and the lava, though very irregular, and lying in mixed ruin and confufion immediately around the crater, affumes a more uniform appearance at fome diftance, layer refting regularly upon layer, with a gradual declivity the whole way down to the fea. This difpofition of the layers is particularly obfervable in the weft fide, where they happen to terminate in an abrupt precipice. The eruptions that took place at different periods appear here diftinctly marked by the different layers that are found with regular divifions between them; the glaffy lava being undermoft, the compact next, the cellular lava next above, over it the volcanic afhes and lighter fubftances, and a layer of vegetable mould covering the whole."

The ifland appears indeed in fuch a ftate of volcanic inflammation, that from the fhips decks at night were obferved, upon the heights of the ifland, feveral fires iffuing out of the crevices of the earth, more confiderable, but in other refpects refembling fomewhat the nightly flames at Pietra Mala, in the mountains between Florence and Bologna, or thofe near Bradley in Lancafhire, occafioned by fome of the coal-pits having taken fire. In the day nothing more than fmoke could be perceived.

The length of the ifland from north to fouth is upwards of four miles, its breadth from eaft to weft about two miles and a half, and its circumference eleven miles, comprehending a furface of about eight fquare miles, or 5120 acres, almoft the whole of which is covered with a fertile foil. The ifland is inacceffible except on the eaft fide, where the great crater forms a harbour, the entrance to which is deepening annually, and might by the aid of art be made fit for the paffage of large fhips. The tides run in and out at the rate of three miles an hour, and rife perpendicularly eight or nine feet on the full and change of the moon; a northerly wind making the higheft tide. The water is eight or ten fathoms deep clofe to the edge of the crater; and in the bafon formed by the crater itfelf, the variation of the compafs was found to be nineteen degrees and fifty minutes weftward of the north pole.

On the ifland, which has no native inhabitants, were found three Frenchmen and two natives of England, who at the end of the American war had emigrated to Bofton. The whole five had come laft from the Ifle of France in the Indian Ocean, and had been left on the ifland of Amfterdam, about five months before the arrival of the Lion, for the purpofe of procuring a cargo of 25,000 feal-fkins for the Canton market, which, as they had already procured 8000, they hoped to complete in about ten months more. The veffel which brought them from the Ifle of France was gone to Nootka Sound, with a view of bringing a quantity of fea-otter fkins to China; and afterwards of calling for the cargo of feal-fkins at this place, to be carried to China likewife; proceeding thus alternately to Nootka and Amfterdam ifland as long as the owners fhould find their account in it.

The feals, whofe fkins are thus an article of commerce, are found here in greater numbers in the fummer than in the winter, when they generally keep in deep water, and under the weeds, which fhelter them from the inclemency of the weather. In the fummer months they come afhore, fometimes in droves of 800 or 1000 at a time, out of which about 100 are deftroyed, that number being as many as five men can fkin and peg down to dry in the courfe of a day. Little of the oil which thefe animals might furnifh is collected, for want of cafks to put it in; part of the beft is boiled, and ferves thofe people inftead of butter. The feal of Amfterdam is the *phoca urfina* of Linnæus. The female weighs ufually from 70 to 120 pounds, and is from three to five feet in length, but the male is confiderably larger. In general they are not fhy: fometimes they plunge into the water inftantly upon any one's approach, but at other times remain fteadily on the rocks, bark, and rear themfelves up in a menacing pofture; but the blow of a ftick upon the nofe feemed fufficient to difpatch them. As the fkins alone were the objects wanted, the carcafes were left on the ground to putrify at leifure, ftrewed in fuch numbers as to render it difficult to avoid treading on them in walking along. The people thus employed were remarkable for the fqualor and filth of their perfons, clothes, and dwelling; yet none of them feemed defirous of leaving the place before the bufinefs they came upon fhould be completed. One of them, an Englifhman, who had been a confiderable time upon the ifland on a former adventure, gave but an unfavourable account of the weather during the winter months, which are always boifterous, with hail and fnow; but in fummer he acknowledged it to be very fine.

The fea fupplies this ifland with great varieties of excellent fifh, particularly a kind of cod, which was equally relifhed whether frefh or falted. Cray fifh were in fuch abundance on the bar acrofs the entrance into the crater, that at low water they might be taken with the hand; and at the anchorage of the fhips, when bafkets, in which were proper baits, were let down into the fea, they were in a few minutes drawn up filled with cray fifh. This circumftance is the more extraordinary, that in the fame place were found abundance of fharks and dog fifh of uncommon fize, which are known to be fo voracious and fuch enemies to all other fifh. The bafon of the crater abounds with tench, bream, and perch; and the perfon who with a hook and line has caught any of thefe fifh in the cold water of the bafon, may with a flight motion of his hand let them drop into the adjoining hot fpring already mentioned, in which they will be boiled and rendered fit for eating in the fpace of fifteen minutes. This was often practifed by the gentlemen of the embaffy, and furnifhed them at once with a fingular amufement and a highly relifhed repaft.

Of all the birds which frequent this ifland, fo extraordinary in its origin, formation, and appearance, not one is common to the fame degree of latitude in the northern hemifphere. Of the larger kind were feveral fpecies of the *albatrofs*; on examining one of which, diftinguifhed by the name of *exulans*, it was found, that inftead of having only the rudiments of a tongue, as naturalifts generally fuppofe, it had one equalling half the length of the bill. Another large bird is likewife common here, called the great *black petrel*, or *procellaria equinoctialis* of Linnæus. It is the determined enemy of the albatrofs, as well as of the *blue petrel* of Amfterdam, or *procellaria forfteri*. This blue petrel, which is about the fize of a pigeon, conftitutes the principal food of the feal-catchers on the ifland. During the day-time they hide themfelves in the ground, in order to efcape, if poffible, their deftroyer the black petrel. At night they come abroad, and thence are termed *night birds* by the people at Amfterdam; but being fond of flocking to any light, they fall into another fnare laid for them by the feal-catchers, who kindle torches to attract them, and then kill them in multitudes. The pretieft of the feathered tribe, inhabiting or vifiting Amfterdam, is the filver bird, or *fterna hirundo*, about the fize of a large fwallow or fwift, with a forked or fwallow tail. The bill and legs are of a bright crimfon colour, the belly white, and the back and wings of a bluifh afh colour. This bird fubfifts chiefly on fmall fifh, which it it picks up as they are swimming over the surface of the water.

This singular island lies in 38° 42′ S. Lat. and in 76° 54′ E. Long. from Greenwich. St Paul's, or the island lying in sight and to the northward, differed in appearance materially from Amsterdam. It presented no very high land, or any rising in a conic form; and seemed to be overspread with shrubs or trees of a middling size. It was said to abound with fresh water, but to have no good anchorage near it, nor any place of easy landing.—*Sir George Staunton's Account of an Embassy to the Emperor of China.*

AMELINS, *Ecor a*, is a south eastern head branch of Wabash river, whose mouth is 9 miles N. E. from the mouth of Salamanie river, and 45 miles S. W. from the Miami village and fort.—*Morse.*

AMOENIA, a thriving township in Dutchess county, New-York, 6 miles distant from Sharon, in Connecticut. It contains 3078 inhabitants, of whom 383 are electors.—*ib.*

AMHERST, a township in Cumberland county, Nova-Scotia, situated on Chignecto Bason, on the S. side of La Planch River, and on the rivers Napan and Macon. The navigation of the two last is difficult on account of shoals. The town was settled by North Irish, Yorkshire and New-England people.—*ib.*

Amherst, the shire-town of Hillsborough county, New-Hampshire, is a town of some note, formerly *Souhegan West*, and was originally granted from *Massachusetts*. It has 2369 inhabitants, and was incorporated in 1762. The Aurean Academy was founded here in 1790. A few years ago, the township being much infested with wolves, the people, on a day appointed, surrounded a large swamp which they frequented, and kept up an incessant firing of guns and beating of drums the whole day; which music forced the wolves to decamp the following night, with dismal howlings; and they have never done any mischief in the town since. Amherst lies on a northern branch of Souhegan River, which falls into Merrimack River, and is 60 miles W. of Portsmouth, and 53 N. W. of Boston. N. lat. 42. 54. W. long. 71. 33.—*ib.*

Amherst, a township in Hampshire county, Massachusetts, containing 1233 inhabitants; 91 miles westerly from Boston, and about eight north-easterly from Northampton.—*ib.*

Amherst *County*, in Virginia, lies between the Blue Ridge and the tide waters, and contains 13,703 inhabitants, including 5296 slaves. It lies on the north of James River.—*ib.*

AMICU, a lake in the province of Cumana, South-America, whose waters run southwardly through Parima River into the Amazon.—*ib.*

AMONOOSUCK, an Indian name given to two rivers in New-Hampshire: the one is called *Upper* Amonoosuck, passing through a tract of excellent meadow. It rises near the north end of the White Hills, runs northerly about 15 miles, where is a carrying place of about three miles to Amariscoggin River. From thence the river runs S. W. and W. nearly 18 miles, and empties into the Connecticut at Northumberland, near the Upper Coos.

The other is called *Great* or *Lower* Amonoosuck, which rises on the west side of the White Mountains. It falls into the Connecticut just above the town of Haverhill, in Lower Coos, by a mouth 100 yards wide. About two miles from its mouth it receives *Wild Amonoosuck*, 40 yards wide from Franconia and Lincoln Mountains. Two or three hours rain raises the water in this last mentioned river several feet, and occasions a current so furious as to put in motion stones of a foot in diameter, but its violence soon subsides.—*ib.*

AMOTAPE, a town near Tumbez, lying near the shore of the South Sea, in the empire of Peru. Being near a river of fine water, the adjacent country is highly improved. Lat. 4. 15. 43. S.—*ib.*

AMPALLA, by some authors called *Ampalia*, a city and seaport in Guatimala Gulf, in that of Mexico, 350 miles S. E. of the city of Guatimala, and carries on a brisk trade in cochineal, cocoa, hides, indigo, &c.—*ib.*

AMPARES, a jurisdiction under the archbishop of Plata, eastward of that city, in the empire of Peru. It abounds in grain and cattle.—*ib.*

AMUSKEAG *Falls*, in New-Hampshire, are on Merrimack River, sixteen miles below Concord, and seven below Hookset Falls. It consists of three pitches, one below the other, so that the water falls about 80 feet in the course of half a mile. The second pitch, which may be seen from the road, on the W. side, is truly majestic. In the middle of the upper part of the fall is a high rocky island, on the top of which are a number of pits, made exactly round, like barrels or hogsheads, some of which are capable of holding several tons; formed by the circular motion of small stones, impelled by the force of the descending water. There is a bridge across the falls 556 feet in length, and 20 in breadth, consisting of 2000 tons of timber, and made passable for travellers 57 days after it was begun. N. lat. 42. 59.—*ib.*

ANACLASTIC curves, a name given by M. de Mairan to certain apparent curves formed at the bottom of a vessel full of water, to an eye placed in the air; or the vault of the heavens, seen by refraction through the atmosphere.

ANAPHORA, in astrology, the second house, or that part of the heavens which is 30 degrees from the horoscope. The term *anaphora* is also sometimes applied promiscuously to some of the succeeding houses, as the 5th, the 8th, and the 11th. In this sense *anaphora* is the same as *epanaphora*, and stands opposed to *cataphora*.

ANASTATIA, St. a small island close to the coast of East-Florida, situated S. of Mastances Inlet, where the river Mastances forms two islands of the same name at its mouth. St. Anastatia island is bounded on the N. by St. Augustine's bar. Here is a quarry of fine stone for building.

ANASTROUS signs, in astronomy, a name given to the *duodecatemoria*, or the twelve portions of the ecliptic, which the signs possessed anciently, but have since deserted by the precession of the equinox.

ANCHOR of a ship, is an instrument which, as it is commonly made, has been sufficiently described in the Encyclopædia. An improvement, however, has been proposed on its construction by Mr James Stu nd of the parish of St Anne, Middlesex, who obtained a patent for his invention, dated Feb. 9, 1796.

The whole of this invention consists in making the anchor

anchor with one fluke or arm inſtead of two, and contriving to load that fluke or arm in ſuch a manner as to make it always fall the right way. With this view Mr Stuard would have the ſhank of the anchor made very ſhort, that it may *cant* the more when ſuſpended by the cable; and he would have the arm and it made of bars in one length, that there may be no ſhoot or joining in the whole inſtrument. The bend of the ſhank and arm he would have rounded, and not angular as in the common anchor; and on this bend he would have a ſmall ſhackle, or two plates with a ſmall bolt between them, for the buoy rope to be made faſt to. Inſtead of wood. he propoſes for the ſtock of the anchor a bar of wrought iron, loaded or covered at the ends with knobs of caſt iron; and he would have the palm of the fluke or arm either to be compoſed entirely of caſt iron, or to be a caſt iron ſhell filled with lead. This weight of the palm, the ſhortneſs of the ſhank, and the ſtructure of the ſtock, will no doubt make the anchor fall the right way; which, having no upper fluke, will never be tripped by the cable taking hold of it on the ſhip's ſwinging, nor will it prove ſo dangerous as the common anchor to ſuch veſſels as may happen to ground by it.

ANCOCUS or RANCOCUS *Creek*, in New-Jerſey, a water of the Delaware, 6 miles S. W. from Burlington. It is navigable 16 miles; and conſiderable quantities of lumber are exported from it—*Morſe*.

ANDAGUAYLAS, a juriſdiction in South-America, in the empire of Peru, ſubject to the archbiſhop of Lima; lying E. by S. of the city of Guamanga. It abounds in ſugar plantations, grain of moſt ſorts, and fruits.—*ib*.

ANDERSON (Alexander), an eminent mathematician, was born at Aberdeen towards the end of the 16th century Where he was educated, or under what maſters, we have not learned; probably he ſtudied the belles lettres and philoſophy in the univerſity of his native city, and, as was the practice in that age of all who could afford it, went afterwards abroad for the cultivation of other branches of ſcience. But wherever he may have ſtudied, his progreſs in ſcience muſt have been rapid; for, early in the 17th century, we find him profeſſor of mathematics in the univerſity of Paris, where he publiſhed ſeveral ingenious works; and among others, 1. *Supplementum Apollonii Redivivi; ſive analyſis problematis hactenus deſiderati ad Appollonii Pergæi doctrinam* περι νευσεων, *a Marino Ghetaldo Patritio Raguſino hujuſque, non ita pridem reſtitutam. In qua exhibetur mechanice æqualitatum tertii gradus ſive ſolidarum, in quibus magnitudo omnino data, æquatur homogeneæ ſub altero tantum coefficiente ignoto. Huic ſubnexa eſt variorum problematum practice*, Paris, 1612, *in* 4to.—2. Απολογια: *Pro Zetetico Apolloniani problematis a ſe jam pridem edito in ſupplemento Apollonii Redivivi. Ad clariſſimum et ornatiſſimum virum Marinum Ghetaldum Patritium Raguſinum. In qua ad ea quæ obiter mihi perſtrinxit Ghetaldus reſpondetur, et analytice clarius detegitur*. Paris, 1615, in 4to.—3. *Franciſci Vietæ Fontenacenſis de Æquationum Recognitione et Emendatione Tractatus duo*, with a dedication, preface, and appendix, by himſelf. Paris, 1615, in 4to.—4. Vieta's *Angulares Sectiones;* to which he added demonſtrations of his own. Our profeſſor was couſin german to Mr David Anderſon of Finſhaugh, a gentleman who alſo poſſeſſed a ſingular turn for mathematical knowledge. This mathematical genius was hereditary in the family of the Anderſons; and from them it ſeems to have been tranſmitted to their deſcendants of the name of Gregory, who have for ſo many generations been eminent in Scotland as profeſſors either of mathematics, or, more lately, of the theory and practice of phyſic. The daughter of the David Anderſon juſt mentioned, was the mother of the celebrated James Gregory, inventor of the reflecting teleſcope; and obſerving in her ſon, while yet a child, a ſtrong propenſity to mathematical ſtudies, ſhe inſtructed him in the elements of that ſcience herſelf. From the ſame lady deſcended the late Dr Reid of Glaſgow, who was not leſs eminent for his knowledge of mathematics than for his writings as a metaphyſician.

The preciſe dates of Alexander Anderſon's birth and death, we have not learned either from Dempſter, Mackenzie, or Dr Hutton, who ſeems to have uſed every endeavour to procure information; nor are ſuch of his relations as we have had an opportunity of conſulting, ſo well acquainted with his private hiſtory as we expected to find them.

ANDOVER, a large, fertile and thriving town in Eſſex county, Maſſachuſetts. It contains 2863 inhabitants, in two pariſhes. In the South pariſh are a paper mill and powder mill, from the latter of which the army received large ſupplies of gun-powder in the late war. There is an excellent academy in this town, called "Phillips Academy," which owes its exiſtence to the liberal benefactions of the family whoſe name it bears. Andover is under excellent cultivation, particularly that part which is watered by Shawſheen River. It lies about 20 miles W. from Newburyport, and about 22 N. from Boſton.—*Morſe*.

ANDOVER, in Hillſborough, New-Hampſhire, contains 645 inhabitants, and was incorporated in 1779. —*ib*.

ANDOVER, is the ſouth-weſternmoſt townſhip in Windſor county, Vermont, has Cheſter on the E. lies 32 miles N. E. of Bennington, and contains 275 inhabitants.—*ib*.

ANDOVER, a place in Suſſex county, New-Jerſey, near the ſource of Pequeſt river, 5 miles S. E. from New-Town, and 16 in the ſame direction from Walpack.—*ib*.

ANDREW's, ST. a ſmall town in the conteſted country between New-Brunſwick and the United States; ſituated in the rear of an iſland of the ſame name, on the E. ſide of the arm of the inner bay of Paſſamaquoddy, called Scoodick. The town is regularly laid out in the form of an oblong ſquare. The few inhabitants are chiefly employed in the lumber trade. The common tide riſes here about 18 feet.—*ib*.

ANDREW's, ST. a townſhip in Caledonia county, Vermont, 100 miles N. E from Bennington.—*ib*.

ANDREW's, ST. a pariſh in Charleſton diſtrict, South Carolina, containing 2947 inhabitants, of whom 370 are whites and 2546 ſlaves.—*ib*.

ANDREW's SOUND, ST. lies S. of Jekyl's Iſland, and is formed by it and a ſmall iſland at the mouth of Great Satilla river. The ſmall river oppoſite this ſound ſeparates Camden from Glynn county, in Georgia.—*ib*.

ANDROSCOGGIN, or *Amariſcoggin river*, in the diſtrict of Maine, may be called the main weſtern branch of the Kennebeck. Its ſources are N. of Lake

Umbagog.

Umbagog. Its courſe is ſoutherly till it approaches near to the White Mountains, from which it receives Mooſe and Peabody rivers. It then turns to the E. and then to the S. E. in which courſe it paſſes within two miles of the ſea-coaſt, and then turning N. runs over Pejepſkaeg falls into Merry-Meeting-Bay, where it forms a junction with the Kennebeck, 20 miles from the ſea. Formerly, from this bay to the ſea, the confluent ſtream was called Sagadahock. The lands on this river are very good.—*Morse.*

ANEGADA, one of the Virgin Iſles in the Weſt-Indies, and dependent on Virgin Gorda. It is about 6 leagues long, is low, and almoſt covered by water at high tides. On the S. ſide is Treaſure point. Lat. 18. 35. N. long. 63. W.—*ib.*

ANGARAEZ, a province in South-America, in the empire of Peru, ſubject to the archbiſhop of Lima, 20 leagues N. W. by W. of the city of Guamanga. It abounds in all kinds of grain and fruits, beſides vaſt droves of cattle for labour and ſuſtenance.—*ib.*

ANGUILLA, a bank and iſland E. of the Great Bahama Bank, and N. of the iſland of Cuba. Long. 78. 10. to 79½. lat. 23½. to 24. 10. N.—*ib.*

ANGUILLE, Cape, a point of land in Newfoundland iſland, on the W. ſide, in the Gulf of St. Lawrence, 6 leagues N. from Cape-Ray, the S. W. extremity of the iſland, in lat. 47. 57. N.—*ib.*

Anguille, a bay on the N. N. E. ſide of the iſland of St. John's, in the Gulf of St. Lawrence, oppoſite Magdalen Iſles; and having St. Peter's harbour on the S. E. and Port Chimene on the N. W. —*ib.*

ANHINGA, in ornithology, a ſpecies of the pelicanus; conſiſts of four known varieties, two peculiar to America, one to Senegal, and the fourth to the region about the Cape of Good Hope. This laſt is thus deſcribed by Le Vaillant in his New Travels into the Interior Parts of Africa.

" The denomination of *Slange-Hals-Voogel*, given to it by the Hottentots, characteriſes the anhinga in a very ſimple and accurate manner. Buffon, who was ſtruck with the conformation peculiar to birds of this kind, has delineated them by a ſimilar expreſſion. Plate III. 'The anhinga (ſays he) exhibits a reptile grafted on the body of a bird.' Indeed there is no perſon who, upon ſeeing the head and neck only of an anhinga, while the reſt of the body is hid among the foliage of the tree on which it is perched, would not take it for one of thoſe ſerpents accuſtomed to climb and reſide in trees; and the miſtake is ſo much the eaſier, as all its tortuous motions ſingularly favour the illuſion. In whatever ſituation the anhinga may be ſeen, whether perched on a tree, ſwimming in the water, or flying in the air, the moſt apparent and remarkable part of its body is ſure to be its long and ſlender neck, which is continually agitated by an oſcillatory motion, unleſs in its flight, when it becomes immoveable and extended, and forms with its tail a perfectly ſtraight and horizontal line.

" The true place which nature ſeems to have aſſigned to the anhingas, in the numerous claſs of the palmipedes, is exactly between the cormorant and the grebe. They partake indeed equally of both theſe genera of birds, having the ſtraight ſlender bill and the long neck of the latter; while they approach the former by the conformity of their feet, the four toes of which are joined by a ſingle membrane. They partake alſo of the cormorant by their flight; having like it the wings larger and fitter for the purpoſe than thoſe of the grebe, which are ſhort and weak. The tail of the anhinga is extremely long; a characteriſtic very ſingular and remarkable in a water fowl, and which ought, it would ſeem, to render them totally diſtinct from diving birds, which in general have little or no tail. By this trait they approach ſtill nearer to the cormorants; for tho' the tails of the latter are ſhorter, the tails of both have a great reſemblance to each other, ſince their quills are equally ſtrong, elaſtic, and proper to form a rudder when theſe fowls ſwim through the water in purſuit of fiſh, which conſtitute their principal nouriſhment. When the anhinga ſeizes a fiſh, he ſwallows it entire if it be ſmall enough, and if too large he carries it off to a rock or the ſtump of a tree, and fixing it under one of his feet, tears it to pieces with his bill.

" Though water is the favourite element of this bird, it builds its neſt and rears its young on rocks and trees; but it takes great care to place them in ſuch a manner, that it can precipitate them into a river as ſoon as they are able to ſwim, or the ſafety of the little family may require it.

The male anhinga differs from the female, which is ſmaller, in having the whole under part of the body, from the breaſt to the root of the tail, of a beautiful black, while the latter has the ſame parts of a yellow iſabella colour. It has alſo, on each ſide of its neck, a white ſtripe, which extends from the eye to the middle of its length, and interſects a reddiſh ground. A very ſingular characteriſtic, common to all the anhingas, is that of having the feathers of the tail deeply ſtriated, and as it were ribbed. It is a very ſagacious bird, eſpecially when ſurpriſed ſwimming; for its head is the only part which it expoſes above the water; and if the ſportſman once miſs that part, the anhinga plunges out of ſight entirely, and never more ſhows itſelf but at very great diſtances, and then no longer at a time than is abſolutely neceſſary for breathing.

ANNAPOLIS *River*, in Nova-Scotia, is of ſmall ſize. It riſes in the E. near the head waters of the ſmall rivers which fall into the baſon of Minas. Annapolis river paſſes into the bay of Fundy through the baſon of its own name, in the S. ſide of which, at the mouth of the river, ſtands the town and fort of Annapolis Royal. It is navigable for ſhips of any burden 10 miles, for thoſe of 100 tons, 15 miles; and is paſſable for boats within 20 miles of Horton. The tide flows up 30 miles.—*Morse.*

Annapolis, a county on the above river, adjoining to King's county, having 5 townſhips, viz. Wilmot, Granville, Annapolis, the chief towns, Clare, and Monckton. It is chiefly inhabited by Acadians, Iriſh, and New-Englanders.—*ib.*

ANN ARUNDEL *County*, in Maryland, lies between Patapſco and Patuxent Rivers, and has Cheſapeak Bay S. E. Annapolis is the chief town. This county contains 22,598 inhabitants, of whom 10,131 are ſlaves.—*ib.*

ANN, Cape, is the point of land in the town of that name, or Glouceſter, which forms the N. ſide of Maſſachuſetts Bay, as Cape Cod does the S. ſide. N. lat. 42. 45. long. 70. 17. W. See *Glouceſter*. This

Cape was so named in honour of Ann, consort of King James I.—*ib.*

ANN, St. a lake in Upper Canada, northerly from Lake Superior, which sends its waters north-easterly into James's Bay, through Albany River. Its north-eastern point lies in N. lat. 50. W. long. 88.—*ib.*

ANN, St. is the chief town of the province of Parana, in the E. division of Paraguay, South America.—*ib.*

ANN's, St. a port on the E. side of Cape Breton Island, where fishing vessels often put in. It lies on the N. W. side of the entrance into Labrador Lake. W. long. 60. N. lat. 47.—*ib.*

ANN's, St. is a small town on the River St. John's, province of New-Brunswick, about 80 miles from St. John's. It is at present the seat of government.—*ib.*

ANN, Fort, in the state of New-York, lies at the head of batteaux navigation, on Wood Creek, which falls into South Bay, Lake Champlain, near Skenesborough. It lies 6½ miles S. W. by S. from Skenesborough Fort; 10 E. S. E. from Fort George, and 12 N. E. by N. from Fort-Edward, on Hudson River. Such was the savage state of this part of the country, and the layers of trees laid lengthwise and across, and so broken with creeks and marshes, that General Burgoyne's army, in July, 1777, could scarcely advance above a mile in a day, on the road to Fort-Edward. They had no fewer than 40 bridges to construct, one of which was of log work 2 miles in length; circumstances which in after ages will appear hardly credible.—*ib.*

ANSON, an interior county of N. Carolina, in Fayette district, having Mecklinburg county N. and Bladen and Cumberland counties on the E. It contains 5133 inhabitants, including 828 slaves.—*ib.*

ANTECEDENTAL calculus. See Calculus in this Supplement.

ANTES, in architecture, small pilastres placed at the corners of buildings.

ANTHONY's Falls, St. in the River Mississippi, lie about 10 miles N. W. of the mouth of St. Pierre River, which joins the Mississippi from the W. and are situated in about lat. 44. 50. N. and were so named by father Louis Hennipin, who travelled into these parts about the year 1680, and was the first European ever seen by the natives there. The whole river, 250 yards wide, falls perpendicularly above 30 feet, and forms a most pleasing cataract. The rapids below, in the space of 300 yards, render the descent considerably greater; so that when viewed at a distance, they appear to be much higher than they really are. In the middle of the falls is a small island, about 40 feet broad, and somewhat longer, on which grow a few hemlock and spruce trees; and about half way between this island and the eastern shore, is a rock, lying at the very edge of the fall, in an oblique position, 5 or 6 feet broad, and 30 or 40 long. These falls are peculiarly situated, as they are approachable without the least obstruction from any intervening hill or precipice; which cannot be said, perhaps, of any other considerable fall in the world. The scene around is exceedingly beautiful. It is not an uninterrupted plain, where the eye finds no relief, but composed of many gentle ascents, which, in the spring and summer, are covered with verdure, and interspersed with little groves, that give a pleasing variety to the prospect.

At a little distance below the falls is a small island, about 1½ acre, on which grow a great number of oak trees, all the branches of which, able to bear the weight, are, in the proper season of the year, loaded with eagles nests. Their instinctive wisdom has taught them to choose this place, as it is secure, on account of the rapids above, from the attacks either of man or beast.—*Morse.*

Anthony's *Kill*, a western water of Hudson River. Its mouth is 7 miles above that of Mohawk River, with which likewise it communicates at the E. end of Long Lake.—*ib.*

Anthony's *Nose*, a point of land in the Highlands, on Hudson River, in the state of New-York, from which to Fort Montgomery on the opposite side, a large boom and chain was extended in the late war, which cost not less than 70,000l. sterling. It was partly destroyed and partly carried away by General Sir Henry Clinton, in October, 1777. Also, the name given to the point of a mountain on the N. bank of Mohawk River, about 30 miles above Schenectady. Around this point runs the stage road.—*ib.*

ANTICS, in architecture, figures of men and animals placed as ornaments to buildings.

ANTICUM, in architecture, a porch; also that part of a temple which lies between the body of the temple and the portico, and is therefore called the outer temple.

ANTIETAM *Creek*, in Maryland, rises by several branches in Pennsylvania, and empties into Potowmack River, 3 miles S. S. E. from Sharpsburg. Elizabeth and Funk's towns stand on this creek. It has a number of mills and forges.—*Morse.*

ANTIMETER, or Reflecting Sector, an instrument invented by Mr William Garrard, for the purpose of measuring angles, particularly small ones, with a greater degree of accuracy than can be done by Hadley's quadrant or by the sextant.

The frame of this instrument is similar to that of Hadley's quadrant, having two radii, a limb, and braces; but with this difference, that the further radius is produced upwards of four inches beyond the centre of motion of the index; and the great speculum, or what is called the index-glass in Hadley's quadrant, being placed there, is called the *upper centre*. In this instrument there is no provision for the back observation. The horizon-glass is like that in Hadley's quadrant; there are two sight vanes, to suit two different situations of the large speculum or object glass: these vanes are adapted to receive a small telescope. On the centre of the index, where the index glass of Hadley's quadrant is fixed, is a brass or bell-metal semicircle, two inches in diameter, and one eighth of an inch thick: this semicircle is screwed fast to the index, in such a manner that the axis of the index is a tangent to it. On the upper centre are two circular brass plates, which revolve concentrically, either together or separately. The under plate has a lever, or part perpendicular to the plane of the instrument, projecting downwards, a little beyond the lower centre: this lever is acted upon by the semicircular plate at the lower centre, to which it is always kept close by a spring on the other side. In the upper of the above mentioned circular plates are two

two circular perforations or slits, through one of which a screw takes into the head of the instrument, and thro' the other a screw takes into the lower moveable plate. The large speculum is fastened to the upper plate; and by the above mentioned screws the position of this glass may be altered. A circular plate is fixed to the lower centre by three pillars: in its centre is a nut to admit a screw, by which the plate carrying the large speculum may be fastened here occasionally.

The scale on the limb is divided into 45 equal parts or degrees, and not into half degrees as is the case in Hadley's quadrant, by reason of the double reflection. These divisions are numbered in a retrogade order; zero being at the extremity of the further radius. Although the limb contains 45 degrees, yet the greatest angle which can be measured, the large speculum remaining fixed to the circular plate, is $10^{\circ} 18' 21''.8$; the distance between the two centres being four inches, and the radius of the semicircle one inch. Agreeable to these dimensions, the inventor has given a table exhibiting the value of each primary division on the limb; he hath also given a more ample table, adapted to a distance between the centres of three times the radius of the semicircle, which he says hath been found the most convenient in practice. If an angle greater than $10^{\circ} 18'$ is wanted, it may be measured by the method of *anticipation*, as the inventor calls it, which is as follows: Let the screw which fastens the two circular plates on the upper centre be made fast, and loosen the screw which fastens the upper circular plate to the instrument: Now adjust the glasses by the usual method; bring forward the index to any given division on the limb, and make it fast; also fasten the screw which was before loose, and loosen the other screw; then bring the index to zero, and proceed as before.

The inventor gives the following directions for adjusting and using the instrument.

The first thing to be attended to is, to set the horizon-glass perpendicular to the plane of the instrument, which is performed as follows: Hold the instrument with its plane perpendicular to the horizon, and look over backwards into the glass and beyond it. If the limb of the instrument appears in a right line with its reflection, the glass is upright; but if it does not appear so, loosen or tighten the little screw on the foot of the glass until it be adjusted: Then with the instrument, as in taking an altitude, look through the sight vane or telescope at some distant object, with the index fixed in any intended situation; the two screws at the upper centre being loose, turn the glass about till the same object appears nearly in the same part of the horizon-glass: Next hold it in a horizontal position, and adjust the object-glass or large speculum with the screws which are behind and before, on the foot of it, till the object and its reflection are seen in the same horizontal line. Lastly, with the instrument upright, turn the tangent-screw belonging to the horizon-glass at the back of the instrument, until there be a perfect coincidence of the object and its reflection that way, and the adjustments are complete.

ANTIPARALLELS, in geometry, are those lines which make equal angles with two other lines, but contrary ways; that is, calling the former pair the first and second lines, and the latter pair the third and fourth lines, if the angle made by the first and third lines be equal to the angle made by the second and fourth, and contrariwise the angle made by the first and fourth equal to the angle made by the second and third; then each pair of lines are antiparallels with respect to each other, viz. the first and second, and the third and fourth. So, if AB and AC be any two lines, and FC and FE be two others, cutting them so, Plate II. fig. 5.

that the angle B is equal to the angle E,
and the angle C is equal to the angle D;

then BC and DE are antiparallels with respect to AB and AC; also these latter are antiparallels with regard to the two former. It is a property of these lines, that each pair cuts the other into proportional segments, taking them alternately,

viz. AB : AC : : AE : AD : : DB : EC,
and FE : FC : : FB : FD : : DE : BC.

ANTONIO DE SUCHITEPEC, ST. a town in Mexico or New Spain, on the coast of the Pacific Ocean. N. lat. 15. W. long. 93 5.—*Morse.*

ANTONIO, ST. the capital of the province of Apachiera, in New-Mexico.—*ib.*

ANTONIO, a town in the province of Navarre, in North-America, on a river which runs S. W. into the Gulph of California.—*ib.*

ANTONIO, CAPE ST. the most western point of the island of Cuba; having on the N. W. a number of islets and rocks, called Los Colorados, between which and the cape is the channel of Guaniguanica. N. lat. 22. 15. W. long. $85\frac{1}{2}$.—*ib.*

ANTONIO DE CABO, ST. a town in Brazil, in South-America, near Cape St. Augustine, subject to the Portuguese. Here they make a considerable quantity of sugar. S. lat. 8. 34. W. long. 35. 22.—*ib.*

ANTONIO ST. a town in New-Mexico, on the W. side of Rio Bravo River, below St. Gregoria. Also, the name of a town on the river Hondo, which falls into the Gulf of Mexico, N. E. of Rio de Brava; and on the eastern side of the river, S. by W. from Texas.—*ib.*

ANTERIM, a township in Hillsborough county, New-Hampshire, having 528 inhabitants, incorporated in 1777; 75 miles W. of Portsmouth, and about the same distance N. W. of Boston.—*ib.*

ANVILLE, or *Miller's Town*, in Dauphine county, Pennsylvania, at the head of Tulpehocken Creek. When the canal between the Susquehannah and Schuylkill, along these creeks, is completed, this town will probably rise to some consequence. It lies 18 miles N. E. by E. from Harrisburg, and 65. N. W. from Philadelphia.—*ib.*

ANZERMA, is a town and province of Popayan, in South-America, having mines of gold. It is seated on the river Coca. N. lat. 4. 58.—*ib.*

APACHIERA, an audience and province of New-Mexico, whose capital is St. Fe, in N. lat. 36. 30. W. long. 104.—*ib.*

APALACHES or *St. Mark's R.* rises in the country of the Seminole Indians, in E. Florida, in N. lat. 31. 30. near the N. W. source of Great Satilla River; runs S. W through the Apalachy country, into the bay of Apalachy, in the Gulph of Mexico, about 15 miles below St. Mark's. It runs about 135 miles, and falls into the Bay near the mouth of Apalachicola River.—*ib.*

APALACHICOLA, a river between E. and W.

Florida, having its source in the Apalachian Mountains, in the Cherokee country, within ten miles of Tugaloo, the upper branch of Savannah River. From its source to the mouth of Flint River, a distance of 300 miles, it is called Chata-Uche, or Chatahooche River. Flint River falls into it from the N. E. below the Lower Creek Towns, in N. lat. 31. From thence it runs near 80 miles and falls into the Bay of Apalachy, or Apalachicola, in the Gulf of Mexico, at Cape Blaize. From its source to the 33d deg. of N. lat. its course is S. W. from thence to its mouth it runs nearly S. See *Chata-Ucha* and *Flint Rivers*.—*ib.*

Apalachicola, is likewise the name of the mother town or capital of the Creek or Muscogulge confederacy, called Apalachucla by Bartram. It is, says he, sacred to peace; no captives are put to death or human blood spilt here: and when a general peace is proposed, deputies from all the towns in the confederacy meet here to deliberate. On the other hand, the great Coweta Town, 12 miles higher up the Chata-Uche River, is called the *Bloody Town*, where the Micos chiefs and warriors assemble when a general war is proposed; and there captives and state malefactors are put to death. Apalachicola is situated a mile and an half above the ancient town of that name, which was situated on a peninsula formed by the doubling of the river, but deserted on account of inundations. The town is about 3 days journey from Tallassee, a town on the Tallapoose River, a branch of the Mobile River. See *Coweta*, and *Tallassee*.—*ib.*

APALACHY *Country*, extends across Flint and Apalaches Rivers, in East Florida, having the Seminole country on the N. E. Apalachy, or Apalachya, is by some writers, applied to a town and harbour in Florida, 90 miles E. of Pensacola, and the same distance W. from Del Spiritu Santo River. The tribes of the Apalachian Indians lie around it.—*ib.*

APERTURE, in optics, has been defined in the Encyclopædia, but no rule was given there for finding a just aperture. As much depends upon this circumstance, our optical readers will be pleased with the following practical rule given by Dr Hutton in his Mathematical Dictionary. "Apply several circles of dark paper, of various sizes, upon the face of the glass, from the breadth of a straw to such as leave only a small hole in the glass; and with each of these, separately, view some distant object, as the moon, stars, &c. then that aperture is to be chosen through which they appear the most distinctly.

"Huygens first found the use of apertures to conduce much to the perfection of telescopes; and he found by experience (*Diopt.* prop. 56.), that the best aperture for an object-glass, for example of 30 feet, is to be determined by this proportion, as 30 to 3, so is the square root of 30 times the distance of the focus of any lens to its proper aperture: and that the focal distances of the eye-glasses are proportioned to the apertures. And M. Auzout says he found, by experience, that the apertures of telescopes ought to be nearly in the subduplicate ratio of their lengths. It has also been found by experience, that object-glasses will admit of greater apertures, if the tubes be blacked within side, and their passage furnished with wooden rings.

"It is to be noted, that the greater or less aperture of an object-glass, does not increase or diminish the visible area of the object; all that is effected by this is the admittance of more or fewer rays, and consequently the more or less bright the appearance of the object. But the largeness of the aperture or focal distance causes the irregularity of its refractions. Hence, in viewing Venus through a telescope, a much less aperture is to be used than for the moon, or Jupiter, or Saturn, because her light is so bright and glaring. And this circumstance somewhat invalidates and disturbs Azout's proportion, as is shown by Dr Hook, Phil. Trans. N° 4."

APOCATASTASIS, or, as it should be written, Apokatastasis, is a Greek word employed in the language of astronomers, to denote the period of a planet, or the time it takes to return to that point of the zodiac whence it set out.

APOQUENEMY *Creek*, falls into Delaware Bay from Middletown, in New-castle county, Delaware, a mile and an half below Reedy Island. A canal is proposed to extend from the southern branch of this creek, at about 4 miles from Middletown, to the head of Bohemia River, nearly 8 miles distant; which will form a water communication between Delaware Bay, and that of Chesapeak, through Elk River.—*ib.*

APPLE *Island*, a small uninhabited island in St. Lawrence River, in Canada, on the S. side of the river, between Basque and Green Islands. It is surrounded by rocks, which renders the navigation dangerous.—*ib.*

Apple *Town*, an Indian village on the E. side of Seneca Lake, in New-York, between the townships of Ovid on the S. and Romulus on the N.—*ib.*

APPOMATOX, is the name of a southern branch of James River, in Virginia. It may be navigated as far as Broadways, 8 or 10 miles from Bermuda Hundred, by any vessel which has crossed Harrison's Bar, in James River. It has 8 or 9 feet water a mile or two farther up to Fisher's Bar, and 4 feet on that and upwards to Petersburg, where all navigation ceases.—*ib.*

APOLO BAMA, a jurisdiction consisting of missions belonging to the Franciscans, subject to the bishop of Cusco, 60 leagues from that city, in the empire of Peru. These consist of 7 towns of converted Indians. To protect these from the insults of the other Indians, and to give credit to the missionaries, a militia is kept here, under a major-general, formed by the inhabitants.—*ib.*

APOTOME, is a term employed by Euclid to denote the difference between two lines or quantities which are only commensurable in power. Such is the difference between 1 and $\sqrt{2}$, or the difference between the side of a square and its diagonal. The doctrine of apotomes in lines, as delivered by this ancient mathematician in the tenth book of his Elements, is a very curious subject, and has always been admired by such as understood it. The first algebraical writers in Europe, such as Lucas de Burgo, Cardan, Tartalea, Stifelius, &c. employed a considerable portion of their works on an algebraical exposition of that which led them to the doctrine of surd quantities.

APPARENT conjunction of the planets, is when a right line supposed to be drawn through their centres, passes through the eye of the spectator, and not through the

the centre of the earth. And, in general, the apparent conjunction of any objects, is when they appear or are placed in the fame right line with the eye.

Apparent Diameter of a planet or other heavenly body, is not the real length of the diameter of that body, but the angle which it fubtends at the eye, or under which it appears.

Apparent Diftance, is that which we judge an object to be from us, when feen afar off; and which is almoft always very different from the true diftance.

Apparent Figure, is the figure or fhape under which an object appears when viewed at a diftance; and is often very different from the true figure. Thus a ftraight line, viewed at a diftance, may appear but as a point; a furface, as a line; and a folid, as a furface.

Apparent Motion, is either that motion which we perceive in a diftant body that moves, the eye at the fame time being either in motion or at reft; or that motion which an object at reft feems to have, while the eye itfelf only is in motion.

Apparent Place of a Planet, &c. in aftronomy, is that point in the furface of the fphere of the world where the centre of the luminary appears from the furface of the earth.

APPARITION, in aftronomy, denotes a ftar's or other luminary's becoming vifible, which before was hid. So, the heliacal rifing, is rather an apparition than a proper rifing.

APURIMA, or *Aporamac*, a very rapid river in Peru, South-America, 30 miles from the river Abanzai.—*Morse.*

AQUAFORT, a fettlement on the E. fide of the fouth-eaftern extremity of Newfoundland Ifland, lat. 47. 10. N.—*ib.*

AQUEDOCHTON, the outlet of lake Winnipifeogee, in New-Hampfhire, N. lat. 43. 40. whofe waters pafs through feveral fmaller ones in a S. W. courfe, and empty into Merrimack River, between the towns of Sanburn and Canterbury.—*ib.*

ARARAT, *Mount* or the *Stone Head*, a fhort range of mountains on the N. frontier of North-Carolina, in a N. E. direction from Ararat River, a N. W. branch of Yadkin River.—*ib.*

ARATHAPESCOW, an Indian tribe inhabiting the fhores of the lake and river of that name, in the N. W. part of North-America, between the latitudes of 57. and 59. N. North of this nation's abode, and near the Arctic Circle, is Lake Edlande, around which live the Dog Ribbed Indians.—*ib.*

ARAUCO, a fortrefs and town of Chili, in South-America; fituated in a fine valley, on a river of the fame name, N. by W. from Baldivia. The native Indians are fo brave that they drove the Spaniards out of their country, though deftitute of fire-arms. S. lat. 37. 30. W. long. 73. 20.—*ib.*

ARAZIBO, one of the principal places in Porto Rico Ifland, in the Weft-Indies. It has few inhabitants, and little trade but fmuggling.—*ib.*

ARCAS, an ifland in the Gulf of Mexico, in the Bay of Campeachy. Lat. 20. long. 92. 50.—*ib.*

ARCH, in building, is an artful difpofition and adjuftment of feveral ftones or bricks, generally in a bow-
1 Arch defined. like form, by which their weight produces a mutual preffure and abutment; fo that they not only fupport each other, and perform the office of an entire lintel, but may be extended to any width, and made to carry the moft enormous weights.

In thofe mild climates which feem to have been the firft inhabited parts of this globe, mankind ftood more in need of fhade from the fun than of fhelter from the inclemency of the weather. A very fmall addition to the fhade of the woods ferved them for a dwelling. Sticks laid acrofs from tree to tree, and covered with bruſhwood and leaves, formed the firft houfes in thofe delightful regions. As population and the arts improved, thefe huts were gradually refined into commodious dwellings. The materials were the fame, but more artfully put together. At laft agriculture led the inhabitants out of the woods into the open country. The connection between the inhabitant and the foil became now more conftant and more interefting. The wifh to preferve this connection was natural, and fixed eftablifhments followed of courfe. Durable buildings were more defirable than thofe temporary and perifhable cottages—ftone was fubftituted for timber. 2 History of architecture connected with arches.

But as thefe improved habitations were gradual refinements on the primitive hut, traces of its conftruction remained, even when the choice of more durable materials made it in fome meafure inconvenient. Thus it happened, that while a plain building, intended for accommodation only, confifted of walls, pierced with the neceffary doors and windows, an ornamented building had, fuperadded to thefe effentials, columns, with the whole apparatus of entablature, borrowed from the wooden building, of which they had been effential parts, gradually rendered more fuitable to the purpofes of accommodation and elegance.

This view of ornamental architecture will go far to account for fome of the more general differences of national ftyle which may be obferved in different parts of the world. The Greeks borrowed many of their arts from their Afiatic neighbours, who had cultivated them long before. It is highly probable that architecture travelled from Perfia into Greece. In the ruins of Shufhan, Perfepolis, or Tchilminar, are to be feen the firft models of every thing that diftinguifhes the Grecian architectures. There is no doubt, we fuppofe, among the learned, as to the great priority of thefe monuments to any thing that remains in Greece; efpecially if we take into account the tombs on the mountains, which have every appearance of greater antiquity than the remains of Perfepolis. In thofe tombs we fee the whole *ordonnance* of column and entablature, juft as they began to deviate from their firft and neceffary forms in the wooden buildings. We have the architrave, frize, and corniche; the far-projecting mutules of the Tufcan and Doric orders; the modillions no lefs diftinct; the rudiments of the Ionic capital; the Corinthian capital in perfection, pointing out the very origin of this ornament, viz. a number of long graceful leaves tied round the head of the column with a fillet (a cuftom which we know to have been common in their temples and banqueting rooms). Where the diftance between the columns is great, fo that each had to fupport a weight too great for one tree, we fee the columns cluftered or fluted, &c. In fhort, we fee every thing of the Grecian architecture but the floped roof or pediment; a thing not wanted in a country where it hardly ever rains. 3 Origin of Greek architecture.

The ancient Egyptian architecture feems to be a refinement on the hut built of clay, or unburnt bricks mix- 4 Egyptian;

ed

Arch.

ed with ſtraw—every thing is maſſive, clumſy, and timid —ſmall intercolumnations, and hardly any projections.

5 Arabian, and

The Arabian architecture ſeems a refinement on the tent. A moſque is like a little camp, conſiſting of a number of little bell tents, ſtuck cloſe together round a great one. A caravanſeray is a court ſurrounded by a row of ſuch tents, each having its own dome. The Greek church of St Sophia at Conſtantinople has imitated this in ſome degree: and the copies from it, which have been multiplied in Ruſſia as the ſacred form for a Chriſtian church, have adhered to the original model of cluſtered tents in the ſtricteſt manner. We are ſometimes diſpoſed to think that the painted glaſs (a faſhion brought from the Eaſt) was an imitation of the painted hangings of the Arabs.

6 Chineſe architecture.

The Chineſe architecture is an evident imitation of a wooden building. Sir Geo. Staunton ſays, that the ſingular form of their roofs is a *profeſſed* imitation of the cover of a ſquare tent.

In the ſtone buildings of the Greeks, the roofs were imitations of the wooden ones; hence the lintels, flying corniches, ceilings in compartments, &c.

The pediment of the Greeks ſeems to have ſuggeſted the greateſt improvement in the art of building. In erecting their ſmall houſes, they could hardly fail to obſerve occaſionally, that when two rafters were laid together from the oppoſite walls, they would, by leaning on each other, give mutual ſupport, as in fig. 1. Nor is it unlikely that ſuch a ſituation of ſtones as is repreſented in fig. 2. would not unfrequently occur by accident to maſons. This could hardly fail of exciting a little attention and reflection. It was a pretty obvious reflection, that the ſtones A and C, by overhanging, leaned againſt the intermediate ſtone B, and gave it ſome ſupport, and that B cannot get down without thruſting aſide A and C, or the piers which ſupport them. This was an approach to the theory of an arch; and if this be combined with the obſervation of fig. 1. we get the diſpoſition repreſented in fig. 3. having a perpendicular joint in the middle, and the *principle of the arch* is completed. Obſerve that this is quite different from the principle of the arrangement in fig. 2. In that figure the ſtones act as wedges, and one cannot get down without thruſting the reſt aſide; the ſame principle obtains in fig. 4. conſiſting of five arch ſtones; but in fig. 3. the ſtones B and C ſupport each other by their mutual preſſure (independent of their own weight), ariſing from the tendency of each lateral pair to fall outwards from the pier. This is the principle of the arch, and would ſupport the key-ſtone of fig. 4. although each of its joints were perpendicular, by reaſon of the great friction ariſing from the horizontal thruſt exerted by the adjoining ſtones.

Plate I.

7 Origin of the arch.

This was a moſt important diſcovery in the art of building; for now a building of any width may be roofed with ſtone.

8 Grecian.

We are diſpoſed to give the Greeks the merit of this diſcovery; for we obſerve arches in the moſt ancient buildings of Greece, ſuch as the temple of the ſun at Athens, and of Apollo at Didymos; not indeed as roofs to any apartment, nor as parts of the ornamental deſign, but concealed in the walls, covering drains or other neceſſary openings; and we have not found any *real* arches in any monuments of ancient Perſia or Egypt. Sir John Chardin ſpeaks of numerous and extenſive ſubterranean paſſages at Tchelminar, built of the moſt exquiſite maſonry, the joints ſo exact, and the ſtones ſo beautifully dreſſed, that they look like one continued piece of poliſhed marble; but he nowhere ſays that they are arched; a circumſtance which we think he would not have omitted—no arched door or window is to be ſeen. Indeed one of the tombs is ſaid to be arch-roofed, but it is all of one ſolid rock. No trace of an arch is to be ſeen in the ruins of ancient Egypt; even a wide room is covered with a ſingle block of ſtone. In the pyramids, indeed, there are two galleries, whoſe roofs conſiſt of many pieces; but their conſtruction puts it beyond doubt that the builder did not know what an arch was: for it is covered in the manner repreſented in fig. 5. where every projecting piece is more than balanced behind, ſo that the whole aukward maſs could have ſtood on two pillars. The Greeks therefore ſeem entitled to the honour of the invention. The arched dome, however, ſeems to have ariſen in Etruria, and originated in all probability from the employment of the augurs, whoſe buſineſs it was to obſerve the flight of birds. Their ſtations for this purpoſe were *templa*, ſo called *a templando*, "on the ſummits of hills." To ſhelter ſuch a perſon from the weather, and at the ſame time allow him a full proſpect of the country around him, no building was ſo proper as a dome ſet on columns; which accordingly is the figure of a temple in the moſt ancient monuments of that country. We do not recollect a building of this kind in Greece except that called the *Lanthern of Demoſthenes*, which is of very late date, whereas they abounded in Italy. In the later monuments and coins of Italy or of Rome, we commonly find the Etruſcan dome and the Grecian temple combined; and the famous pantheon was of this form, even in its moſt ancient ſtate.

Arch.

It does not appear that the arch was conſidered as a part of the *ornamental* architecture of the Greeks during the time of their independency. It is even doubtful whether it was employed in roofing their temples. In none of the *ancient* buildings where the roof is gone, can there be ſeen any rubbiſh of the vault, or mark of the ſpring of the arch. It is not unfrequent, however, after the Roman conqueſts, and may be ſeen in Athens, Delos, Palmyra, Balbek, and other places. It is very frequent in the magnificent buildings of Rome; ſuch as the Coliſeum, the baths of Diocleſian, and the triumphal arches, where its form is evidently made the object of attention. But its chief employment was in bridges and aqueducts; and it is in thoſe works that its immenſe utility is the moſt conſpicuous: For by this happy contrivance a canal or a road may be carried acroſs any ſtream, where it would be almoſt impoſſible to erect piers ſufficiently near to each other for carrying lintels. Arches have been executed 130 feet wide, and their execution demonſtrates that they may be made four times as wide.

It was uſed at firſt only in bridges and aqueducts.

As ſuch ſtupendous arches are the greateſt performances of the maſonic art, ſo they are the moſt difficult and delicate. When we reflect on the immenſe quantity of materials thus ſuſpended in the air, and compare this with the ſmall coheſion which the firmeſt cement can give to a building, we ſhall be convinced that it is not by the force of the cement that they are kept together: they ſtand faſt only in conſequence of the proper balance of all their parts. Therefore, in order to

10 Difficulty of conſtructing it.

to erect them with a well-founded confidence of their durability, this balance ſhould be well underſtood and judiciouſly employed. We doubt not but that this was underſtood in ſome degree by the engineers of antiquity. But they have left us none of their knowledge.

11 Skill and myſteries of the Dionyſiacs.

They muſt have had a great deal of mechanical knowledge before they could erect the magnificent and beautiful buildings whoſe ruins ſtill enchant the world; but they kept it among themſelves. We know that the Dionyſiacs of Ionia were a great corporation of architects and engineers, who undertook, and even monopolized, the building of temples, ſtadiums, and theatres, preciſely as the fraternity of maſons in the middle ages monopolized the building of cathedrals and conventual churches. Indeed the Dionyſiacs reſembled the myſtical fraternity now called free maſons in many important particulars. They allowed no ſtrangers to interfere in their employment; they recogniſed each other by ſigns and tokens; they profeſſed certain myſterious doctrines, under the tuition and tutelage of Bacchus, to whom they built a magnificent temple at Teos, where they celebrated his myſteries as ſolemn feſtivals; and they called all other men profane, becauſe not admitted to theſe myſteries. But their chief myſteries and moſt important ſecrets ſeem to be their mechanical and mathematical ſciences, or all that academical knowledge which forms the regular education of a civil engineer. We know that the temples of the gods and the theatres required an immenſe apparatus of machinery for the celebration of ſome of their myſteries; and that the Dionyſiacs contracted for thoſe jobs, even at far diſtant places, where they had not the privilege of building the edifice which was to contain them. This is the moſt likely way of explaining the very ſmall quantity of mechanical knowledge that is to be met with in the writings of the ancients. Even Vitruvius does not appear to have been of the fraternity, and ſpeaks of the Greek architects in terms of reſpect next to veneration. The *Collegium Murariorum*, or incorporation of maſons at Rome, does not ſeem to have ſhared the ſecrets of the Dionyſiacs.

12 The art of building arches underſtood in the middle ages.

The art of building arches has been moſt aſſiduouſly cultivated by the aſſociated builders of the middle ages of the Chriſtian church, both Saracens and Chriſtians, and they ſeem to have indulged in it with fondneſs: they multiplied and combined arches without end, placing them in every poſſible ſituation.

Having ſtudied this branch of the art of building with ſo much attention, they were able to erect the moſt magnificent buildings with materials which a Greek or Roman architect could have made little or no uſe of.

13 Better than by the Greeks and Romans.

There is infinitely more ſcientific ſkill diſplayed in a Gothic cathedral, than in all the buildings of Greece and Rome. Indeed theſe laſt exhibit very little knowledge of the mutual balance of arches, and are full of groſs blunders in this reſpect; nor could they have reſiſted the ſhock of time ſo long, had they not been almoſt ſolid maſſes of ſtone, with no more cavity than was indiſpenſably neceſſary.

Anthemius and Iſidorus, whom the Emperor Juſtinian had ſelected as the moſt eminent architects of Greece for building the celebrated church of St Sophia at Conſtantinople, ſeem to have known very little of this matter. Anthemius had boaſted to Juſtinian, that he would outdo the magnificence of the Roman pantheon, for he would hang a greater dome than it aloft in the air. Accordingly he attempted to raiſe it on the heads of four piers, diſtant from each other about 115 feet, and about the ſame height. He had probably ſeen the magnificent vaultings of the temple of Mars the Avenger, and the temple of Peace at Rome, the thruſts of which are withſtood by two maſſes of ſolid wall, which join the ſide walls of the temple at right angles, and extend ſidewiſe to a great diſtance. It was evident that the walls of the temple could not yield to the preſſure of the vaulting without puſhing theſe immenſe buttreſſes along their foundations. He therefore placed four buttreſſes to aid his piers. They are almoſt ſolid maſſes of ſtone, extending at leaſt 90 feet from the piers to the north and to the ſouth, forming as it were the ſide walls of the croſs. They effectually ſecured them from the thruſts of the two great arches of the nave which ſupport the dome; but there was no ſuch proviſion againſt the puſh of the great north and ſouth arches. Anthemius truſted for this to the half dome, which covered the ſemicircular eaſt end of the church, and occupied the whole eaſtern arch of the great dome. But when the dome was finiſhed, and had ſtood a few months, it puſhed the two eaſtern piers with their buttreſſes from the perpendicular, making them lean to the eaſtward, and the dome and half dome fell in. Iſidorus, who ſucceeded to the charge on the death of Anthemius, ſtrengthened the piers on the eaſt ſide, by filling up ſome hollows, and again raiſed the dome. But things gave way before it was cloſed; and while they were building in one part it was falling in in another. The pillars and walls of the eaſtern ſemicircular end were much ſhattered by this time. Iſidorus ſeeing that they could give no reſiſtance to the puſh which was ſo evidently directed that way, erected ſome clumſy buttreſſes on the eaſt wall of the ſquare which ſurrounded the whole Greek croſs, and was roofed in with it, forming a ſort of cloiſter round the whole. Theſe buttreſſes, ſpanning over this cloiſter, leaned againſt the piers of the dome, and thus oppoſed the thruſts of the great north and ſouth arches. The dome was now turned for the third time, and many contrivances were adopted for making it extremely light. It was made offenſively flat: and, except the ribs, it was roofed with pumice ſtone; but notwithſtanding theſe precautions, the arches ſettled ſo as to alarm the architects, and they made all ſure by filling up the whole from top to bottom with arcades in three ſtories. The loweſt arcade was very lofty, ſupported by four noble marble columns, and thus preſerved, in ſome meaſure, the church in the form of a Greek croſs. The ſtory above formed a gallery for the women, and had ſix columns in front, ſo that they did not bear fair on thoſe below. The third ſtory was a dead wall filling up the arch, and pierced with three rows of ſmall ill-ſhaped windows. In this unworkmanlike ſhape it has ſtood till now, and is the oldeſt church in the world; but it is an ugly miſhapen maſs, more reſembling an overgrown potter's kiln, ſurrounded with furnaces pieced and patched, than a magnificent temple. We have been thus particular in our account of it, becauſe this hiſtory of the building ſhows that the ancient architects had acquired no diſtinct notions of the action of arches. Almoſt any maſon of our time would know, that as the ſouth arch would puſh the pier to the eaſtward, while the eaſt arch puſhed it to the ſouthward, the

14 Defects of the church of St Sophia at Conſtantinople.

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the buttress which was to withstand these thrusts must not be placed on the south side of the pier, but on the south-east side, or that there must be an eastern as well as a southern buttress. No such blunders are to be seen in a Gothic cathedral. Some of them appear, to a careless spectator, to be very massive and clumsy; but when judiciously examined, they will be found very bold and light, being pierced in every direction by arcades, and the walls are divided into cells like a honeycomb, so that they are very stiff, while they are very light.

15 Such as are never found in a Gothic church.

About the middle, or rather towards the end, of last century, when the Newtonian mathematics opened the road to true mechanical science, the construction of arches engrossed the attention of the first mathematicians. The first hint of a principle that we have met with is Dr Hooke's assertion, that the figure into which a chain or rope, perfectly flexible, will arrange itself when suspended from two hooks, is, when inverted, the proper form for an arch composed of stones of uniform weight. This he affirmed on the same principle which is made use of in the Encyclopædia in the article Roof, § 25. viz. that the figure which a flexible festoon of heavy bodies assumes, when suspended from two points, is, when inverted, the proper form for an arch of the same bodies, touching each other in the same points; because the forces with which they mutually press on each other in this last case, are equal and opposite to the forces with which they pull at each other in the case of suspension.

16 Dr Hooke's principle of arches

This principle is strictly just, and may be extended to every case which can be proposed. We recollect seeing it proposed, in very general terms, in the St. James's Chronicle in 1759, when plans were forming for Blackfriar's Bridge in London; and since it is perhaps equal, in practical utility, to the most elaborate investigations of the mathematicians, our readers will not be displeased with a more particular account of it in this place.

17 Explained,

Let ABC (fig. 6.) be a parcel of magnets of any size and shape, and let us suppose that they adhere with great force by any points of contact. They will compose such a flexible festoon as we have been speaking of, if suspended from the points A and C. If this figure be inverted, preserving the same points of contact, they will remain in equilibrio. It will indeed be that kind of equilibrium which will admit of no disturbance, and which may be called a *tottering equilibrium*. If the form be altered in the smallest degree, by varying the points of contact (which indeed are points in the *figure of equilibration*), the magnets will no more recover their former position than a needle, which we had made to stand on its point, will regain its perpendicular position after it has been disturbed.

But if we suppose planes *de*, *fg*, *hi*, &c. drawn, that the points of mutual contact *a*, *b*, *c*, each bisecting the angle formed by the lines that unite the adjoining contacts (*fg*, for example, bisecting the angle formed by *ab*, *bc*), and if we suppose that the pieces are changed for others of the same weights, but having flat sides, which meet in the planes *de*, *fg*, *hi*, &c. it is evident that we shall have an arch of equilibration, and that the arch will have some stability, or will bear a little change of form without tumbling down: for it is plain that the equilibrium of the original festoon obtained only in the points *a*, *b*, *c*, of contact, where the pressures were perpendicular to the touching surfaces; therefore if the curve *a*, *b*, *c*, still passes through the touching surfaces perpendicularly, the conditions that are required for equilibrium still obtain. The case is quite similar to that of the stability of a body resting on a horizontal plane. If the perpendicular through the centre of gravity falls within the base of the body, it will not only stand, but will require some force to push it over. In the original festoon, if a small weight be added in any part, it will change the form of the curve of equilibration a little, by changing the points of mutual contact. This new curve will gradually separate from the former curve as it recedes from A or C. In like manner, when the festoon is set up as an arch, if a small weight be laid on any part of it, it will bring the whole to the ground, because the shifting of the points of contact will be just the contrary to what it should be to suit the new curve of equilibration. But if the same weight be laid on the same part of the arch now constructed with flat joints, it will be sustained, if the new curve of equilibration still passes through the touching surfaces.

These conclusions, which are very obviously deducible from the principle of the festoon, shew us, without any further discussion, that the longer the joints are, the greater will be the stability of the arch, or that it will require a greater force to break it down. Therefore it is of the greatest importance to have the arch stones as long as economy will permit; and this was the great use of the ribs and other apparent ornaments in the Gothic architecture. The great projections of those ribs augmented their stiffness, and enabled them to support the unadorned copartments of the roof, composed of very small stones, seldom above six inches thick. Many old bridges are still remaining, which are strengthened in the same way by ribs.

Having thus explained, in a very familiar manner, the stability of an arch, we proceed to give the same popular account of the general application of the principle.

18 And applied.

Suppose it to be required to ascertain the form of an arch which shall have the span AB (fig. 7.), and the height F 8, and which shall have a road-way of the dimensions CDE above it. Let the figure ACDEB be inverted, so as to form a figure A *c d e* B. Let a chain of uniform thickness be suspended from the points A and B, and let it be of such a length that its lower point will hang at, or rather a little below, *f*, corresponding to F. Divide AB into a number of equal parts, in the points 1, 2, 3, &c. and draw vertical lines, cutting the chain in the corresponding points 1, 2, 3, &c. Now take pieces of another chain, and hang them on at the points 1, 2, 3, &c. of the chain A *f* B. This will alter the form of the curve. Cut or trim these pieces of chain, till their lower ends all coincide with the inverted road-way *c d e*. The greater lengths that are hung on in the vicinity of A and B will pull down these points of the chain, and cause the middle point *f* (which is less loaded) to rise a little, and will bring it near to its proper height.

It is plain that this process will produce an arch of perfect equilibration; but some farther considerations are necessary for making it exactly suit our purpose. It is an arch of equilibration for a bridge, that is so loaded that the weight of the arch stones is to the weight of the matter with which the haunches and crown are loaded, as the weight of the chain A *f* B is to

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to the sum of the weights of all the little bits of chain very nearly. But this proportion is not known beforehand; we must therefore proceed in the following manner: Adapt to the curve produced in this way a thickness of the arch stones as great as are thought sufficient to ensure stability; then compute the weight of the arch stones, and the weight of the gravel or rubbish with which the haunches are to be filled up to the road-way. If the proportion of these two weights be the same with the proportion of the weights of chain, we may rest satisfied with the curve now found; but if different, we can easily calculate how much must be added equally to, or taken from, each appended bit of chain, in order to make the two proportions equal. Having altered the appended pieces accordingly, we shall get a new curve, which may perhaps require a very small trimming of the bits of chain to make them fit the road-way. This curve will be infinitely near to the curve wanted.

We have practised this method for an arch of 60 feet span and 21 feet height, the arch stones of which were only two feet nine inches long. It was to be loaded with gravel and shivers. We made a previous computation, on the supposition that the arch was to be nearly elliptical. The distance between the points 1, 2, 3, &c. were adjusted, so as to determine the proportion of the weights of chain agreeable to the supposition. The curve differed considerably from an ellipse, making a considerable angle with the verticals at the spring of the arch. The real proportion of the weights of chain, when all was trimmed so as to suit the road-way, was considerably different from what was expected. It was adjusted. The adjustment made very little change in the curve. It would not have changed it two inches in any part of the real arch. When the process was completed, we constructed the curve mathematically. It did not differ sensibly from this mechanical construction. This was very agreeable information; for it showed us that the first curve, formed by about two hours labour, on a supposition considerably different from the truth, would have been sufficiently exact for the purpose, being in no place three inches from the accurate curve, and therefore far within the joints of the intended arch stones. Therefore this process, which any intelligent mason, though ignorant of mathematical science, may go through with little trouble, will give a very proper form for an arch subject to any conditions.

19
The chief defect of the curve found according to this principle.

The chief defect of the curve found in this way is a want of elegance, because it does not spring at right angles to the horizontal line; but this is the case with all curves of equilibration, as we shall see by and by. It is not material: for, in the very neighbourhood of the piers, we may give it any form we please, because the masonry is solid in that place; nay, we apprehend that a deviation from the curve of equilibration is proper. The construction of that curve supposes that the pressure on every part of the arch is vertical; but gravel, earth, and rubbish, exert somewhat of a hydrostatical pressure laterally in the act of settling, and retain it afterwards. This will require some more curvature at the haunches of an arch to balance it; but what this lateral pressure may be, cannot be deduced with confidence from any experiments that we have seen. We are inclined to think that if, instead of dividing the horizontal line AB in the points 1, 2, 3, &c. we divide the chain itself into equal parts, the curve will approach nearer to the proper form.

20
Theory founded on this principle.

After this familiar statement of the general principle, it is now time to consider the theory founded on it more in detail. This theory aims at such an adjustment of the position of the arch stones to the load on every part of the arch, that all shall remain in equilibrio, although the joints be perfectly polished, and without any cement. The whole may be reduced to two problems. The first is to determine the vertical pressure or load on every point of a line of a given form, which will put that line in equilibrio. The second is to determine the form of a curve which shall be in equilibrio when loaded in its different points, according to any given law.

The whole theory is deducible from § 27. of the article Roof. The fundamental proposition in that section states the proportions between the various pressures or thrusts which are exerted at the angles of an assemblage of beams or other pieces of solid heavy matter, freely moveable about those angles, as so many joints, but retaining their position by the equilibrium of those pressures. It is there demonstrated, "that the thrust at any angle, if estimated in a horizontal direction, is the same throughout, and may be represented by any horizontal line BT, fig. 8. (Roofs, fig. 10. Pl. CCCCXL); and that if a vertical line QTS be drawn through T, the thrust exerted at any angle D by the piece CD, in its own direction, will then be represented by BR, drawn parallel to CD; and in like manner, that the thrust in the direction ED is represented by BS, &c.; and, lastly, that the vertical thrusts or loads, at each angle B, C, D, by which all these other pressures are excited, are represented by the portions QC, CR, RS, of the vertical intercepted by those lines; that is, all these pressures are to the uniform horizontal thrust as the lines which represent them are to BT. The horizontal thrust, therefore, is a very proper unit, with which we may compare all the others. Its magnitude is easily deduced from the same proposition; for QS is the sum of all the vertical pressures of the angles, and therefore represents the weight of the whole assemblage. Therefore as QS is to BT, so is the weight of the whole to the horizontal thrust.

21
Accommodated to the construction of an arch vault,

To accommodate this theory to the construction of a curvelineal arch vault, let us first suppose the vault to be polygonal, composed of the cords of the elementary arches. Let AVE (fig. 9.) be a curvelineal arch, of which V is the vertex, and VX the vertical axis, which we shall consider as the axis or abscissa of the curve, while any horizontal line, such as HK, is an ordinate to the curve. About any point C of the curve as a centre describe a circle BLD, cutting the curve in B and D. Draw the equal cords CB, CD. Draw also the horizontal line CF, cutting the circle in F. Describe a circle BCDQ passing through B, C, D. Its centre O will lie in a line CCQ, which bisects the angle BCD, and C *d*, which touches this circle in C, will bisect the angle *b* C *d*, formed by the equal cords BC, CD. Draw CLP perpendicular to *cb*, and DP perpendicular to CD, meeting CL in P. Through L draw the tangent GLM, meeting CD in G, and the vertical line CM in M. Draw the tangent F *a*, cutting the cords BC, CD, in *b* and *d*, and the tangent to the circle BCDQ in *c*. Lastly, draw *d* N parallel to *b c*.

From

Arch. From what is demonstrated in § 27. of the article Roof, it appears, that if BC, CD be two pieces of an equilibrated heavy polygon, and if CF represent the horizontal thrust in every angle of the polygon, C d and C b will severally represent the thrusts exerted by the pieces DC, BC, and that $b\,d$, or CN, will represent the weight lying on the angle BCD, by which those thrusts are balanced.

As the reader may not have the article Roof at hand, this equilibrium may be recalled to his remembrance in the following manner: Produce d C to o, so that C o may be equal to C d. Draw $b\,n$ to the vertical parallel to d B, and join $n\,o$. It is evident that $b\,n\,o$ C is a parallelogram, and that n C ($= b\,d$)=CN. Now the thrust or support of the piece BC is exerted in the direction C b, while that of DC is exerted in the direction C o. These two thrusts are equivalent to the thrust in the diagonal C n; and it is with this compound thrust that the load or vertical pressure CN is in *immediate* equilibrium.

22 And demonstrated. Because b CL, NCF, are right angles, and FCL is common to both, the angles b CF and MCL are equal. Therefore the right angled triangles b CF and MCL are similar. And since CF is equal to CL, $c\,b$ is equal to CM. It is evident that the triangles GCM and d CN are similar. Therefore CG : C d = CM : CN, = C b : CN. Therefore we have $\mathrm{CN} = \frac{\mathrm{C}b \times \mathrm{C}d}{\mathrm{CG}}$. But because CDP and CLG are right angles, and therefore equal, and the angle GCP is common to the two triangles GCL, PCD, and CD is equal to CL, we have CG equal to CP. Therefore $\mathrm{CN} = \frac{\mathrm{C}b \times \mathrm{C}d}{\mathrm{CP}}$. Also, since CDP is a right angle, DP meets the diameter in Q, the opposite point of the circumference, and the angle DQC is equal to DC d, or DC b (because b C d is bisected by the tangent), that is, to PCQ (because the right angles b CP, c DO are equal, and c DP is common). Therefore PQ is equal to PC; and if PO be drawn perpendicular to CQ, it will bisect it, and O is the centre of the circle BCDQB.

Now let the points B and D continually approach to C (by diminishing the radius of the small circle), and ultimately coincide with it. It is evident that the circle BCDQ is ultimately the equicurve circle, and that PC ultimately coincides with OC, the radius of curvature. Also C $b \times$ C d becomes ultimately C c^2. Therefore CN, the vertical load on any point of a curve of equilibration, is $= \frac{\mathrm{C}c^2}{\text{Rad. Curv.}}$

It is farther evident, that CF is to C c as radius to the secant of the elevation of the tangent above the horizon. Therefore we have the load on any point of the curve always proportional to $\frac{\text{Sec.}^2 \text{ Elev.}}{\text{Rad. Curv.}}$

This load on every elementary arch of the wall is commonly a quantity of solid matter incumbent on that element of the curve, and pressing it vertically; and it may be conceived as made up of a number of heavy lines standing vertically on it. Thus, if the element E e of the curve were lying horizontally, a little parallelogram RE $e\,r$, standing perpendicularly on it, would represent its load. But as this element E e has a sloping position, it is plain that, in order to have the same quantity of heavy matter pressing it vertically, the height of the parallelogram must be increased till it meets in $e\,\rho$, the line R e drawn parallel to the tangent EG. It is evident that the angle RE ρ is equal to the angle AEG. Therefore we have ER : E ρ = Rad. : Sec. Elev. Arch.

If therefore the arch is kept in equilibrio by the vertical pressure of a wall, we must have the height of the wall above any point proportional to $\frac{\text{Sec.}^3 \text{ Elev.}}{\text{Rad. of Curv.}}$ 23

Cor. I. If OS be drawn perpendicular to the vertical CS, CS will be half the vertical cord of the equicurve circle. The angle OCS is equal to c CF, that is, to the angle of elevation. Therefore 1 : Sec. Elev. = CS : CO, and the secant of elevation may be expressed by $\frac{\mathrm{CO}}{\mathrm{CS}}$, and its cube by $\frac{\mathrm{CO}^3}{\mathrm{CS}^3}$. Therefore the height of wall is proportional to $\frac{\mathrm{CO}^3}{\mathrm{CS}^3 \times \mathrm{CO}}$, or to $\frac{\mathrm{CO}^2}{\mathrm{CS}^3}$, or $\frac{\mathrm{CO}^2}{\mathrm{CS}^2 \times \mathrm{CS}}$, or to $\frac{\text{Sec.}^2 \text{ of Elev.}}{\text{Vert. Cord of Curv.}}$ Corollaries.

Cor. II. If we make the arch VC = z, the abscissa VH=x, the ordinate HC=y, the radius osculi CO=r, and the $\frac{1}{2}$ vertical cord CS = s, the height of wall pressing on any point is proportional to $\frac{\dot{z}^3}{\dot{y}^3 r}$; or to $\frac{\dot{z}^2}{\dot{y}^2 s}$, or $\frac{\dot{x}^2+\dot{y}^2}{\dot{y}^2 s}$. Therefore, when the equation of the curve is given, and the height of wall on any one point of it is also given, we can determine it for any other point: for the equation of the curve will always give us the relation of $\dot{z}$, $\dot{x}$, and $\dot{y}$, and the value of r or s. This may be illustrated by an example or two. For this purpose it will generally be most convenient to assume the height above the vertex V for the unit of computation. The thickness of the arch at the crown is commonly determined by other circumstances. At the vertex the tangent to the arch is horizontal, and therefore the cube of the secant is unity or 1. Call the height of wall, at the crown, H, and let the radius of curvature in that point be R, and its half cord R (it being then coincident with the radius), and the height on any other point h. We have $\frac{1}{\mathrm{R}} : \frac{\dot{z}^3}{\dot{y}^3 r} = \mathrm{H} : h$, and $h = \mathrm{H} \times \frac{\dot{z}^3}{\dot{y}^3} \times \frac{\mathrm{R}}{r}$. The other formula gives $h = \mathrm{H} \times \frac{\dot{z}^2}{\dot{y}^2} \times \frac{\mathrm{R}}{s}$.

24 Illustrated by examples. *Examp.* 1. Suppose the arch to be a segment of a circle, as in fig. 10. where AE is the diameter, and O the centre. In this arch the curvature is the same throughout, or $\frac{\mathrm{R}}{r} = 1$. Therefore $h = \mathrm{H} \times \frac{\dot{z}^3}{\dot{y}^3}$, or $= \mathrm{H} \times$ Cube Sec. Elev.

This gives a very simple calculus. To the logarithm of H add thrice the logarithm of the secant of elevation. The sum is the logarithm of h.

It gives also a very simple construction. Draw the vertical CS, cutting the horizontal diameter in S. Draw ST, cutting the radius OC perpendicularly in T. Draw the horizontal line T z, cutting the vertical in z. Join $z\,o$. Make C u = V v, and draw $u\,x$ parallel to $z\,o$. C c must be made = C x. The demonstration is evident.

It is very easy to see that if CV is an arch of 60°, and V v is $\frac{1}{14}$th of VC, the points v and c will be on a level;

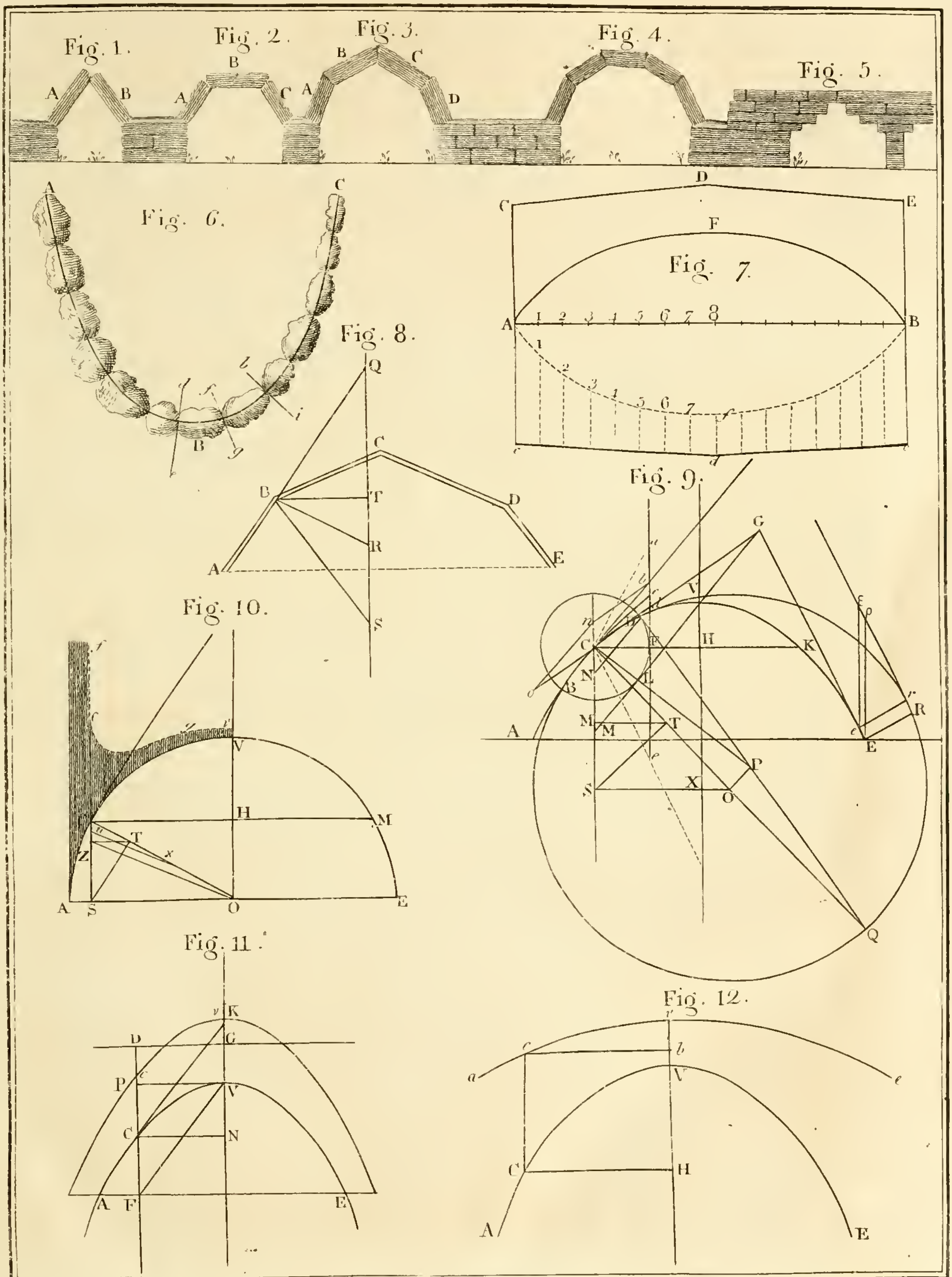
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.

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a level; for the fecant of CV is twice CO, and therefore C c is 8 times V v, which is $\frac{1}{7}$th of VH.

The dotted line $v\,g\,c\,f$ is drawn according to this calculus or conftruction. It falls confiderably below the horizontal line in the neighbourhood of c; and then, paffing very obliquely through c, it rifes rapidly to an unmeafurable height, becaufe the vertical line through A is its affymptote. This muft evidently be the cafe with every curve which fprings at right angles with a horizontal line.

It is plain that if v V be greater, all the other ordinates of the curve $v\,g\,c\,f$, refting on the circumference AVE, will be greater in the fame proportion, and the curve will cut the horizontal line drawn through v in fome point nearer to v than c is. Hence it appears that a circular arch cannot be put in equilibrio by building on it up to a horizontal line, whatever be its fpan, or whatever be the thicknefs at the crown. We have feen that when this thicknefs is only $\frac{1}{14}$th of the radius, an arch of 120 degrees will be too much loaded at the flanks. This thicknefs is much too fmall for a bridge, being only $\frac{1}{25}$th of the fpan CM, whereas it fhould have been almoft double of this, to bear the inequalities of weight that may occafionally be on it. When the crown is made ftill thinner, the outline is ftill more depreffed before it rifes again. There is therefore a certain fpan, with a correfponding thicknefs at the crown, which will deviate leaft of all from a horizontal line. This is an arch of about 54 degrees, the thicknefs at the crown being about one-fourth of the fpan, which is extravagantly great. It appears in general therefore, that the circle is not a curve fuited to the purpofes of a bridge or an arcade, which requires an outline nearly horizontal.

Examp. 2. Let the curve be a parabola AVE (fig. 11.), of which V is the vertex, and DG the directrix. Draw the diameters DCF, GVN, the tangent CK, VP, and the ordinates VF and CN. It is well known that GV is to DC as VP^2 to CK^2, or as CN^2 to CK^2. Alfo 2 GV is the radius of the ofculating circle at V, and 2 DC is one-half of the vertical cord of the ofculating circle at C. Therefore $CN^2 : CK^2$ (or $\dot{y}^2 : \dot{z}^2$) $= R : s$, and $s = \frac{\dot{z}^2}{\dot{y}^2}R$. But C c, or $h = H \times \frac{\dot{z}^2 R}{\dot{y}^2 S}$. Therefore

$$h = H \times \frac{\dot{z}^2 \quad R}{\dot{y}^2 \frac{\dot{z}^2}{\dot{y}^2}R}, \; = H \times \frac{\dot{z}^2 R}{\dot{z}^2 R}, \; = H. \quad \text{Therefore}$$

$C\,c = v\,V$.

It follows from this inveftigation, that the back or extrados of a parabolic arch of equilibration muft be parallel to the arch or foffit itfelf; or that the thicknefs of the arch, eftimated in a vertical direction, muft be equal throughout; or that the extrados is the fame parabola with the foffit or intrados.

We have felected thefe two examples merely for the fimplicity and perfpicuity of the folutions, which have been effected by means of elementary geometry only, inftead of employing the analytical value of the radius of the ofculatory circle viz. $\frac{\dot{z}^3}{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}$, which would have involved us at leaft in the elements of fecond fluxions. We have alfo preferred fimplicity to elegance in the inveftigation, becaufe we wifh to inftruct the practical engineer, who may not be a proficient in the higher mathematics.

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25 The converfe of the problem, namely, to find the form of the arch when the figure of the back of it is given, is the moft ufual queftion of the two, at leaft in cafes which are moft important and moft difficult. Of thefe perhaps bridges are the chief. Here the neceffity of a road-way, of eafy and regular afcent, confines us to an outline nearly horizontal, to which the curve of the arch muft be adapted. This is the moft difficult problem of the two; and we doubt whether it can be folved without employing infinite approximating feriefes inftead of accurate values.

To find the form of an arch when the figure of its back is given.

Let $a\,v\,e$ (fig. 12.) be the intended outline or extrados of the arch AVE, and let v Q be the common axis of both curves. From c and C, the correfponding points, draw the ordinates $c\,h$, CH. Let the thicknefs v V at the top be a, the abfciffa $v\,h$ be $= u$, and VH $= x$, and let the equal ordinates $c\,h$, CH be y, and the arch VC be z.

Then, by the general theorem, $c\,C = \frac{\dot{z}^3}{r\,\dot{y}^3}$, r being the radius of curvature. This, by the common rules, is $= \frac{\dot{z}^3}{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}$. This gives us $c\,C \doteq \frac{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}{\dot{y}^3}$, or $= \frac{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}{\dot{y}^3} \times C$; where C is a conftant quantity, found by taking the real value of $c\,C$ in V, the vertex of the curve. But it is evident that it is alfo $= a + x - u$. Therefore $a + x - u = \frac{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}{\dot{y}^3} \times C, = \frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

If we now fubftitute the true value of u (which is given, becaufe the extrados is fuppofed to be of a known form), expreffed in terms of y, the refulting equation will contain nothing but x and y, with their firft and fecond fluxions, and known quantities. From this equation the relation of x and y muft be found by fuch methods as feem beft adapted to the equation of the extrados.

Fortunately the procefs is more fimple and eafy in the moft common and ufeful cafe than we fhould expect from this general rule. We mean the cafe where the extrados is a ftraight line, efpecially when this is horizontal. In this cafe u is equal to o.

Example. To find the form of the balanced arch AVE (fig. 13.), having the horizontal line $c\,v$ for its extrados. Plate II.

Keeping the fame notation, we have $u = o$, and therefore $a + x = \frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

Affume $\dot{y} = \frac{\dot{x}}{v}$; then $\frac{\dot{x}}{\dot{y}} = v$, and $\frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$, $= \frac{C v \dot{v}}{\dot{x}}$, that is $a + x = \frac{C v \dot{v}}{\dot{x}}$. Therefore $a\dot{x} + x\dot{x} = C v \dot{v}$; and by taking the fluents, we have $2ax + x^2 = C v^2$; and $\dot{v} = \sqrt{\frac{2ax + x^3}{C}}$. Confequently, $\dot{y} =$

$\dot{y} = \frac{\sqrt{C}\,\dot{x}}{\sqrt{2ax \times x^2}}\left(\text{being} = \frac{\dot{x}}{v}\right)$. Taking the fluent of this, we have $y = \sqrt{C} \times L\,(2ax + 2x^2 + 2\sqrt{2ax + x^2})$. But at the vertex, where $x = 0$, we have $y = \sqrt{C} \times L\,(2a)$. The corrected fluent is therefore $y = \sqrt{C} \times L\,\frac{a + x + \sqrt{2ax + x^2}}{a}$.

It only remains to find the conſtant quantity C. This we readily obtain by ſelecting ſome point of the extrados where the values of x and y are given by particular circumſtances of the caſe. Thus, when the ſpan $2s$ and height h of the arch are given, we have $s = \sqrt{C} \times L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)$, and conſequently $\sqrt{C} = \frac{s}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}$. Therefore

the general value of $y = s \times \frac{L\left(\frac{a + x + \sqrt{2ax + x^2}}{a}\right)}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}$;

$$= \frac{s}{L\frac{a + h + \sqrt{2ah + h^2}}{a}} \times L\,\frac{a + x + \sqrt{2ax + x^2}}{a}.$$

As an example of the uſe of this formula, we ſubjoin a table calculated by Dr Hutton of Woolwich for an arch, the ſpan of which is 100 feet and the height 40, which are nearly the dimenſions of the middle arch of Blackfriars Bridge in London.

y	x	y	x	y	x
0	6,000	21	10,381	36	21,774
2	6,035	22	10,858	37	22,948
4	6,144	23	11,368	38	24,190
6	6,324	24	11,911	39	25,505
8	6,580	25	12,489	40	26,894
10	6,914	26	13,106	41	28,364
12	7,330	27	13,761	42	29,919
13	7,571	28	14,457	43	31,563
14	7,834	29	15,196	44	33,299
15	8,120	30	15,980	45	35,135
16	8,430	31	16,811	46	37,075
17	8,766	32	17 693	47	39,126
18	9,168	33	18,627	48	41,293
19	9,517	34	19,617	49	43,581
20	9,934	35	20,665	50	46,000

26 Defects of the Catenarian curve.

The figure for this propoſition is exactly drawn according to theſe dimenſions, that the reader may judge of it as an object of ſight. It is by no means deficient in gracefulneſs, and is abundantly roomy for the paſſage of craft; ſo that no objection can be offered againſt its being adapted on account of its mechanical excellency.

The reader will perhaps be ſurpriſed that we have made no mention of the celebrated Catenarean curve, which is commonly ſaid to be the beſt form for an arch; but a little reflection will convince him, that although it is the only form for an arch conſiſting of ſtones of equal weight, and touching each other only in ſingle points, it cannot ſuit an arch which muſt be filled up in the haunches, in order to form a road-way. He will be more ſurpriſed to hear, after this, that there is a certain thickneſs at the crown, which will put the Catenarea in equilibrio, even with a horizontal road-way; but this thickneſs is ſo great as to make it unfit for a bridge, being ſuch that the preſſure at the vertex is equal to the horizontal thruſt. This would have been about 37 feet in the middle arch of Blackfriars Bridge. The only ſituation therefore in which the Catenarean form would be proper, is an arcade carrying a height of dead wall; but in this ſituation it would be very ungraceful. Without troubling the reader with the inveſtigation, it is ſufficient to inform him that in a Catenarean arch of equilibration the abſciſſa VH is to the abſciſſa $v\,h$ in the conſtant ratio of the horizontal thruſt to its exceſs above the preſſure on the vertex.

27 Inutility of the common theory of equilibration.

This much will ſerve, we hope, to give the reader a clear notion of this celebrated theory of the equilibrium of arches, one of the moſt delicate and important applications of mathematical ſcience. Volumes have been written on the ſubject, and it ſtill occupies the attention of mechanicians. But we beg leave to ſay, with great deference to the eminent perſons who have proſecuted this theory, that their ſpeculations have been of little ſervice, and are little attended to by the practitioner. Nay, we may add, that Sir Chriſtopher Wren, perhaps the moſt accompliſhed architect that Europe has ſeen, ſeems to have thought it of little value: for, among the fragments which have been preſerved of his ſtudies, there are to be ſeen ſome imperfect diſſertations on this very ſubject, in which he takes no notice of this theory, and conſiders the balance of arches in quite another way. Theſe are collected by the author of the account of Sir Chriſtopher Wren's family. This man's great ſagacity, and his great experience in building, and, ſtill more his experience in the repairs of old and crazy fabrics, had ſhown him many things very inconſiſtent with this theory, which appears ſo ſpecious and ſafe. The general facts which occur in the failure of old arches are highly inſtructive, and deſerve the moſt careful attention of the engineer; for it is in this ſtate that their defects, and the proceſs of nature in their deſtruction, are moſt diſtinctly ſeen. We venture to affirm, that a very great majority of theſe facts are irreconcileable to the theory. The way in which circular arches commonly fail, is by the ſinking of the crown and the riſing of the flanks. It will be found by calculation, that in moſt of the caſes it ought to have been juſt the contrary. But the cleareſt proof is, that arches very rarely fail where their load differs moſt remarkably from that which this theory allows. Semicircular arches have ſtood the power of ages, as may be ſeen in the bridges of ancient Rome, and in the numerous arcades which the ancient inhabitants have erected. Now all arches which ſpring perpendicularly from the horizontal line, require, by this theory, a load of infinite height; and, even to a conſiderable diſtance from the ſpringing of the arch, the load neceſſary for the theoretical equilibrium is many times greater than what is ever laid on thoſe parts; yet a failure in the immediate neighbourhood of the ſpring of an arch is a moſt rare phenomenon, if it ever was obſerved. Here is a moſt remarkable deviation from the theory; for, as is already obſerved, the load is frequently not the fourth part of what the theory requires.

Many other facts might be adduced which ſhow great deviations

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deviations from the legitimate refults from the theory. We hope to be excufed, therefore, by the mathematicians for doubting of the juftnefs of this theory. We do not think it erroneous, but defective, leaving out circumftances which we apprehend to be of great importance; and we imagine that the defects of the theory have arifen from the very anxiety of the mechanicians to make it perfect. The arch ftones are fuppofed to be perfectly fmooth or polifhed, and not to be connected by any cement, and therefore to fuftain each other merely by the equilibrium of their vertical preffure. The theory enfures this equilibrium, and this only, leaving unnoticed any other caufes of mutual action.

28
Its defects.

The authors who have written on the fubject fay exprefsly, that an arch which thus fuftains itfelf muft be ftronger than another which would not; becaufe when, in imagination, we fuppofe both to acquire connection by cement, the firft preferves the influence of this connection unimpaired; whereas in the other, part of the cohefion is wafted in counteracting the tendency of fome parts to break off from the reft by their want of equilibrium. This is a very fpecious argument, and would be juft, if the forces which are mutually exerted between the parts of the arch in its fettled ftate were merely vertical preffures, or, where different, were inconfiderable in comparifon with thofe which are really attended to in the conftruction.

But this is by no means the cafe. The forms which the ufes for which arches are erected oblige us to adopt, and the loads laid on the different points of the arch, frequently deviate confiderably from what are neceffary for the equilibrium of vertical preffures. The varying load on a bridge, when a great waggon paffes along it, fometimes bears a very fenfible proportion to the weight of that point of the arch on which it refts. It is even very doubtful whether the preffures which are occafioned by the weight of the ftuff employed for filling up the flanks really act in a vertical direction, and in the proportion which is fuppofed. We are pretty certain that this is not the cafe with fand, gravel, fat mould, and many fubftances in very general ufe for this purpofe. When this is the cafe, the preffures fuftained by the different parts of the arch are often very inconfiftent with the theory—a part of the arch is overloaded, and tends to fall in, but is prevented by the cement. This part of the arch therefore acts on the remoter parts by the intervention of the parts between, employing thofe intermediate parts as a kind of levers to break the arch in a remote part, juft as a lintel would be broken. We apprehend that a mathematician would be puzzled how to explain the ftability of an arch cut out of a folid and uniform mafs of rock. His theory confiders the mutual thrufts of the arch ftones as in the direction of the tangents to the arch. Why fo? becaufe he fuppofes that all his polifhed joints are perpendicular to thofe tangents. But in the prefent cafe he has no exifting joints; and there feems to be nothing to direct his imagination in the affumption of joints, which, however, are abfolutely neceffary for employing his theory, becaufe, without a fuppofition of this kind, there feems no conceiving any mutual abutment of the arch ftones. Afk a common, but intelligent, mafon what notion he forms of fuch an arch? We apprehend that he will confider it as no arch, but as a lintel, which may be broken like a wooden lintel, and which refifts entirely by its cohefion. He will not readily conceive that, by cutting the under fide of a ftone lintel into an arched form, and thus taking away more than half of its fubftance, he has changed its nature of a lintel, or given it any additional ftrength. Nor would there be any change made in the way in which fuch a mafs of ftone would refift being broken down, if nothing were done but forming the under fide into an arch. If the lintel be fo laid on the piers that it can be broken without its parts pufhing the piers afide (which will be the cafe if it lies on the piers with horizontal joints), it will break like any other lintel; but if the joints are directed downwards, and converging to a point within the arch, the broken ftone (fuppofe it broken at the crown by an overload in that part) cannot be preffed down without forcing the piers outwards. Now, in this mode of acting, the mind cannot trace any thing of the ftatical equilibrium that we have proceeded on in the foregoing theory. The two parts of the broken lintel feem to pufh the piers afide in the fame manner that two rafters pufh outwards the walls of a houfe, when their feet are not held together by a tye-beam. If the piers cannot be pufhed afide (as when the arch abuts on two folid rocks), nothing can prefs down the crown which does not crufh the ftone.

This conclufion will be ftrictly true if the arch is of fuch a form that a ftraight line drawn from the crown to the pier lies wholly within the folid mafonry. Thus if the vault confift of two ftraight ftones, as in fig. 1. or if it confift of feveral ftones, as in fig. 14. difpofed in two ftraight lines, no weight laid on the crown can deftroy it in any other way but by crufhing it to powder.

29
When it is to be called into the aid of the builder.

But when ftraight lines cannot be drawn from the overloaded part to the firm abutments through the folid mafonry, and when the cohefion of the parts is not able to withftand the tranfverfe ftrains, we muft call the principles of equilibrium to our aid; and, in order to employ them with fafety, we muft confider how they are modified by the excitement of the cohering forces.

The cohefion of the ftones with each other by cement or otherwife, has, in almoft every fituation, a bad effect. It enables an overload at the crown to break the arch near the haunches, caufing thofe parts to rife, and then to fpread outwards, juft as a Manfarde or Kirb roof would do if the trufs-beam which connects the heads of the lower rafters were fawn through. This can be prevented only by loading that part more than is requifite for equilibrium. It would be prudent to do this to a certain degree, becaufe it is by this cohefion that the crown always becomes the weakeft part of the arch, and fuffers more by any occafional load.

We expect that it will be faid in anfwer to all this, that the cohefion given by the ftrongeft cement that we can employ, nay the cohefion of the ftone itfelf, is a mere nothing in comparifon with the enormous thrufts that are in a ftate of continual exertion in the different parts of an arch. This is very true; but there is another force which produces the fame effect, and which increafes nearly in the proportion that thofe thrufts increafe, becaufe it arifes from them. This is the friction of the ftones on each other. In dry freeftone this friction confiderably exceeds one-half of the mutual preffure. The reflecting reader will fee that this produces the fame effect, in the cafe under confideration, that cohefion heſion would do; for while the arch is in the act of failing, the mutual preſſure of the arch ſtones is acting with full force, and thus produces a friction more than adequate to all the effects we have been ſpeaking of.

30 Proceſs of the breaking of an arch.

When theſe circumſtances are conſidered, we imagine that it will appear that an arch, when expoſed to a great overload on the crown (or indeed on any part), divides, of itſelf, into a number of parts, each of which contains as many arch ſtones as can be pierced (ſo to ſpeak) by one ſtraight line, and that it may then be conſidered as nearly in the ſame ſituation with a polygonal arch of long ſtones butting on each other like ſo many beams in a Norman roof (ſee Roof, n° 49), but without their braces and ties. It tends to break at all thoſe angles; and it is not ſufficiently reſiſted there, becauſe the materials with which the flanks are filled up have ſo little coheſion, that the angle feels no load except what is immediately above it; whereas it ſhould be immediately loaded with all the weight which is diffuſed over the adjoining ſide of the polygon. This will be the caſe, even though the curvelineal arch be perfectly equilibrated. We recollect ſome circumſtances in the failure of a conſiderable arch, which may be worth mentioning. It had been built of an exceedingly ſoft and friable ſtone, and the arch ſtones were too ſhort. About a fortnight before it fell, chips were obſerved to be dropping off from the joints of the archſtones about ten feet on each ſide of the middle, and alſo from another place on one ſide of the arch, about twenty feet from its middle. The maſons in the neighbourhood prognoſticated its ſpeedy downfal, and ſaid that it would ſeparate in thoſe places where the chips were breaking off. At length it fell; but it firſt ſplit in the middle, and about 15 or 16 feet on each ſide, and alſo at the very ſpringing of the arch. Immediately before the fall a ſhivering or crackling noiſe was heard, and a great many chips dropped down from the middle between the two places from whence they had dropped a fortnight before. The joints opened above at thoſe new places above two inches, and in the middle of the arch the joints opened below, and in about five minutes after this the whole came down. Even this movement was plainly diſtinguiſhable into two parts. The crown ſunk a little, and the haunches roſe very ſenſibly, and in this ſtate it hung for about half a minute. The arch ſtones of the crown were hanging by their upper corners. When theſe ſplintered off, the whole fell down.

We apprehend that the procedure of nature was ſomewhat in this manner. Straight lines can be drawn within the archſtones from A (fig. 15.) to B and D, and from thoſe points to C and E. Each of the portions ED, DA, AB, BC, reſiſt as if they were of one ſtone, compoſing a polygonal vault EDABC. When this is overloaded at A, A can deſcend in no other way than by puſhing the angles B and D outwards, cauſing the portions BC, DE, to turn round C and E. This motion muſt raiſe the points B and D, and cauſe the arch ſtones to preſs on each other at their *inner* joints *b* and *d*. This produced the copious ſplintering at theſe joints immediately preceding the total downfal. The ſplintering which happened a fortnight before aroſe from this circumſtance, that the lines AB and AD, along which the preſſure of the overload was propagated, were tangents to the ſoffit of the arch in the points F, H, and G, and therefore the ſtrain lay all on theſe corners of the arch ſtones, and ſplintered a little from off them till the whole took a firmer bed. The ſubſequent phenomena are evident conſequences of this diſtribution and modification of preſſure, and can hardly be explained in any other way; at leaſt not on the theoretical principles already ſet forth: for in this bridge the loads at B and D were very conſiderably greater than what the equilibrium required; and we think that the firſt obſerved ſplintering at H, F, and G, was moſt inſtructive, ſhowing that there was an extraordinary preſſure at the inner joints in thoſe places, which cannot be explained by the uſual theory.

Not ſatisfied with this ſingle obſervation, after this way of explaining it occurred to us, and not being able to find any ſimilar fact on record, the writer of this article got ſome ſmall models of arches executed in chalk, and ſubjected them to many trials, in hopes of collecting ſome general laws of the internal workings of arches which finally produce their downfal. He had the pleaſure of obſerving the above mentioned circumſtances take place very regularly and uniformly, when he overloaded the models at A. The arch always broke at ſome place B conſiderably beyond another point F, where the firſt chipping had been obſerved. This is a method of trial that deſerves the attention both of the ſpeculatiſt and the practitioner.

If theſe reflections are any thing like a juſt account of the procedure of nature in the failure of an arch, it is evident that the ingenious mathematical theory of equilibrated arches is of little value to the engineer. We ventured to ſay as much already, and we reſted a good deal on the authority of Sir Chriſtopher Wren. He was a good mathematician, and delighted in the application of this ſcience to the arts. He was a celebrated architect; and his reports on the various works committed to his charge, ſhow that he was in the continual habit of making this application. Several ſpecimens remain of his own methods of applying them. The roof of the theatre of Oxford, the roof of the cupola of St. Paul's, and in particular the mould on which he turned the inner dome of that cathedral, are proofs of his having ſtudied this theory moſt attentively. He flouriſhed at the very time that it occupied the attention of the greateſt mechanicians of Europe; but there is nothing to be found among his papers which ſhows that he had paid much regard to it. On the contrary, when he has occaſion to deliver his opinion for the inſtruction of others, and to explain to the Dean and Chapter of Weſtminſter his operations in repairing that collegiate church, this great architect conſiders an arch juſt as a ſenſible and ſagacious maſon would do, and very much in the way that we have juſt now been treating it: (See *Account of the Family of Wren*, p. 356, &c.) Supported therefore by ſuch authority, we would recommend this way of conſidering an arch to the ſtudy of the mathematician; and we would deſire the experienced maſon to think of the moſt efficacious methods for reſiſting this tendency of arches to riſe in the flanks. Unfortunately there ſeems to be no preciſe principle to point out the place where this tendency is moſt remarkable.

We are therefore highly pleaſed with the ingenious contrivance of Mr. Mylne, the architect of Blackfriars Bridge in London, by which he determines this point with

Arch. with precision, by making it impossible for the overloaded arch to spring in any other place. Having thus confined the failure to a particular spot, he with equal art opposes a resistance which he believes to be sufficient; and the present condition of that noble bridge, which does not in any place show the smallest change of shape, proves that he was not mistaken. Looking on this work as the first, or at least the second, specimen of masonic ingenuity that is to be seen in the world, we imagine that our readers will be pleased with a particular account of its most remarkable circumstances.

31 Construction of Blackfriars Bridge. Plate III.

The span *k a* (fig. 16.) of the middle arch is 100 feet, and its height OV is 40, and the thickness KV of the crown is six feet seven inches. Its form is nearly elliptical; the part AVZ being an arch of a circle whose centre is C, and radius 56 feet, and the two lateral portions A *k* B and Z *a* E being arches described with a radius of 35 feet nearly. The thickness of the pier at *a b* is 19 feet. The thickness of the arch increases from the crown V to Y, where it is eight or nine feet. All the arch stones have their joints directed to the centres of their curvature. The joints are all joggled, having a cubic foot of hard stone let half way into each. By this contrivance the joints cannot slide, nor can any weight laid on the crown ever break the arch in that part, if the piers do not yield; for a straight line from the middle of KV to the middle of the joint YI is contained within the solid masonry, and does not even come near the inner joints of the arch stones. Therefore the whole resists like one stone, and can be broken only by crushing it. The joint at Z is very nearly perpendicular to a line YF drawn to the outer edge of the foundation of the pier. By this it was intended to take off all tendency of the pressure on the joint *d* Z to overset the pier; for if we suppose, according to the theory of equilibration, that this pressure is necessarily exerted perpendicularly to the joint, its direction passes through the fulcrum at F, round which it is thought that the pier must turn in the act of oversetting. This precaution was adopted, in order to make the arch quite independent of the adjoining arches; so that although any of them should fall, this arch should run no risk.

Still farther to secure the independence of the arch, the following construction was practised to unite it into one mass, which should rise all together. All below the line *a b* is built of large blocks of Portland stone, dovetailed with sound oak. Four places in each course are interrupted by equal blocks of a hard stone called *Kentish rag*, sunk half way in each course. These act as joggles, breaking the courses, and preventing them from sliding laterally.

The portion *a* Y of the arch is joggled like the upper part. The interior part is filled up with large blocks of Kentish rag, forming a kind of coursed rubble-work, the courses tending to the centres of the arch. The under corner of each arch stone projects over the one below it. By this form it takes fast hold of the rubble-work behind it. Above this rubble there is constructed the inverted arch I *c* G of Portland stone. This arch shares the pressure of the two adjoining arches, along with the arch stones in Y *a* and in G *b*. Thus all tend together to compress and keep down the rubble-work in the heart of this part of the pier. This is a very useful precaution; for it often happens, that when the centres of the arches are struck, before the piers are built up to their intended height, the thrust of the arches squeezes the rubble-work horizontally, after the morter has set, but before it has dried and acquired its utmost hardness. Its bond is broken by this motion, and it is squeezed up, and never acquires its former firmness. This is effectually prevented by the pressure exerted by the back of the inverted arch.

Above this counter arch is another mass of coursed rubble, and all is covered by a horizontal course of large blocks of Portland stone, butting against the back of the arch stone ZI and its corresponding one in the adjoining arch. This course connects the feet of the two arches, preserves the rubble work from too great compression, and protects it from soaking water. This last circumstance is important; for if the water which falls on the road-way is not carried off in pipes, it soaks through the gravel or other rubbish, rests on the morter, and keeps it continually wet and soft. It cannot escape through the joints of good masonry, and therefore fills up this part like a funnel.

Supposing the adjoining arch fallen, and all tumbled off that is not withheld by its situation, there will still remain in the pier a mass of about 3500 tons. The weight of the portion VY is about 2000 tons. The directions of the thrusts RY and YF are such, that it would require a load of 4500 tons on VY to overturn the pier round F. This exceeds VY by 2500 tons; a weight incomparably greater than any that can ever be laid on it.

Such is the ingenious construction of Mr. Mylne. It evidently proceeds on the principles recommended above; principles which have occurred to his experience and sagacious mind during the course of his extensive practice. We have seen attempts by other engineers to withstand the horizontal thrusts of the arch by means of counter arches inserted in the same manner as here, but extending much farther over the main arch; but they did not appear to be well calculated for producing this effect. A counter arch springing from any point between Y and V has no tendency to hinder that point from rising by the sinking of the crown; and such a counter arch will not resist the precisely horizontal thrust so well as the straight course of Mr. Mylne.

THE great incorporation of architects who built the cathedrals of Europe departed entirely from the styles of ancient Greece and Rome, and introduced another, in which arcades made the principal part. Not finding in every place quarries from which blocks could be raised in abundance of sufficient size for forming the far-projecting corniches of the Greek orders, they relinquished those proportions, and adopted a style of ornament which required no such projections: and having substituted arches for the horizontal architrave or lintel, they were now able to erect buildings of vast extent with spacious openings, and all this with very small pieces of stone. The form which had been adopted for a Christian temple occasioned many intersections of vaultings, and multiplied the arches exceedingly. Constant practice gave opportunities of giving every possible variety of these intersections, and taught the art of balancing arch against arch in every variety of situation. An art so multifarious, and so much out of the road of

32 Origin of the Gothic arches.

Arch.

of ordinary thought, could not but become an object of fond study to the architects most eminent for ingenuity and invention. Becoming thus the dupes of their own ingenuity, they were fond of displaying it even when not necessary. At last arches became their principal ornament, and a wall or ceiling was not thought dressed out as it should be till filled full of mock arches, crossing and butting on each other in every direction. In this process in their ceilings they found that the projecting mouldings, which we now call the Gothic tracery, formed the chief supports of the roofs. The plane surfaces included between those ribs were commonly vaulted with very small stones, seldom exceeding six or eight inches in thickness. This tracery therefore was not a random ornament. Every rib had a position and direction that was not only proper, but even necessary. Habituated to this scientific arrangement of the mouldings, they did not deviate from it when they ornamented a smooth surface with mock arches; and in none of the highly ornamented *ancient* buildings will we find any false positions. This is by no means the case in many of the modern imitations of Gothic architecture, even by our best architects. Ignorant of the directing principle, or not attending to it, in their stucco work, they please the unskilled eye with pretty radiated figures: but in these we frequently see such abutments of mouldings as would infallibly break the arches, if these mouldings were really performing their ancient office, and supporting a vaulting of considerable extent. Nay, this began even before the Gothic style was finally abandoned. Several instances are to be found in the highly enriched vaultings of New College, and Christ Church in Oxford, in St George's Chapel at Windsor, and Henry VII's Chapel in Westminster.

33 Degeneracy of that style.

We call the middle ages rude and barbarous; but there was surely much knowledge in those who could execute such magnificent and difficult works. The working drafts which were necessary for such varieties of oblique intersections must have required considerable skill, and would at present occupy many very expensive volumes of *masons jewels* and *carpenters manuals*, and the like. All this knowledge was kept a profound secret by the corporation, and on its breaking up we had all to learn again.

There is no appearance, however, that those architects had studied the theory of equilibrated arches. They had adopted an arch which was very strong, and permitted considerable irregularities of pressure—we mean the pointed arch. The very deep mouldings with which it was ornamented, made the arch stones very long in proportion to the span of the arch. But they had studied the mutual thrust of arches on each other with great care; and they contrived to make every invention for this purpose become an ornament, so that the eye *required* it as a necessary part of the building. Thus we frequently see small buildings having buttresses at the sides. These are necessary in a large vaulted building, for withstanding the outward thrust of the vaulting; but they are useless when we have a flat ceiling within. Pinnacles on the heads of the buttresses are now considered as ornaments; but originally they were put there to increase the weight of the buttress: even the great tower, in the centre of a cathedral, which now constitutes its great ornament, is a load almost indispensably necessary, for enabling the four principal columns to withstand the combined thrust of the aisles, of the nave, and transepts. In short, the more closely we examine the ornaments of this architecture, the more shall we perceive that they are essential parts, or derived from them by imitation: and the more we consider the whole style of it, the more clearly do we see that it is all deduced from the relish for arcades, indulged in the extreme, and pushed to the limit of possibility of execution.

34 Great skill of the ablest Gothic architects.

35. Dome or cupola

THERE is another species of arch which must not be overlooked, namely, the DOME or CUPOLA, with all its varieties, which include even the pyramidal steeple or spire.

It is evident that the erection of a dome is also a scientific art, proceeding on the principles of equilibration, and that these principles admit and require the same or similar modifications, in consequence of the cohesion and friction of the materials. At first sight, too, a dome appears a more difficult piece of work than a plain arch; but when we observe potters kilns and glasshouse domes and cones of vast extent, erected by ordinary bricklayers, and with materials vastly inferior in size to what can be employed in common arches of equal extent, we must conclude that the circumstance of curvature in the horizontal direction, or the abutment of a circular base, gives some assistance to the artist. Of this we have complete demonstration in the case of the cone. We know that a vaulting in the form of a pent roof could not be executed to any considerable extent, and would be extremely hazardous, even in the smallest dimensions; while a cone of the greatest magnitude can be raised with very small stones, provided only that we prevent the bottom from flying out, by a hoop, or any similar contrivance. And when we think a little of the matter, we see plainly, that if the horizontal section be perfectly round, and the joints be all directed to the axis, they all equally endeavour to slide inwards, while no reason can be offered why any individual stone should prevail. They are all wedges, and operate only as wedges. When we consider any single course, therefore, we see that it cannot fall in, even though it may be part of a curve which could not stand as a common arch; nay, we see that a dome may be constructed, having the convexity of the curve, by the revolution of which it is formed, turned towards the axis, so that the outline is concave. We shall afterwards find that this is a stronger dome by far than if the convexity were outwards, as in a common arch. We see also that a cone may be loaded on the top with the greatest weight, without the smallest danger of forcing it down, so long as the bottom course is firmly kept from bursting outwards. The stone lanthern on the top of St Paul's cathedral in London weighs several hundred tons, and is carried by a brick cone of eighteen inches thick, with perfect safety, as long as the bottom course is prevented from bursting outwards. The reason is evident: The pressure on the top is propagated along the cone in the direction of the slant side; and, so far from having any tendency to break it in any part, it tends rather to prevent its being broken by any irregular pressure from foreign causes.

36. Of easier construction than a plain arch.

37 Proper construction of octagonal pyramids.

For the same reasons the octagonal pyramids, which form the spires of Gothic architecture, are abundantly firm, although very thin. The sides of the spire of Salisbury

Saliſbury cathedral are not eight inches thick after the octagon is fully formed. It is proper, however, to direct the joints to the axis of the pyramid, and to make the courſing joints perpendicular to the ſlant ſide, becauſe the projecting mouldings which run along the angles are the abutments on which the whole pannel depends. A conſiderable art is neceſſary for ſupporting thoſe pannels or ſides of the octagon which ſpring from the angles of the ſquare tower. This is done by beginning a very narrow pointed arch on the ſquare tower at a great diſtance below the top; ſo that the legs of the arch being very long, a ſtraight line may be drawn from the top of the keyſtone of the arch through the whole arch ſtones of the legs. By this diſpoſition the thruſts ariſing from the weight of theſe four pannels are made to meet on the maſſive maſonry in the middle of the ſides of the tower, at a great diſtance below the ſpringing of the ſpire. This part, being loaded with the great maſs of perpendicular wall, is fully able to withſtand the horizontal thruſt from the legs of thoſe arches. In many ſpires theſe thruſts are ſtill farther reſiſted by iron bars which croſs the tower, and are hooked into pieces of braſs firmly bedded in the maſonry of the ſides.

38 Examples of ſuch conſtruction.

There is much nice balancing of this kind to be obſerved in the highly ornamented open ſpires; ſuch as thoſe of Bruſſels, Mechlin, Antwerp, &c. We have not many of this ſort in Britain. In thoſe of great magnitude, the judicious eye will diſcover that parts, which a common ſpectator would conſider as mere ornaments, are neceſſary for completing the balance of the whole. Tall pinnacles, nay, even pillars carrying entablatures and pinnacles, are to be ſeen ſtanding on the middle of the ſlender leg of an arch. On examination, we find that this is neceſſary, to prevent the arch from ſpringing upwards in that place by the preſſure at the crown. The ſteeple of the cathedral of Mechlin was the moſt elaborate piece of architecture in this taſte in the world, and was really a wonder; but it was not calculated to withſtand a bombardment, which deſtroyed it in 1578.

Such frequent examples of irregular and whimſical buildings of this kind, ſhow that great liberties may be taken with the principle of equilibration without riſk, if we take care to ſecure the baſe from being thruſt outwards. This may always be done by hoops, which can be concealed in the maſonry; whereas, in common arches, theſe ties would be viſible, and would offend the eye.

It is now time to attend to the principle of equilibrium, as it operates in a ſimple circular dome, and to determine the thickneſs of the vaulting when the curve is given, or the curve when the thickneſs is given.

Plate II.

39 Stability of a dome depends on principles

Therefore, let B *b* A (fig. 17.) be the curve which produces the dome by revolving round the vertical axis AD. We ſhall ſuppoſe this curve to be drawn through the middle of all the arch ſtones, and that the courſing or horizontal joints are every where perpendicular to the curve. We ſhall ſuppoſe (as is always the caſe) that the thickneſs KL, HI, &c. of the arch ſtones is very ſmall in compariſon with the dimenſions of the arch. If we conſider any portion HA *b* of the dome, it is plain that it preſſes on the courſe, of which HL is an arch ſtone, in a direction *b* C perpendicular to the joint HI, or in the direction of the next ſuperior element *β b* of the curve. As we proceed downwards, courſe after courſe, we ſee plainly that this direction muſt change, becauſe the weight of each courſe is ſuperadded to that of the portion above it, to complete the preſſure on the courſe below. Through B draw the vertical line BCG, meeting *β b*, produced in C. We may take *b c* to preſs the preſſure of all that is above it propagated in this direction to the joint KL. We may alſo ſuppoſe the weight of the courſe HL united in *b*, and acting on the vertical. Let it be repreſented by *b* F. If we form the parallelogram *b* FGC, the diagonal *b* G will repreſent the direction and intenſity of the whole preſſure on the joint KL. Thus it appears that this preſſure is continually changing its direction, and that the line, which will always coincide with it, muſt be a curve concave downward. If this be preciſely the curve of the dome, it will be an equilibrated vaulting; but ſo far from being the ſtrongeſt form, it is the weakeſt, and it is the limit to an infinity of others, which are all ſtronger than it. This will appear evident, if we ſuppoſe that *b* G does not coincide with the curve A *b* B, but paſſes without it. As we ſuppoſe the arch ſtones to be exceedingly thin from inſide to outſide, it is plain that this dome cannot ſtand, and that the weight of the upper part will preſs it down, and ſpring the vaulting outwards at the joint KL. But let us ſuppoſe, on the other hand, that *b* G falls within the curvelineal element *b* B. This evidently tends to puſh the arch ſtone inward, toward the axis, and would cauſe it to ſlide in, ſince the joints are ſuppoſed perfectly ſmooth and ſlipping. But ſince this takes place equally in every ſtone of this courſe, they muſt all abut on each other in the vertical joints, ſqueezing them firmly together. Therefore, reſolving the thruſt *b* G into two, one of which is perpendicular to the joint KL, and the other parallel to it, we ſee that this laſt thruſt is withſtood by the vertical joints all around, and there remains only the thruſt in the direction of the curve. Such a dome muſt therefore be firmer than an equilibrated dome, and cannot be ſo eaſily broken by overloading the upper part. When the curve is concave upwards, as in the lower part of the figure, the line *b* C always falls below *b* B, and the point C below B. When the curve is concave downwards, as in the upper part of the figure, '*b* C' paſſes above, or without *b* B. The curvature may be ſo abrupt, that even *b*' G' ſhall paſs without '*b* B', and the point G' is above B'. It is alſo evident that the force which thus binds the ſtones of a horizontal courſe together, by puſhing them towards the axis, will be greater in flat domes than in thoſe that are more convex; that it will be ſtill greater in a cone; and greater ſtill in a curve whoſe convexity is turned inwards: for in this laſt caſe the line *b* G will deviate moſt remarkably from the curve. Such a dome will ſtand (having poliſhed joints) if the curve ſprings from the baſe with any elevation, however ſmall; nay, ſince the friction of two pieces of ſtone is not leſs than half of their mutual preſſure, ſuch a dome will ſtand, although the tangent to the curve at the bottom ſhould be horizontal, provided that the horizontal thruſt be double the weight of the dome, which may eaſily be the caſe if it do not riſe high.

40 Different from that of a common arch.

Thus we ſee that the ſtability of a dome depends on very different principles from that of a common arch, and is in general much greater. It differs alſo in another

ther very important circumſtance, viz. that it may be open in the middle: for the uppermoſt courſe, by tending equally in every part to ſlide in toward the axis, preſſes all together in the vertical joints, and acts on the next courſe like the key-ſtone of a common arch. Therefore an arch of equilibration, which is the weakeſt of all, may be open in the middle, and carry at top another building, ſuch as a lanthern, if its weight do not exceed that of the circular ſegment of the dome that is omitted. A greater load than this would indeed break the dome, by cauſing it to ſpring up in ſome of the lower courſes; but this load may be increaſed if the curve is flatter than the curve of equilibration: and any load whatever, which will not cruſh the ſtones to powder, may be ſet on a truncate cone, or on a dome formed by a curve that is convex toward the axis; provided always that the foundation be effectually prevented from flying out, either by a hoop, or by a ſufficient maſs of ſolid pier on which it is ſet. We have mentioned the many failures which happened to the dome of St Sophia in Conſtantinople. We imagine that the thruſt of the great dome, bending the eaſtern arch outward as ſoon as the pier began to yield, deſtroyed the half dome which was leaning on it, and thus, almoſt in an inſtant, took away the eaſtern abutment. We think that this might have been prevented, without any change in the injudicious plan, if the dome had been hooped with iron, as was practiſed by Michael Angelo in the vaſtly more ponderous dome of St Peter's at Rome, and by Sir Chriſtopher Wren in the cone and the inner dome of St Paul's at London. The weight of the latter conſiderably exceeds 3000 tons, and they occaſion a horizontal thruſt which is nearly half this quantity, the elevation of the cone being about 60°. This being diſtributed round the circumference, occaſions a ſtrain on the hoop $= \frac{7}{2 \times 22}$ of the thruſt, or nearly 238 tons. A ſquare inch of the worſt iron, if well forged, will carry 25 tons with perfect ſafety; therefore a hoop of 7 inches broad and $1\frac{1}{2}$ inches thick will completely ſecure this circle from burſting outwards. It is, however, much more completely ſecured; for beſides a hoop at the baſe of very nearly theſe dimenſions, there are hoops in different courſes of the cone which bind it into one maſs, and cauſe it to preſs on the piers in a direction exactly vertical. The only thruſts which the piers ſuſtain are thoſe from the arches of the body of the church and the tranſepts. Theſe are moſt judiciouſly directed to the entering angles of the building, and are there reſiſted with inſuperable force by the whole lengths of the walls, and by four ſolid maſſes of maſonry in the corners. Whoever conſiders with attention and judgment the plan of this cathedral, will ſee that the thruſts of theſe arches, and of the dome, are incomparably better balanced than in St Peter's church at Rome. But to return from this ſort of digreſſion.

41 Excellency of the dome of St Paul's.

42 Theory of the curves proper for domes.

We have ſeen that if b G, the thruſt compounded of the thruſt b C, exerted by all the courſes above HILK, and if the force b F, or the weight of that courſe, be every where coincident with b B, the element of the curve, we ſhall have an equilibrated dome; if it falls within it, we have a dome which will bear a greater load; and if it falls without it, the dome will break at the joint. We muſt endeavour to get analytical expreſſions of theſe conditions. Therefore draw the ordinates $b\,\delta\,b''$, BDB'', C d C''. Let the tangents at b and b'' meet the axis in M, and make MO, MP, each equal to $b\,c$, and complete the parallelogram MONP, and draw OQ perpendicular to the axis, and produce b F, cutting the ordinates in E and e. It is plain that MN is to MO as the weight of the arch HAb to the thruſt $b\,c$ which it exerts on the joint KL (this thruſt being propagated through the courſe HILK); and that MQ, or its equal $b\,e$, or $\delta\,d$, may repreſent the weight of the half AH.

Let AD be called x, and DB be called y. Then $b\,e = \dot{x}$, and e C $= \dot{y}$ (becauſe $b\,c$ is in the direction of the element $\beta\,b$). It is alſo plain, that if we make $\dot{y}$ conſtant, BC is the ſecond fluxion of x, or BC $= \ddot{x}$, and $b\,e$ and BE may be conſidered as equal, and taken indiſcriminately for $\dot{x}$. We have alſo b C $= \sqrt{\dot{x}^2 + \dot{y}^2}$. Let d be the depth or thickneſs HI of the arch ſtones. Then $d\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the trapezium HL: and ſince the circumference of each courſe increaſes in the proportion of the radius y, $d\,y\sqrt{\dot{x}^2 + \dot{y}^2}$ will expreſs the whole courſe. If $\int$ be taken to repreſent the ſum or aggregate of the quantities annexed to it, the formula will be analogous to the fluent of a fluxion, and $\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the whole maſs, and alſo the weight of the vaulting, down to the joint HI. Therefore we have this proportion $\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2} : d\,y\sqrt{\dot{x}^2 + \dot{y}^2} = b\,e : b\,\text{F}, = b\,e : \text{CG}, = \delta d : \text{CG}, = \dot{x} : \text{CG}$. Therefore $\text{CG} = \frac{d\,y\,\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}$.

If the curvature of the dome be preciſely ſuch as puts it in equilibrium, but without any mutual preſſure in the vertical joints, this value of OG muſt be equal to CB, or to $\ddot{x}$, the point G coinciding with B. This condition will be expreſſed by the equation $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \ddot{x}$, or, more conveniently, by $\frac{d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}}$. But this form gives only a tottering equilibrium, independent of the friction of the joints and the coheſion of the cement. An equilibrium, accompanied by ſome firm ſtability, produced by the mutual preſſure of the vertical joints, may be expreſſed by the formula $\frac{d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} > \frac{\ddot{x}}{\dot{x}}$, or by $\frac{d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, where t is ſome variable poſitive quantity, which increaſes when x increaſes.

Arch. creaſes. This laſt equation will alſo expreſs the equilibrated dome, if t be a conſtant quantity, becauſe in this caſe $\frac{\dot{t}}{t}$ is $= o$.

Since a firm ſtability requires that $\frac{dy\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}$ ſhall be greater than $\ddot{x}$, and CG muſt be greater than CB: Hence we learn, that figures of too great curvature, whoſe ſides deſcend too rapidly, are improper. Alſo, ſince ſtability requires that we have $\frac{dy\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\ddot{x}}$ greater than $\int dy\sqrt{\dot{x}^2+\dot{y}^2}$, we learn that the upper part of the dome muſt not be made very heavy. This, by diminiſhing the proportion of b F to b C, diminiſhes the angle $c\,b$ G, and may ſet the point G above B, which will infallibly ſpring the dome in that place. We ſee here alſo, that the algebraic analyſis expreſſes that peculiarity of dome-vaulting, that the weight of the upper part may even be ſuppreſſed.

The fluent of the equation $\frac{dy\sqrt{\dot{x}^2+\dot{y}^2}}{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}=\frac{\ddot{x}}{\dot{x}}+\frac{\dot{t}}{t}$ is moſt eaſily found. It is $L\int dy\sqrt{\dot{x}^2+\dot{y}^2}=L\dot{x}+Lt$, where L is the hyperbolic logarithm of the quantity annexed to it. If we conſider $\dot{y}$ as conſtant, and correct the fluent ſo as to make it nothing at the vertex, it may be expreſſed thus, $L\int dy\sqrt{\dot{x}^2+\dot{y}^2}-La=L\dot{x}-L\dot{y}+Lt$. This gives us $L\frac{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}{a}=L\frac{\dot{x}}{\dot{y}}t$, and therefore $\frac{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}{a}=t\frac{\dot{x}}{\dot{y}}$.

This laſt equation will eaſily give us the depth of vaulting, or thickneſs d of the arch, when the curve is given. For its fluxion is $\frac{dy\sqrt{\dot{x}^2+\dot{y}^2}}{a}=\frac{\dot{t}\dot{x}+t\ddot{x}}{\dot{y}}$, and $d=\frac{a\dot{t}\dot{x}+at\ddot{x}}{y\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$, which is all expreſſed in known quantities; for we may put in place of t any power or function of x or of y, and thus convert the expreſſion into another, which will ſtill be applicable to all ſorts of curves.

Inſtead of the ſecond member $\frac{\ddot{x}}{\dot{x}}+\frac{\dot{t}}{t}$, we might employ $\frac{p\ddot{x}}{\dot{x}}$, where p is ſome number greater than unity. This will evidently give a dome having ſtability; becauſe the original formula $\frac{dy\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\int dy\sqrt{\dot{x}^2+\dot{y}^2}}$ will then be greater than $\ddot{x}$. This will give $d=\frac{pa\dot{x}^{p-1}\ddot{x}}{y\dot{y}^p\sqrt{\dot{x}^2+\dot{y}^2}}$. Each of theſe forms has its advantages when applied to particular caſes. Each of them alſo gives $d=\frac{a\ddot{x}}{y\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$ when the curvature is ſuch as is in preciſe equilibrium. And, laſtly, if d be conſtant, that is, if the vaulting be of uniform thickneſs, we obtain the form of the curve, becauſe then the relation of $\ddot{x}$ to $\dot{x}$ and to $\dot{y}$ is given. Arch.

The chief uſe of this analyſis is to diſcover what curves are improper for domes, or what portions of given curves may be employed with ſafety. Domes are generally built for ornament; and we ſee that there is great room for indulging our fancy in the choice. All curves which are concave outwards will give domes of great firmneſs: They are alſo beautiful. The Gothic dome, whoſe outline is an undulated curve, may be made abundantly firm, eſpecially if the upper part be convex and the lower concave outwards.

The chief difficulty in the caſe of this analyſis ariſes from the neceſſity of expreſſing the weight of the incumbent part, or $\int dy\sqrt{\dot{x}^2+\dot{y}^2}$. This requires the meaſurement of the conoidal ſurface, which, in moſt caſes, can be had only by approximation by means of infinite ſerieſes. We cannot expect that the generality of practical builders are familiar with this branch of mathematics, and therefore will not engage in it here; but content ourſelves with giving ſuch inſtances as can be underſtood by ſuch as have that moderate mathematical knowledge which every man ſhould poſſeſs who takes the name of engineer.

The ſurface of any circular portion of a ſphere is very eaſily had, being equal to the circle deſcribed with a radius equal to the chord of half the arch. This radius is evidently $=\sqrt{x^2+y^2}$.

In order to diſcover what portion of a hemiſphere may be employed (for it is evident that we cannot employ the whole) when the thickneſs of the vaulting is uniform, we may recur to the equation or formula $\frac{dy\dot{x}\sqrt{\dot{x}^2-\dot{y}^2}}{\ddot{x}}=\int dy\sqrt{\dot{x}^2+\dot{y}^2}$. Let a be the radius of the hemiſphere. We have $\dot{x}=\frac{ay\dot{y}}{\sqrt{a^2-y^2}}$, and $\ddot{x}=\frac{a^2\dot{y}^2}{\overline{a^2-y^2}|^{\frac{3}{2}}}$. Subſtituting theſe values in the formula, we obtain the equation $y^2\sqrt{a^2-y^2}=\int\frac{a^2y\dot{y}}{\sqrt{a^2-y^2}}$. We eaſily obtain the fluent of the ſecond member $=a^3-a^2\sqrt{a^2-y^2}$, and $y=a\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$. Therefore if the radius of the ſphere be 1, the half breadth of the dome muſt not exceed $\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$, or 0,786, and the height will be 618. The arch from the vertex is about 51° 49′. Much more of the hemiſphere cannot ſtand, even though aided by the cement, and by the friction of the courſing joints. This laſt circumſtance, by giving connection to the upper parts, causes the whole to press more vertically on the course below, and thus diminishes the outward thrust; but it at the same time diminishes the mutual abutment of the vertical joints, which is a great cause of firmness in the vaulting. A Gothic dome, of which the upper part is a portion of a sphere not exceeding 45° from the vertex, and the lower part is concave outwards, will be very strong, and not ungraceful.

43 Dome of St Peter's at Rome.

But the public taste has long rejected this form, and seems rather to select more elevated domes than this portion of a sphere; because a dome, when seen from a small distance, always appears flatter than it really is. The dome of St Peter's is nearly an ellipsoid externally, of which the longer axis is perpendicular to the horizon. It is very ingeniously constructed. It springs from the base perpendicularly, and is very thick in this part. After rising about 50 feet, the vaulting separates into two thin vaultings, which gradually separate from each other. These two shells are connected together by thin partitions, which are very artificially dovetailed in both, and thus form a covering which is extremely stiff, while it is very light. Its great stiffness was necessary for enabling the crown of the dome to carry the elegant stone lanthern with safety. It is a wonderful performance, and has not its equal in the world; but it is an enormous load in comparison with the dome of St. Paul's, and this even independent of the difference of size. If they were of equal dimensions, it would be at least five times as heavy, and is not so firm by its gravity; but as it is connected in every part by iron bars (lodged in the solid masonry, and well secured from the weather by having lead melted all round them), it bids fair to last for ages, if the foundations do not fail.

Plate II.

If a circle be described round a centre placed anywhere in the transverse axis AC (fig. 18. N° 1.) of an ellipse, so as to touch the ellipse in the extremities B, *b*, of an ordinate, it will touch it internally, and the circular arch B *a b* will be wholly within the elliptical arch BA *b*. Therefore, if an elliptical and a spherical vaulting spring from the same base, at the same angle with the horizon, the spherical vaulting will be within the elliptical, will be flatter and lighter, and therefore the weight of the next course below will bear a greater proportion to the thrust in the direction of the curve; therefore the spherical vaulting will have more stability. On the contrary, and for similar reasons, an oblate elliptical vaulting is preferable to a spherical vaulting springing with the same inclination to the horizon. (Fig. 18. N° 2.)

44 Dimensions of the best form of a dome.

Persuaded, that what has been said on the subject convinces the reader that a vaulting perfectly equilibrated throughout is by no means the best form, provided that the base is secured from separating, we think it unnecessary to give the investigation of that form, which has a considerable intricacy; and shall content ourselves with merely giving its dimensions. The thickness is supposed uniform. The numbers in the first column of the table express the portion of the axis counted from the vertex, and those of the second column are the lengths of the ordinates.

AD	DB	AD	DB	AD	BD
0,4	100	610,4	1080	2990	1560
3,4	200	744	1140	3442	1600
11,4	300	904	1200	3972	1640
26,6	400	1100	1260	4432	1670
52,4	500	1336	1320	4952	1700
91,4	600	1522	1360	5336	1720
146,8	700	1738	1400	5756	1740
223,4	800	1984	1440	6214	1760
326,6	900	2270	1480	6714	1780
465,4	1000	2602	1520	7260	1800

The curve delineated in fig. 19. is formed according to these dimensions, and appears destitute of gracefulness; because its curvature changes abruptly at a little distance from the vertex, so that it has some appearance of being made up of different curves pieced together. But if the middle be occupied by a lanthern of equal, or of smaller weight, this defect will cease, and the whole will be elegant, nearly resembling the exterior dome of St Paul's in London.

It is not a small advantage of dome-vaulting that it is lighter than any that can cover the same area. If, moreover, it be spherical, it will admit considerable varieties of figure, by combining different spheres. Thus, a dome may begin from its base as a portion of a large hemisphere, and may be broken off at any horizontal course, and then a similar or a greater portion of a smaller sphere may spring from this course as a base. It also bears being intersected by cylindrical vaultings in every direction, and the intersections are exact circles, and always have a pleasing effect. It also springs most gracefully from the heads of small piers, or from the corners of rooms of any polygonal shape; and the arches formed by its intersections with the walls are always circular and graceful, forming very handsome spandrels in every position. For these reasons Sir Christopher Wren employed it in all his vaultings, and he has exhibited many beautiful varieties in the transepts and the aisles of St Paul's, which are highly worthy of the observation of architects. Nothing can be more graceful than the vaultings at the ends of the north and south transepts, especially as finished off in the fine inside view published by Gwynn and Wale. 45 Advantages of dome-vaulting.

We conclude this article with observing, that the connection of the parts, arising from cement and from friction, has a great effect on dome-vaulting. In the same way as in common arches and cylindrical vaulting, it enables an overload on one place to break the dome in a distant place. But the resistance to this effect is much greater in dome-vaulting, because it operates all round the overloaded part. Hence it happens that domes are much less shattered by partial violence, such as the falling of a bomb or the like. Large holes may be broken in them without much affecting the rest; but, on the other hand it greatly diminishes the strength which should be derived from the mutual pressure in the vertical joints. Friction prevents the sliding in of the arch stones which produces this mutual pressure in the vertical joints, except in the very highest courses, and even there 46 Effects of cement and friction in dome vaulting.

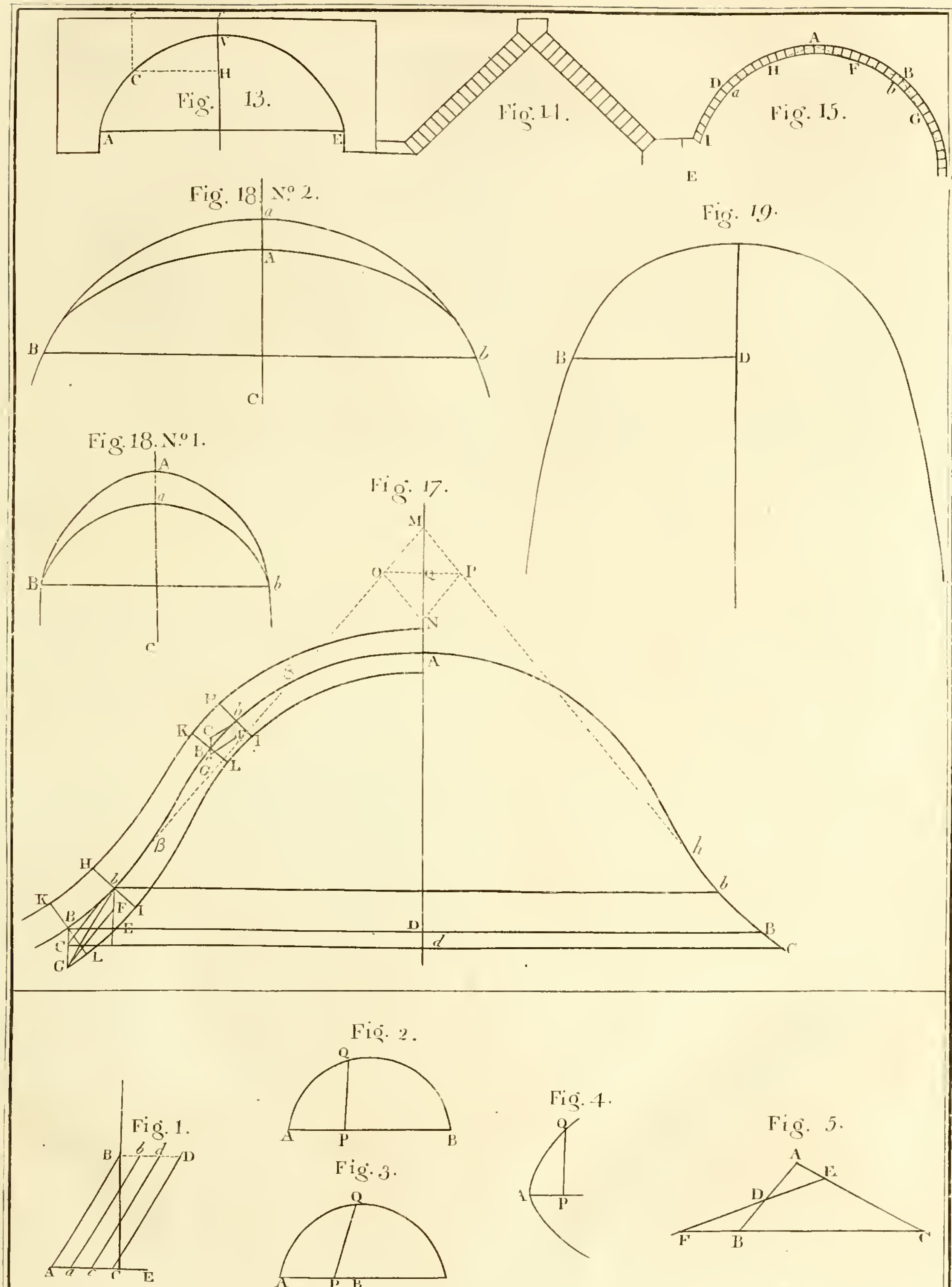


Fig. 13.
Fig. 14.
Fig. 15.
Fig. 18 N.º 2.
Fig. 19.
Fig. 18. N.º 1.
Fig. 17.
Fig. 2.
Fig. 1.
Fig. 3.
Fig. 4.
Fig. 5.

J. Bowre sc.

there it greatly diminishes it. These causes make a great change in the form which gives the greatest strength: and as their laws of action are but very imperfectly understood as yet, it is perhaps impossible, in the present state of our knowledge, to determine this form with tolerable precision. We see plainly, however, that it allows a greater deviation from the best form than the other kind of vaulting, and domes may be made to rise perpendicular to the horizon at the base, although of no great thickness; a thing which must not be attempted in a plane arch. The immense addition of strength which may be derived from hooping, largely compensates for all defects; and there is hardly any bounds to the extent to which a very thin dome vaulting may be carried, when it is hooped or framed in the direction of the horizontal courses. The roof of the Halle du Bled at Paris is but a foot thick, and its diameter is more than 200, yet it appears to have abundant strength. It is, on the whole, a noble specimen of architecture.

47 The iron bridge at Sunderland described.

We must not conclude this article without taking notice of that magnificent and elegant arch which has been erected in cast iron at Weremouth, near Sunderland, in the county of Durham. The inventor and architect is Rowland Burdon, Esq; one of the representatives of that county in the present Parliament.

This arch is a segment of a circle whose diameter is about 444 feet. The span or cord of the arch is 236 feet, and its versed sine or spring is 34 feet. It springs at the elevation of 60 feet from the surface of the river at low water, so that vessels of 200 or perhaps 300 tons burden may pass under it in the middle of the stream, and even 50 feet on each side of it.

The sweep of the arch consists of a series of frames of cast iron, which butt on each other, in the same manner as the voussoirs of a stone arch. One of these frames or blocks (as we shall call them in future) is represented in fig. 1. as seen in front. It is cast in one piece; and consists of three pieces or arms BC, BC, BC, the middle one of which is two feet long, the upper being somewhat more, and the lower somewhat less, because their extremities are bounded by the radius drawn from the centre of the arch. These arms are four inches square, and are connected by other pieces KL, of such length that the whole length of the block is five feet in the direction of the radius. Each arm has a flat groove on each side, which is expressed by the darker shading, three inches broad and three-fourths of an inch deep. A section of this block, through the middle of KL, is represented by the light-shaded part BBB, in which the grooves are more distinctly perceived. These grooves are intended for receiving flat bars of malleable iron, which are employed for connecting the different blocks with each other. Fig. 2. represents two blocks united in this manner. For this purpose each arm has two square bolt-holes. The ends of the arms being nicely trimmed off, so that the three ends butt equally close on the ends of the next block; and the bars of hammered iron being also nicely fitted to their grooves, so as to fill them completely, and have their bolt-holes exactly corresponding to those in the blocks, they are put together in such a manner that the joints or meetings of the malleable bars may fall on the middle between the bolt-holes in the arms. Flat headed bolts of wrought iron

Plate IV.

are then put through, and keys or forelocks are driven through the bolt-tails, and thus all is firmly wedged together, binding each arm between two bars of wrought iron. These bars are of such length as to connect several blocks.

In this manner a series of about 125 blocks are joined together, so as to form the precise curve that is intended. This series may be called a rib, and it stands in a vertical plane. The arch consists of six of these ribs, distant from each other five feet. These ribs are connected together so as form an arch of 32 feet in breadth, in the following manner.

Fig. 3. represents one of the bridles or cross pieces which connect the different ribs, as it appears when viewed from below. It is a hollow pipe of cast iron, four inches in diameter, and has at each end two projecting shoulders, pierced with a bolt hole near their extremities, so that the distance between the bolt-holes in the shoulders of one end is equal to the distance between the holes in the arms of the blocks, or the holes in the wrought iron bars. In the middle of the upper and of the underside of each end may be observed a square prominence, more lightly shaded than the rest. These projections also advance a little beyond the flat of the shoulders, forming between them a shallow notch, about an inch deep, which receives the iron of the arms, where they butt on each other, and thus gives an additional firmness to the joint. The manner in which the arms are thus grasped by these notches in the bridles is more distinctly seen in fig. 2. at the letter H in the middle of the upper rail.

The rib having been all trimmed and put together, so as to form the exact curve, the bolts are all taken out, and the horizontal bridles are then set on in their places, and the bolts are again put in and made fast by the forelocks. The bolts now pass through the shoulders of the bridles, through the wrought iron bars, and through the cast iron arm that is between them, and the forelocks bind all fast together. The manner in which this connection is completed is distinctly seen in fig. 2. which shows in perspective a double block in front, and a single block behind it. The butting joints of the two front blocks are at the letters E, E, E; the holes in the shoulders of the horizontal cross pieces are at H.

48 Its construction simple and judicious,

This construction is beautifully simple and very judicious. A vast addition of strength and of stiffness is procured by lodging the wrought iron bars in grooves formed in the cast iron rails; and for this purpose it is of great importance to make the wrought iron bars fill the grooves completely, and even to be so tight as to require the force of the forelocks to draw them home to the bottom of the grooves. There can be no doubt but that this arch is able to withstand an enormous pressure, as long as the abutments from which it springs do not yield. Of this there is hardly any risk, because they are masses of rock, faced with about four or five yards (in some places only) of solid block masonry. The mutual thrusts of the frames are all in the direction of the rails, so that no part bears any transverse strain. We can hardly conceive any force that can overcome the strength of those arms by pressure or crushing them. The manner in which the frames are connected into one rib, effectually secures the butting joints from slipping; and the accuracy with which the whole can be executed, ed, ſecures us againſt any warping or deviation of a rib from the vertical plane.

But when we conſider the prodigious ſpan of this arch, and reflect that it is only five feet thick, it ſhould ſeem that the moſt perfect equilibration is indiſpenſably neceſſary. It is but like a film, and muſt be ſo ſupple that an overload on any part muſt have a great tendency to bend it, and to cauſe it to riſe in a diſtant part; and this effect is increaſed by the very firmneſs with which the whole ſticks together. The overloaded part acts on a diſtant part, tending to break it with all the energy of a long lever. This can be prevented only by means of the ſtiffneſs of the diſtant part. It is very true, the arch cannot break in the extrados except by tearing aſunder the wrought iron bars which connect the blocks along the upper rail, and each of theſe requires more than a hundred tons to tear it aſunder; yet an overload of five tons on any rib at its middle will produce this ſtrain at twenty feet from the ſides, ſuppoſing the ſides held firm in their poſition. It were deſirable therefore that ſomething were done to ſtiffen the arch at the ſides, by the manner of filling up the ſpandrels, or ſpace between the arch and the road-way. This is filled up in a manner that is extremely light and pleaſing to the eye, namely, by large caſt iron circles, which touch the extrados of the arch and touch the road-way. The road-way reſts on them as on ſo many hoops, while they reſt on the back of the arch, and alſo touch each other laterally. We cannot think that this contributes to the ſtrength of the arch; for theſe hoops will be eaſily compreſſed at the points of contact, and, changing their ſhape, will oppoſe very little reſiſtance. We think that this part of the arch might have been greatly ſtiffened and ſtrengthened, by connecting it with the road way by truſſed frames, in the ſame way that a judicious carpenter would have framed a roof. If a ſtrong caſt iron pillar had been made to reſt on the arch at about 20 feet from the impoſt, and been placed in the direction of a radius, the top of this pillar might have been connected by a diagonal bar of wrought iron with the impoſt of the arch, and with the crown of the arch by another ſtring or bar of the ſame materials. Theſe two ties would cauſe the radial pillar to preſs ſtrongly on the back of the arch, and they muſt be torn aſunder before it could bend in that place in the ſmalleſt degree. Suppoſing them of the ſame dimenſions as the bars in the arms, their poſition would give them near ten times the force for reſiſting the ſtrain produced by an overload on the crown.

49 Though in one particular capable, perhaps of improvement.

This beautiful arch contains only 260 tons of iron, of which about 55 are wrought iron. The ſuperſtructure is of wood, planked over a-top. This floor is covered with a coating of chalk and tar, on which is laid the materials for the carriage road, conſiſting of marle, limeſtone, and gravel, with foot-ways of flag-ſtones at the ſides. The weight of the whole did not exceed a thouſand tons; whereas the lighteſt ſtone arch which could have been erected would have weighed fifteen thouſand. It was turned on a very light but ſtiff ſcaffolding, moſt judiciouſly conſtructed for the preſervation of its form, and for allowing an uninterrupted paſſage for the numerous ſhips and ſmall craft which frequent the buſy harbour of Sunderland. The mode of framing the arch was ſo ſimple and eaſy, that it was put up in ten days! without an accident; and when all was finiſhed, and the ſcaffolding removed, the arch did not ſenſibly change its form. The whole work was executed in three years, and coſt about L. 26,000.

ARCHITECTURE is an art of ſo much importance, and capable of ſo many embelliſhments, as to have employed the attention and talents of men of ſcience in almoſt every age, and in every country. It is generally thought to have been carried to the utmoſt perfection among the Greeks and Romans; and it has been the aim of the moſt eminent architects of modern times to imitate with fidelity the buildings of thoſe accompliſhed nations. There is, however, another ſpecies of architecture, which was introduced into Europe in the middle ages, and is of ſuch a nature as to ſtrike every unprejudiced obſerver with admiration and aſtoniſhment. The architecture to which we allude has been called, perhaps with little propriety,

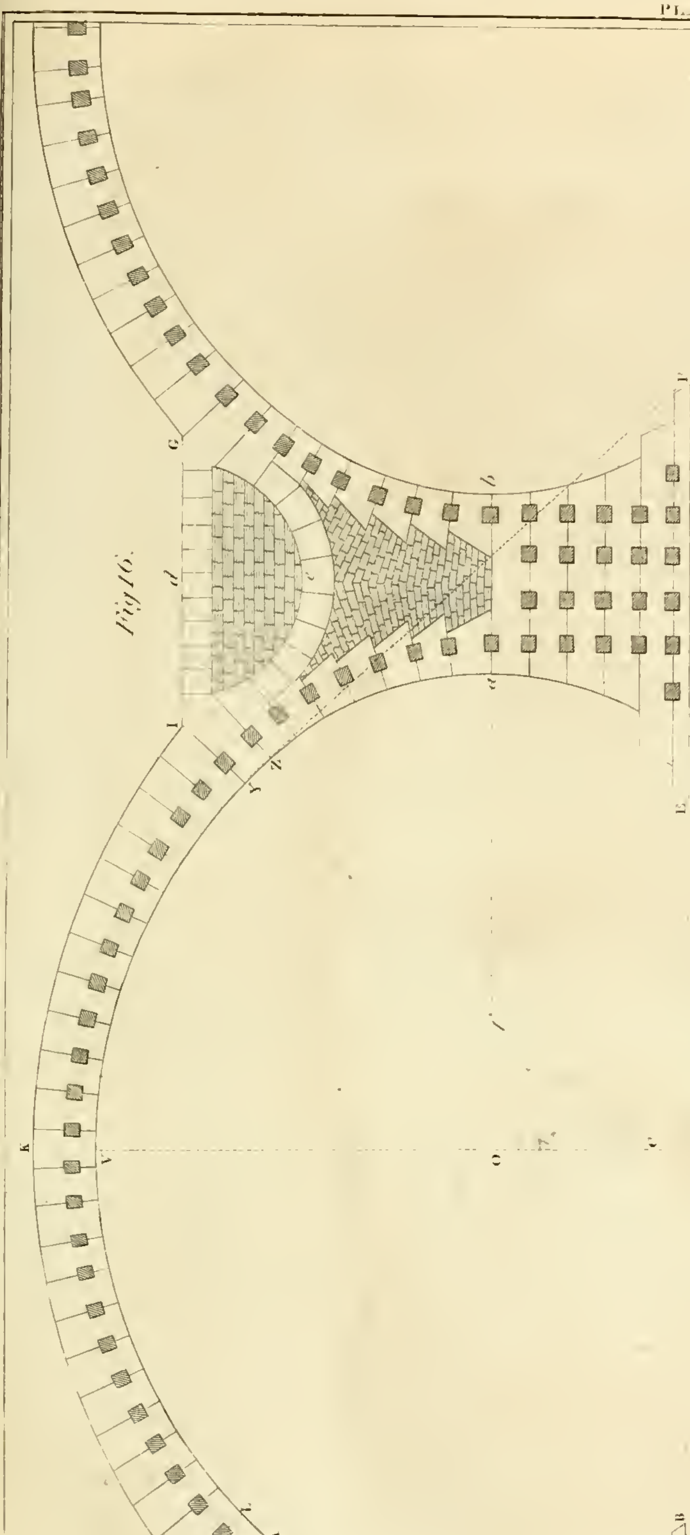
Gothic Architecture. It is that which is to be viewed in all our ancient cathedrals, and in other large buildings, which have been erected from the middle of the 12th to the beginning of the 16th century. That ſuch edifices have been conſtructed on principles of ſcience, has been ſhown elſewhere (ſee Roof, *Encycl.* and Arch, in this *Suppl.*): but a queſtion ſtill preſents itſelf to the inquiſitive mind, "How came ſuch ſtructures to be thought of by a people whom we are accuſtomed to call ignorant and barbarous?" This queſtion has occupied the attention of many ingenious men, who have attributed the Gothic ſtyle of building, ſome to neceſſity, and others to an imitation of the works of nature. That, where materials are bad, larger edifices can be erected in the Gothic than in the Grecian ſtyle, has been made ſufficiently evident in the articles to which we have referred; and that neceſſity is the parent of invention, is an adage which has been too long received to be now called in queſtion. But whence came the peculiarities of the Gothic ornaments in building, the pointed arch, and the double row of cluſtered pillars compoſed of ſlender ſhafts, which, reaching from the ground almoſt to the roof of the building, are there ſpread out in all directions, forming the ribs or *groins* of a vaulted roof?

The moſt ſatisfactory ſolution of this queſtion which we have ſeen, is in a memoir publiſhed in the fourth volume of the Tranſactions of the Royal Society of Edinburgh, by Sir James Hall, Bart. with whoſe permiſſion the following abſtract is laid before our readers.

"Although the connection between beauty and utility be ſtill involved in ſuch obſcurity, that we are unable to decide concerning the univerſality of that connection, of one thing we are certain, that, in a work intended to anſwer ſome uſeful purpoſe, whatever viſibly counteracts that purpoſe always occaſions deformity. Hence it is, that, even where ornament is principally intended, the oſtenſibly uſeful object of the work, if it have any ſuch, muſt be provided for, in the firſt place, in preference to every other conſideration.

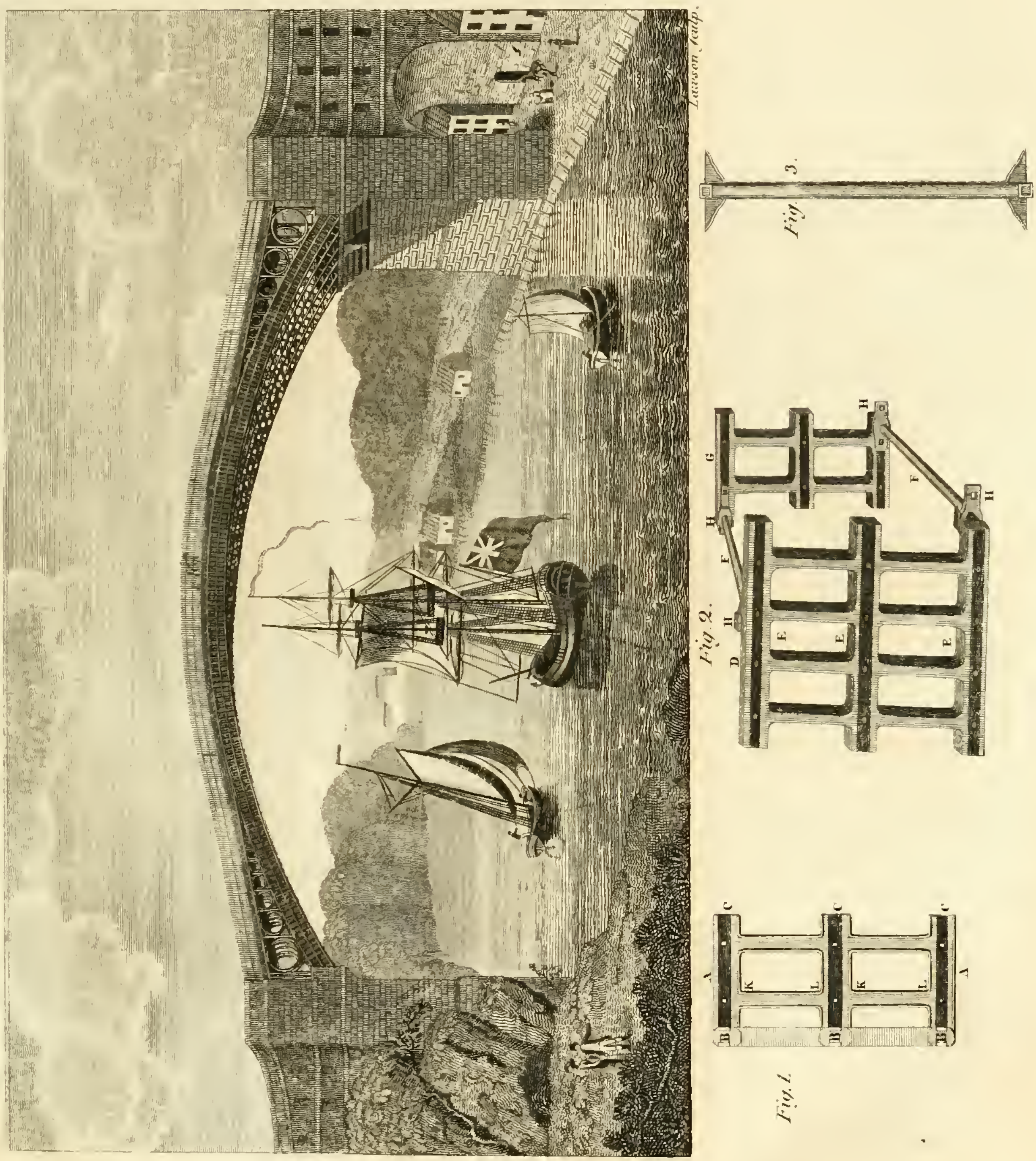
"But in moſt uſeful works, ſome parts occur, the ſhape of which is quite indifferent with reſpect to the propoſed utility, and which, therefore, the artiſt is at liberty to execute as he pleaſes: a liberty which has opened a wide field to the taſte and invention of ingenious men of every age and country, who have turned their attention to the compoſition of ornaments; and

Fig. 16.



MALE ANHINGA

IRON BRIDGE.



Architecture.

whose exertions have been more or less influenced by the state of civilization in which they lived. It would seem, however, if we may judge by those various efforts, that little has been effected by mere human ingenuity; since we see that recourse has been had, almost universally, to nature, the great and legitimate source of beauty; and that ornament has been attained by the imitation of objects, to which she has given a determinate and characteristic form.

"Where the materials employed are themselves possessed of variety and elegance, the attainment of this object requires little or no alteration of their natural forms. Thus cups are made of shells, of cocoa nuts, or of ostrich eggs; the character and beauty of which depend upon the natural form of the materials: and in the case of the bottles used by the Roman Catholic pilgrims an example occurs of an utensil, in which the natural form has undergone little or no variation, since it consists of the hard outward skin of a gourd, of the same shape in which it grew upon the plant (A). This last class of forms has been introduced, by imitation, into works composed of shapeless materials. Thus we have silver cups in the form of those made of shells, and fruit-dishes of stone ware in the form of baskets.

"As stone is not naturally possessed of any peculiar shape, and as the useful object proposed, by structures formed of it, may be accomplished in various ways, very great latitude is left to the invention of the artist. We see, accordingly, that in every country where much refinement has been introduced, great pains have been bestowed in ornamenting stone buildings with figures representing various natural objects; whilst the building itself has been executed in imitation of a structure, composed of materials which naturally possess a determinate and characteristic form. Such was the method followed by the architects of ancient Greece, who constructed temples, and other public edifices, in imitation of a rustic fabric, composed of square beams, supported upon round posts or stems of trees, and who derived the numerous ornaments of that beautiful style from circumstances which would naturally take place in such a structure.

"A faint and distant resemblance, however, of the original, has generally been found to answer all the end proposed by the imitation; a resemblance, which may sometimes be traced in the general distribution of the edifice, sometimes in its minute parts, and not unfrequently in both.

"But the forms of nature thus introduced have been greatly modified by those of masonry. For though stone is by nature shapeless, yet, in the course of practice, many peculiar forms have been long established, and currently employed, in working it; such as straight lines, plain surfaces, square angles, and various mouldings used to soften the effect of abrupt terminations: all of which, originating in motives of mechanical convenience, and of simple ornament, had, in very early times, been appropriated to masonry, and considered as essential in every finished work of stone; so that, when the imitation of nature was introduced, these masonic forms still maintained their ground, and, being blended with the forms of nature, the two classes reciprocally modified each other.

"This combination of art with nature, of which we see the most perfect example in the Corinthian capital, produces what are called architectonic forms, in which the variety of nature, being subjected to the regularity of art, the work acquires that peculiar character which, in a natural object, we consider as offensive, under the name of *formality*; but which, in architecture, we admire as a beauty, under the name of *symmetry*: thus, we reprobate the formality of an avenue, and praise the symmetry of a colonnade.

"Such is the nature of architectonic imitation; a device which probably originated in accident, but to which architecture is indebted for its highest attainments."

As the stone edifices of ancient Greece were constructed in imitation of a wooden fabric, composed of square beams laid at right angles on round posts or stems of trees, Sir James conceives that the Gothic fabrics with pointed arches have been executed in imitation of a rustic dwelling, constructed in the following manner: Suppose a set of round posts driven firmly into the ground in two opposite rows, the interval between the neighbouring posts in the same row being equal to that between the rows, and each post being raised above the ground to a height equal to three of those intervals: then a set of long and flexible rods of willow being applied to each post, let them be thrust into the ground at its base, and bound to it by two tyings, one near the ground, and another at two-thirds of its height; the rods being left loose from this last point upwards, and free to be moved in any direction. Let three rods be connected with each outside corner post, and five with each of the others, and let their position be such as to cover the inside of the post, so that when seen from between the rows the lower part of each post shall be concealed from the view, and present the appearance of a bundle of rods (fig 1.) Plate V.

Things being thus disposed, the skeleton of a thatched roof may be formed by means of the loose ends of the rods. A rod from one of the posts being so bent as to meet a similar one from the post immediately opposite to it, in the middle of the space between them, let the two rods be made to cross each other, and let them be bound together at their crossing (fig. 2.), and we shall have the exact form of the Gothic arch. The same being done with each pair of opposite posts, and a set of pointed arches being formed, let them be connected together by means of a straight pole laid upon the forks of the crossing rods, and bound to each of them, as in fig. 3: then let a loose rod be brought from each of any two contiguous posts in the same row, so as to form a pointed arch, similar to that just described, and nearly of the same height. This being done with every two contiguous posts (fig. 4.), and a new set of pointed arches being thus produced, standing opposite to

(A) "Even in this case, however, the natural form undergoes a certain degree of modification, by the device employed to produce the neck of the bottle. The fruit, while small and tender, is surrounded with a string, which remaining during its growth, prevents the part, thus bound, from swelling with the rest."

to each other in pairs, let each pair be bound by a horizontal pole lying on the opposite forks, and crossing the longitudinal pole described above.

"Two of the rods of each corner post, and three of those of each of the others, being thus disposed of, we have one of each corner post and two of each middle post still to employ, which is done as follows: A pair of these unoccupied rods being brought from any two posts which stand diagonally to each other, and made to meet in the middle, not as in the first case crossing in an angle, but side by side, forming a semicircle, and joined together after the manner of a hoop; and the same being done with every pair of diagonal posts (fig. 5.), the whole rods will have been employed.

"In this manner a frame would be constructed fit to support thatch or other covering; and such a one has probably been often used. It would seem, however, that, for the sake of strength, the number of rods has been increased in each cluster, by the introduction, between every two of them, of an additional rod, which rising with them to the roof, still continues its middle position, as they spread asunder, and meets the horizontal pole at an intermediate point. This is shown in fig. 6. which is drawn with its covering of thatch; and, from the imitation of a dwelling so constructed, we may easily trace the three leading characteristics of Gothic architecture, the pointed arch, the clustered column, and the branching roof, as exhibited in fig. 7."

Upon the same principles Sir James Hall, with much ingenuity, accounts for the peculiar forms of the Gothic door, the Gothic window, and the pointed spire: but it is not our intention to supersede the necessity of having recourse to his memoir, but to excite the desire of our readers to peruse as well that paper as a larger work which he promises on the same subject, and in which we doubt not but they will find both entertainment and instruction. We shall conclude this article, therefore, with an experimental proof of the justness of his hypothesis.

In the greater part of our late attempts at Gothic architecture, it is allowed by every man of taste that we have failed. The failure is to be accounted for by the buildings having been constructed upon no consistent principle, applicable to every part of them, but upon a servile copying of ancient edifices, of which the structure was little understood by the copiers. Sir James Hall, however, by applying his theory to practice, has constructed a building in this style, which has far surpassed, he says, his own expectation, and has certainly gained the approbation of every man of taste and science by whom we have had occasion to hear it mentioned. "A set of posts of ash, about three inches in diameter, were placed in two rows, four feet asunder, and at the interval of four feet in the rows; then a number of slender and tapering willow rods, ten feet in length, were applied to the posts, and, in the manner which we have described, formed into a frame, which being covered with thatch, produced a very substantial roof, under which a person can walk with ease.

"This little structure exhibits, in miniature, all the characteristic features of the Gothic style. It is in the form of a cross, with a nave, a choir, and a north and south transept. The thatch, being so disposed on the frame as not to hide the rods of which it is composed, they represent accurately the pointed and semicircular arches, and all the other peculiarities of a groined roof."

ARCTUS, a name given by the Greeks to two constellations of the northern hemisphere, by the Latins called *Ursa Major* and *Minor*, and by us the *Greater* and *Lesser Bear*.

ARGYLE, a township in Washington county, New-York, on the E. bank of Hudson River, containing 2341 inhabitants, inclusive of 14 slaves. In the state census of 1796, there appears to be 404 electors.—*Morse*.

ARGYLE, a township in Shelburne county, Nova-Scotia, settled by Acadians and Scotch.—*ib.*

ARIES *Kill*, a small creek which runs northerly into Mohawk River, 2½ miles W. from Schoharie River, in New-York.—*ib.*

BINARY ARITHMETIC. See *Binary Arithmetic*, Encycl.

Duodecimal Arithmetic, is that which proceeds from 12 to 12, or by a continual subdivision according to 12. This is greatly used by most artificers in calculating the quantity of their work; as bricklayers, carpenters, painters, tilers, &c.

Harmonical Arithmetic, is so much of the doctrine of numbers as relates to the making the comparisons, reductions, &c. of musical intervals.

Arithmetic of infinites, is the method of summing up a series of numbers, of which the number of terms is infinite. This method was first invented by Dr. Wallis, as appears by his treatise on that subject; where he shows its uses in geometry, in finding the areas of superficies, the contents of solids, &c. But the method of fluxions, which is a kind of universal arithmetic of infinites, performs all these more easily, as well as a great many other things, which the former will not reach.

Logistical Arithmetic, a name sometimes employed for the arithmetic of sexagesimal fractions, used in astronomical computations. Shakerly, in his *Tabulæ Britannicæ*, has a table of logarithms adapted to sexagesimal fractions, which he calls *logistical logarithms*; and the expeditious arithmetic, obtained by means of them, he calls *logistical arithmetic*. The term *logistical arithmetic*, however, or *logistics*, has been used by Vieta and others for the rules of computations in algebra.

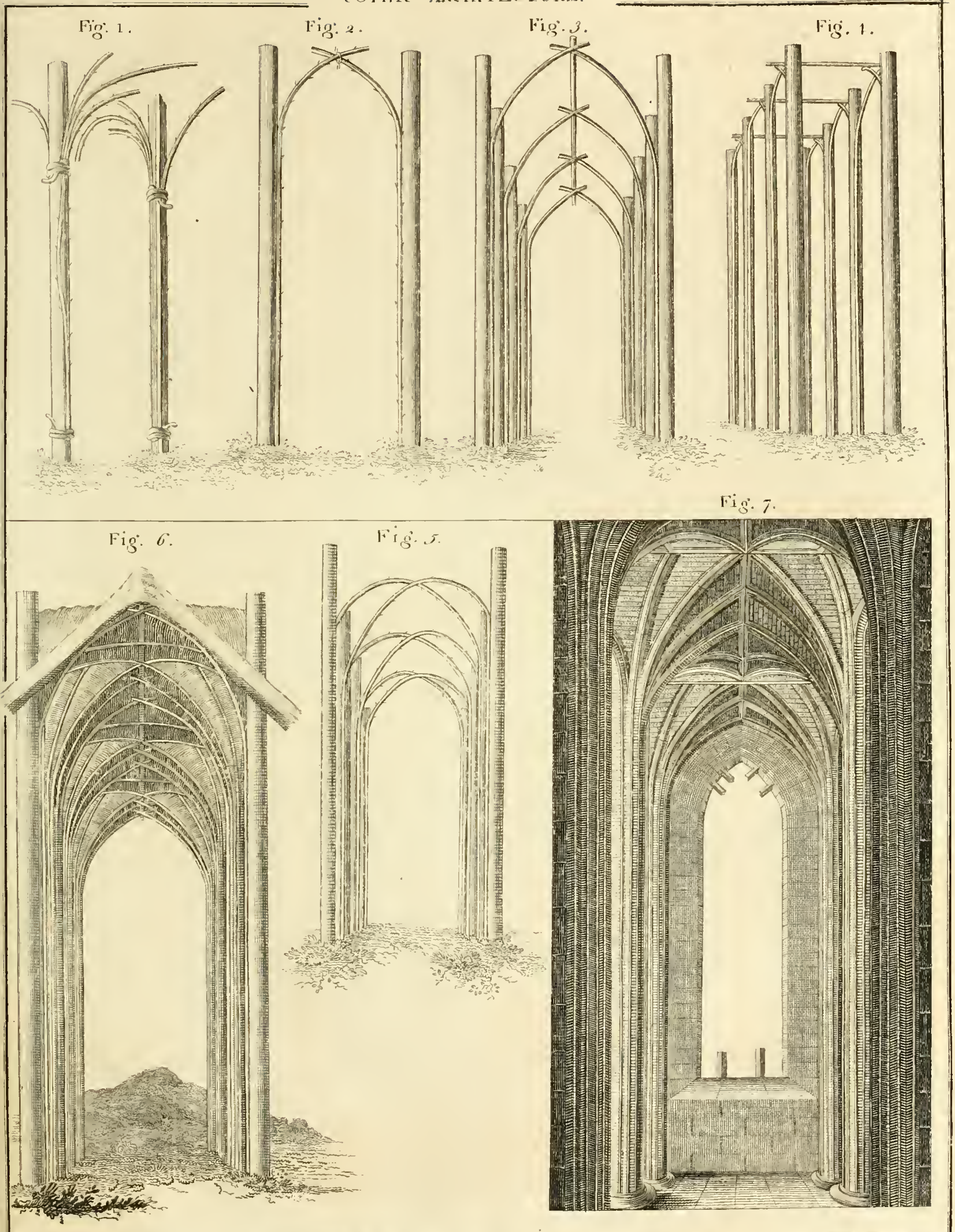
Political Arithmetic. See *Political Arithmetic*, Encycl.

Sexagesimal Arithmetic. See Arithmetic *(Hist.)* Encycl.

Tetractic Arithmetic, is that in which only the four characters, 0, 1, 2, 3, are used. A treatise of this kind of arithmetic is extant by Erhard or Echard Weigel. But both this and binary arithmetic are little better than curiosities, especially with regard to practice; as all numbers are much more compendiously and conveniently expressed by the common decuple scale.

Universal Arithmetic, is the name given by Newton to the science of algebra; of which he left at Cambridge an excellent treatise, being the text-book drawn up for the use of his lectures, while he was professor of mathematics in that university.

ARITHMETICAL complement, of a logarithm, is what the logarithm wants of 10·00000, &c. and the easiest way to find it is, beginning at the left



J. [illegible] Sc.

left hand, to fubtract every figure from 9, and the laft from 10.

ARLINGTON, a townfhip in Bennington county, Vermont, 12 miles N. from Bennington. It has 991 inhabitants.—*Morse.*

ARRACIFFE, a port town of Brazil, in the captainfhip of Pernambaco; efteemed the ftrongeft in all Brazil. The port confifts of a fuburb, in which are fome large houfes, and repofitories for ftores; and is built upon a narrow paffage, with a caftle to defend the entrance. Notwithftanding which, James Lancafter entered the harbour in 1595, with 7 Englifh veffels, and made himfelf mafter of the town and caftle, where he continued a month, and carried off immenfe plunder; but fince that time, the Portuguefe have rendered it almoft inacceffible to enemies. Lat. 8. 20. S. long. 36. 10. W.—*ib.*

ARRAYAL De Porate, a town in Brazil, fituated on the W. fide of Para River, below the junction of its two great branches.—*ib.*

ARROWSIKE, an ifland in the diftrict of Maine, parted from Parker's Ifland by a fmall ftrait. It is within the limits of George-Town, and contains nearly $\frac{1}{7}$ of its inhabitants, and has a church. It contains about 20,000 acres of land, including a large quantity of falt marfh.—*ib.*

ARSACIDES, *the Iflands of the*, the name given by M. de Surville, in 1769, to Solomon's Iflands, on account of the barbarous character of their inhabitants, particularly at Port Praflin. Thefe iflands were vifited by Mr. Shortland in 1788, and by him called New-Georgia.—*ib.*

ARTEDI (John), was born in the year 1705, in the province of Angermania, in Sweden. From nature he inherited an ardent paffion for all branches of natural hiftory, but he excelled moft in that branch of it which is termed *ichthyology*. In 1724 he went to ftudy at the univerfity of Upfal, where fome years afterwards he gained the friendfhip of the immortal Linnæus, who narrates the principal events of his life in the following animated terms.

"In 1728 (fays Linnæus) I came from Lund to Upfal. I wifhed to devote myfelf to medicine. I inquired who, at that univerfity, excelled moft for his knowledge: every one named Artedi. I was impatient to fee him. I found him pale, and in great diftrefs for the lofs of his father, with his thin hair neglected. He refembled the portrait of Ray the naturalift. His judgment was ripe, his thoughts profound, his manners fimple, his virtues antique. The converfation turned upon ftones, plants, animals. I was enchanted with his obfervations, equally ingenious and new; for at the very firft he was not afraid to communicate them to me with the utmoft franknefs. I defired his friendfhip, he afked mine. From that moment we formed a friendfhip; which we cultivated with the greateft ardour for feven months at Upfal. I was his beft friend, and I never had any who was more dear to me. How fweet was that intimacy! With what pleafure did we fee it increafe from day to day! The difference, even of our characters, was ufeful to us. His mind was more fevere, more attentive; he obferved more flowly, and with greater care. A noble emulation animated us. As I defpaired of ever becoming as well inftructed in chemiftry as he, I abandoned it; he alfo ceafed to ftudy botany with the fame ardour, to which I had devoted myfelf in a particular manner. We continued thus to ftudy different branches of fcience; and when one of us excelled the other, he acknowledged him for his mafter. We difputed the palm in ichthyology; but foon I was forced to yield, and I abandoned that part of natural hiftory to him, as well as the amphibia. I fucceeded better than he in the knowledge of birds and infects, and he no longer tried to excel in thefe branches. We marched together as equals in lithology, and the hiftory of quadrupeds. When one of us made an obfervation, he communicated it to the other: fcarce a day paffed in which one did not learn from the other fome new and interefting particular. Thus emulation excited our induftry, and mutual affiftance aided our efforts. In fpite of the diftance of our lodgings, we faw each other every day. At laft I fet out for Lapland; he went to London. He bequeathed to me his manufcripts and his books.

"In 1735 I went to Leyden, where I found Artedi. I recounted my adventures; he communicated his to me. He was not rich, and therefore was unable to be at the expence of taking his degrees in phyfic. I recommended him to Seba, who engaged him to publifh his work on fifhes. Artedi went to join him at Amfterdam.

"Scarcely had I finifhed my *Fundamenta Botanica*. I communicated it to him; he let me fee his *Philofophia Ichthyologica*. He propofed to finifh as quickly as poffible the work of Seba, and to put the laft hand to it. He fhowed me all his manufcripts which I had not feen: I was preffed in point of time, and began to be impatient as being detained fo long. Alas! if I had known this was the laft time I fhould fee him, how fhould I have prolonged it!

"Some days after, as he returned to fup with Seba, the night being dark, he fell into the canal. Nobody perceived it, and he perifhed. Thus died, by water, this great ichthyologift, who had ever delighted in that element."

Of the works of this eminent naturalift there have been two editions, of which the former was publifhed by Linnæus in 1738, and the latter by Dr. Walbaum of Lubeck, in the years 1788, 1789, and 1792. This edition, which is by much the moft valuable, is in three volumes 4to; of which the firft contains the hiftory of the fcience of ichthyology, commencing feveral years before the Chriftian era, and coming down to the prefent times. The fecond prefents to the reader the *Philofophia Ichthyologica* of Artedi, improved by Walbaum, who was benefited by the writings of Monro, Camper, Kætfeuter and others. Here alfo are added tables containing the fyftem of fifhes by Ray, Dale, Schaeffir, Linnæus, Gowan, Scopola, Klein, and Gronovius. The third volume, which completes the collection of Artedi's works, contains the technical definitions of the fcience. After the generic and individual characters, come the names and Latin phrafes of Artedi; the fynonymes of the beft naturalifts; the vulgar names in Englifh, German, Swedifh, Ruffian, Danifh, Norwegian, Dutch, and Samoyed; the feafon and the countries where every kind is found, their varieties, their defcription, and obfervations. The modern difcoveries, even to our own times, are added; fo that in this

this part is collected the obfervations of Gronovius, Brunich, Penant, Forfter, Klein, Bloch, Gmelin, Haffelquift, Brouffonet, Lefke, Buifh, Linnæus, and other great examiners of nature.

ARTHUR KULL, or *Newark Bay*, on the coaft of New-Jerfey, is formed by the union of Paffaic and Hackinfack Rivers.—*Morse.*

ARUNDEL, a townfhip in York county, diftrict of Maine, containing 1458 inhabitants. It lies between Cape Porpoife, and Biddeford on the N. E. on Saco River, 21 miles N. E. from York, and 96 N. E. from Bofton.—*ib.*

ASANGARO, a jurifdiction under the bifhop of Cufco, in Peru, South America, 50 leagues from that city: numbers of cattle are bred here. There are fome filver mines in the N. E. part of it; and it produces papas, quinoas, and canaguas. Of the two laft they make chicha, as others do from maize.—*ib.*

ASHBURNHAM, formerly *Dorchefter Canada*, lies in Worcefter county, Maffachufetts, 30 miles N. of Worcefter, and 55 from Bofton, was incorporated in 1765, and contains 951 inhabitants. It ftands upon the height of land E. of Connecticut River, and W. of Merrimack, on the banks of Little Naukheag. In this townfhip, is a white fand, equal in finenefs to that at Cape Ann, and which, it is judged, would make fine glafs.—*ib.*

ASHBY, a townfhip in Middlefex county, Maffachufetts, 50 miles N. W. from Bofton, containing 751 inhabitants.—*ib.*

ASHCUTNEY, or *Afacutney*, a mountain in Vermont, being partly in the townfhips of Windfor and Weathersfield, and oppofite Claremont on Sugar River, in New-Hampfhire ftate. It is 2031 feet above the fea, and 1732, above high water in Connecticut River, which glides by its E. fide.—*ib.*

ASHFIELD, a townfhip in Hampfhire county, Maffachufetts, about 15 miles N. W. of Northampton, and 117 W. from Bofton, containing 1459 inhabitants.—*ib.*

ASHFORD, a townfhip in Windham county, Connecticut, fettled from Marlborough in Maffachufetts, and was incorporated in 1710. It lies about 38 miles north-eafterly from Hartford, and 76 fouthwefterly from Bofton.—*ib.*

ASHMOT, the principal harbour in Ifle Madame, which is dependent on Cape Breton. See *Breton Cape*.—*ib.*

ASHUELOT, or *Afhwillet*, a fmall river, having a number of branches, whofe moft diftant fource is at the N. end of the Sunapee Mountains, in New-Hampfhire. It runs fouth-wefterly through part of Chefhire county. Below Winchefter it runs W. by N. and empties into Connecticut River, at Hinfdale.—*ib.*

ASPOTAGOEN *Mountain.* This high land lies on the promontory that feparates Mahone from Margaret's Bay, on the coaft of Nova-Scotia. It is feen at a great diftance from the offing, and is the land generally made by the fhips bound from Europe and the Weft-Indies to Halifax. The fummit is about 500 feet above the level of the fea.—*ib.*

ASSENEPOWALS, a lake weftward of Chriftianaux Lake, and through which its waters run into Albany River, in New South Wales.—*ib.*

ASSINIBOILS, or *Affiniboels*, a river and lake in the N. W. part of North America. The river is faid to rife in the Mountain of Bright Stones, runs N. E. into Lake Ouinipique in N. lat. 51 ½ W. long. 106.—*ib.*

The lake is placed in fome maps in the 52d deg. of N. lat. and 96th of W. long. It has communication with Chriftianaux Lake, on the eaftward, which fends its waters to James Bay. Near thefe, lie the countries of the Chriftianaux, and Kiris, called alfo Killiftins.—*ib.*

ASSUMPTION, an epifcopal city, in the province of Paraguay, in the E. divifion of Paraguay or La Plata in S. America. It ftands on the eaftern bank of a river of its name, a little above the place where the Picolmaga falls into it; having Villa Rica on the N. and La Plata on the S. and is nearer the fouthern, than the Pacific ocean; but not far from the middle of that part of the continent. It was built by the Spaniards in 1538, and is remarkable for its healthy fituation, as well as for the number of its inhabitants, and the rich and fruitful territory in which it ftands; which produces a great variety of native and exotic fruits, in the higheft perfection. Here are feveral hundred Spanifh families, defcendants of the flower of the gentry who fettled in this place; while the dregs of their countrymen removed to other parts. There are likewife a number of Meftizos and Mulattoes. The city lies about 50 leagues above the confluence of the Paraguay and Parana, where the former begins to be called, the River de la Plata. Near the city is a lake, noted for having in the middle of it a rock, which fhoots up to a prodigious height like an obelifk. Lat. 26. S. long. 57. 40. W.—*ib.*

ASSUMPTION *River*, in New-York, falls in from the E. into Lake Ontario, after a N. W. and W. courfe of about 28 miles, 5 miles S. E. from Pl. Gaverfe.—*ib.*

ASTRONOMY

IS a fcience which has been cultivated from the earlieft ages, and is converfant about the moft fublime objects of inquiry which can employ the mind of man. It has accordingly been treated at great length in the Encyclopædia; but, in the opinion of fome of the moft judicious readers of that work, the compiler of the fyftem which is there delivered has failed in his attempt to give a perfpicuous and connected view of the fcience in its prefent ftate of improvement. This defect it is our duty to remedy. Our object, therefore, in this fupplementary article, will be to bring into one point of view the phyfical fcience which may be derived from the confideration of the celeftial motions; that is, to deduce from the general laws of thofe motions the inferences with refpect to their fuppofed caufes, which conftitute the philofophy of the aftronomer.

1 Object of this article.

The

The cauſes of all phenomena are not only inferred from the phenomena, but are characteriſed by them; and we can form no notion of their nature but what we conceive as competent to the phenomena themſelves. The aſtronomical phenomena are aſſumed to be the motions of the *bodies*, which we call the *ſun*, the *planets*, the *comets*, &c. The notion which we expreſs by the word *body* in the preſent caſe, is ſuppoſed to be the ſame with that which we form of other objects around us, to which we give the ſame name; ſuch as ſtones, ſticks, the bodies of animals, &c. Therefore the notion which we have of the cauſes of the celeſtial motions muſt be the ſame with that which we have of the cauſes of motion in thoſe more familiar bodies. All men ſeem to have agreed in giving the name FORCES, or MOVING FORCES, to the cauſes of thoſe familiar motions. This is a figurative or metaphorical term. The true and original meaning of it is, the exertion which we are conſcious of making when we ourſelves put other bodies in motion. Force, when uſed without figure, always ſignifies the exertion of a living and acting thing. We are more intereſted in thoſe productions of motion than in any other, and our recollections of them are more numerous. Hence it has happened that we uſe the ſame term to expreſs the cauſe of bodily motion in general, and ſay that a magnet has force, that a ſpring has force, that a moving body has force.

2 Metaphorical uſe of the term *force*.

Our own force is always exerted by the intervention of our own body; and we find that the ſame exertion by which we move a ſtone, enables us to move another man; therefore we conceive his body to reſemble a ſtone in this reſpect, and that it alſo requires the exertion of force to put it in motion. But when we reflect on our employment of force for producing motion in a body, we find ourſelves puzzled how to account for the motion of our own bodies. Here we perceive no intervening exertion but that of willing to do it; yet we find that we cannot move it as we pleaſe. We alſo find that a greater motion requires a greater exertion. It is therefore to this exertion that the reflecting man reſtrains the term *force*; and he acknowledges that every other uſe of it is metaphorical, and that it is a reſemblance in the ultimate effect alone which diſpoſes us to employ the term in ſuch caſes: but we find no great inconvenience in the want of another term.

We farther find, that our exertion is neceſſary, not only for producing motion where there was none before, but alſo for producing any change of motion; and accurate obſervation ſhows us, that the ſame force is required for changing a motion by any given quantity, as for producing that quantity where there was none before.

Laſtly, we are conſcious of exerting force when we reſiſt the exerted force of another; and that an exertion, perfectly ſimilar to this, will prevent ſome very familiar tendencies to motion in the bodies around us: thus an exertion is neceſſary for carrying a weight, that is, for preventing the fall of that weight.

All theſe reſemblances between the effects of our forcible exertions and the changes of motion which accompany the meeting, and ſometimes the mere vicinity of other bodies, juſtify us in the uſe of this figurative language. The reſemblance is found to be the more perfect as we obſerve it with more care, and, in ſhort, appears to be without exception. Bodies are therefore ſaid to *act* on each other, to *reſiſt* each other, to *reſiſt a change of motion*, &c.

Therefore, wherever we obſerve a change of motion, we infer the exiſtence and exertion of a changing force; and we infer the direction of that exertion from the direction of the change; and the quantity of the exertion, or intenſity of the force, from the quantity of the change.

The ſtudy of the cauſes of the celeſtial motions is therefore hardly different from the ſtudy of the motions themſelves; ſince the agency, the kind, and the degree of the moving force, are immediate inferences from the exiſtence, the kind, and the quantity of the change of motion.

3 Our notion of a moving power.

Our notion of a moving power is that of a power which produces motion, that is, a ſucceſſive change of place. Continuation of the motion produced is therefore involved in the very notion of the production of motion; therefore the continued agency of the moving power, or of any power, is not neceſſary for the continuation of the motion. Motion is conſidered as a ſtate or condition of the body; there is not any exertion of power therefore in the continuation of motion: But every change is indicative of a changing cauſe; and when the change is the ſame, in all its circumſtances, the cauſe is neceſſarily conceived to be the ſame or equal.

The condition of a body, in reſpect of motion, can differ from that of another equal body only in its direction and in its velocity. If the directions are the ſame, the difference of conditions can only be in the difference of velocity. One body has a determination, by which it would deſcribe ten feet uniformly in a ſecond, if nothing changed this determination; the other has a determination, by which it would deſcribe twenty feet in a ſecond. Each of theſe determinations are ſuppoſed to be the effects of forces acting ſimilarly in every reſpect. Therefore theſe determinations are the only meaſures of theſe two forces; that is, moving forces are conceived by us as having the proportion of the velocities which they produce in a body by acting in a manner perfectly ſimilar.

4 Meaſure of moving forces.

We can conceive a force acting equally or unequally. If we ſuppoſe it to act equally or uniformly, we ſuppoſe that in equal times it produces equal effects; that is, equal determinations, or equal changes of determination. We have no other notion of equality or uniformity of action. Therefore it muſt produce equal augmentations or diminutions of velocity in equal times; therefore it muſt produce an *uniformly* accelerated or retarded motion. Uniformly accelerated or retarded motion is, therefore, the mark of uniform or unvaried action. In ſuch a motion, the changes of velocity are proportional to the times from the beginning of the action; and if the motion has begun from reſt, the whole acquired velocities are proportional to the times from the beginning of the motion. In this caſe, the ſpaces deſcribed are as the ſquares of the times from the beginning of the motion; and thus we arrive at an oſtenſible mark of the unvaried action of a moving force, viz. ſpaces increaſing in the duplicate ratio of the times: for ſpace and time are all that we can immediately obſerve in any motion that is continually varying; the velocity or determination is only an inference, on the

5 Accelerated motion the mark of unvaried action;

 ſuppoſition

fuppofition that the motion continues unchanged for fome time, or that all action ceafes for fome time.

This abftract reafoning is perfectly agreeable to every phenomenon that we can obferve with diftinctnefs. Thus we cannot, or at leaft we do not, conceive the weight of a body to vary its action during the fall. We confider this weight as the caufe of the fall—as the moving force—and we conceive it to act uniformly. And, in fact, a body falling freely, defcribes fpaces which are proportional, not to the times, but to the fquares of the times, and the fall is a motion uniformly accelerated. In like manner, the motion of a body rifing in the air, in oppofition to gravity, is uniformly retarded.

6 And gives a meafure of the acquired velocity.

This kind of motion alfo gives us a certain meafure of the acquired velocity, although there is not, in fact, any fpace obferved to be uniformly defcribed during any time whatever. In this motion we know that the final determination, produced by the accumulated or continued action of the unvaried force, is fuch that the body would defcribe uniformly twice the fpace which it has defcribed with the accelerated motion.

And it is by this method that we obtain the fimpleft meafure of any moving force, and can compare it with another. If we obferve that by the action of one force (known to be uniform by the fpaces being proportional to the fquares of the times) ten feet have been defcribed in a fecond, and that by the uniform action of another force eighty feet are defcribed in two feconds, we know that the laft force is double of the firft: for in the fecond motion, 80 feet were defcribed in two feconds, and therefore 20 feet of this were defcribed in the firft fecond (becaufe the motion is uniformly accelerated); and at the end of a fecond, the firft body had a determination by which it would defcribe 20 feet uniformly in a fecond; and the fecond body had acquired a determination by which it would have defcribed 40 feet uniformly in the next fecond, had not the moving force continued to act on it, and made it really defcribe 60 feet with an accelerated motion.

Becaufe halves have the fame proportions with the units of which they are the halves, it is plain that we may take the fpaces, defcribed in equal times with motions uniformly accelerated, as meafures of the forces which have produced thofe motions. The velocities generated are, however, the beft meafures.

7 Meafure of the velocity produced by action not uniform.

When the actions of forces are not uniform, it is more difficult to learn what is the meafure of the velocity produced by their accumulated action. But it can be determined with equal accuracy; that is, we can determine what is the velocity which *would have been produced* by the uniform action of the force during the fame time, and therefore we obtain a meafure of the force. Mathematicians are farther able to demonftrate, that if forces vary their continued action in any manner whatever, the proportion of the fpaces defcribed by two bodies in equal times approaches nearer and nearer to the proportion of the fpaces which they would defcribe in thofe times by the uniform action of the forces, as the times themfelves are fmaller; and therefore whenever we can point out the ultimate ratio of the fpaces defcribed in equal times, thefe times being diminifhed without end, we obtain the ratio of the forces.

Motions may be changed, not only in quantity, by acceleration or retardation, but alfo in direction, by deflecting a body from its former direction. When a body, moving uniformly in the direction AB (fig. 1.), has its motion changed in the point B, and, inftead of defcribing BC uniformly in the next moment with the former velocity, defcribes BD uniformly in that moment, it is plain that the motion BD will be the fame, whether the body had begun to move in A, or in F, or in G, or in B, provided only that its determination to move, or its velocity, be the fame in all thofe points. Complete the parallelogram BCDE. It is well known, that if one force act on the body which would make it defcribe BC, and another which would make it defcribe BE, the body will defcribe BD. Hence we learn, that when a body has the motion BC changed into the motion BD, it has been acted on in the point B by a force which would have caufed a body at reft in B to defcribe BE. Thus we can difcover the intenfity and direction of the tranfverfe force which produces any deflection from the former direction. In general, the force is that which would have produced in a body at reft that motion BE, which, when compounded with the former motion BC, produces the new motion BD.

Plate VI.

8 Intenfity and direction of deflecting forces.

Thefe two principles, viz. 1ft, that forces are proportional to the velocities which they produce in the fame circumftances, and, 2d, the compofition of motion or forces, will ferve for all the phyfical inveftigations in aftronomy. All the celeftial motions are curvilineal, and therefore are inftances of continual deflection, and of the continual action of tranfverfe or deflecting forces. We muft therefore endeavour to obtain a general meafure of fuch continual deflecting forces.

9 Meafure of thefe forces obtained.

Let two bodies A and *a* (fig. 2.) defcribe in the fame time the arches AC, *a c* of two circles. They are deflected from the tangents AB, *a b*. Let us fuppofe that the direction of the deflecting forces is known to be that of the chords AE, *a e* of thefe circles. Let thefe be called the DEFLECTIVE CHORDS. Draw CB, *c b*, parallel to AE, *a e*, and CD, *c d* parallel to AB, *a b*. Join AC, *a c*, CE, and *c e*. It is plain that the angle BAC is equal to the angle CEA in the alternate fegment. Therefore ACD is alfo equal to it; and, becaufe the angle CAD is common to the two triangles CAD and EAC, thefe two triangles are fimilar, and $AD : AC = AC : AE$, and $AD = \frac{AC^2}{AE}$. For fimilar reafons $a\,d = \frac{a\,c^2}{a\,e}$. But AD and *a d* are refpectively equal to BC and *b c*. Therefore $BC = \frac{AC^2}{AE}$, and $b\,c = \frac{a\,c^2}{a\,e}$. Therefore $BC : b\,c = \frac{AC^2}{AE} : \frac{a\,c^2}{a\,e}$, or $BC : b\,c = AC^2 \times a\,e : a\,c^2 \times AE$. But BC and *b c* being refpectively equal to AD and *a d*, are equal to the fpaces through which the deflecting forces would have impelled the bodies from a ftate of reft in the time of defcribing the arches AC, *a c*. Therefore when thefe times are diminifhed without end, the *ultimate* ratio of AD and *a d* is the ratio of the forces which deflect the bodies in the points A and *a*. But it is evident that the ultimate ratio of AC to *a c* is the ratio of the velocity in the point A to the velocity in the point *a*; becaufe thefe arches are fuppofed to be defcribed in the fame or equal times. Therefore the deflecting forces, by which bodies are made to defcribe arches of circles,

circles, are to each other as the fquares of the velocities directly, and as the deflective cords of thofe circles inverfely. This ratio may be expreffed fymbolically thus, $F:f=\frac{V^2}{C}:\frac{v^2}{c}$; or thus, in a proportional equation, $f \doteq \frac{v^2}{c}$.

It is eafy to fee that in this laft formula f expreffes directly the line $b\ c$, or the fpace through which the body is actually made to deviate from rectilineal motion in the time of defcribing the arch $a\ c$. It is a third proportional to $a\ e$ the deflective chord, and ac the arch of the circumference defcribed in a fmall moment of time. This is the meafure afforded immediately by obfervation. We have obferved the arch AC that is defcribed, and know the direction and the length of AE from fome circumftances of the cafe. The formula which comes to us, when treating this queftion by the help of fluxions, is $f=\frac{2\ v^2}{c}$. This is perhaps a more proper expreffion of the phyfical fact; for it expreffes twice the line $b\ c$, or the meafure of the velocity which the deflecting force would have generated in the body by acting on it during the time of its defcribing the arch $a\ c$. But it is indifferent which meafure we take, provided we always take the fame meafure. The firft mathematicians, however, have committed miftakes by mixing them.

The planets, however, do not defcribe circles: but all the curves which can be defcribed by the action of finite deflecting forces are of fuch a nature, that we can defcribe a circle through any point, having the fame tangent, and the fame curvature which the planetary curve has in that point, and which therefore ultimately coalefces with it. This being the cafe, it is plain that the planet, while paffing through a point of the curve, and defcribing an indefinitely fmall arch of it, is in the fame condition as if defcribing the coincident arch of the equicurve circle. Hence we obtain this moft general propofition, that *the tranfverfe force by which a planet is made to defcribe any curve, is directly as the fquare of its velocity, and inverfely as the deflective chord of the equicurve circle.*

Farther: The velocity of a body in any point A (fig. 2.) of the curve, is equal to that which the deflective force in that point would generate in the body by acting uniformly on it along AF, one-fourth part of the deflective cord AE of the equicurve circle. It is the fame which the body would acquire at F, after a uniformly accelerated motion along AF.

For it is certain that there is fome length AF, fuch that the velocity acquired at F is the fame with the velocity in the point A of the curve. Draw FG parallel to the tangent, and join AG. Make the arch ACI = 2AF. Then, becaufe the fpace defcribed with a uniformly accelerated motion is one half of the fpace which would be uniformly defcribed with the final velocity, the arch ACI would be uniformly defcribed with the velocity which the body has at A in the time that AF is defcribed with the uniformly accelerated motion; and the arch AB will be to the arch AI as the time of defcribing AB to that of defcribing AI; that is, as the time of falling through AD to that of falling through AF. But the motion along AF being uniformly accelerated, the fpaces are as the fquares of the times. Therefore AD is to AF as the fquare of the arch AC to the fquare of the arch AI. But AD is to AF as the fquare of the chord AC is to the fquare of the chord AG. Therefore the arch AC is to the chord AC as the arch AI is to the chord AG. But the arch and chord AC are ultimately in the ratio of equality. Therefore the chord AG is equal to the arch AI. Therefore AG is double of AF. But becaufe the triangles FAG and GAE are fimilar, AF is to AG as AG to AE; and therefore AE is double of AG and quadruple of AF. Therefore the velocity at A in the curve is that which would be produced by the uniform impulfe of the deflecting force along the fourth part of the deflective chord of the equicurve circle.

10 Two ufeful affections of curvilineal motions.

Thefe two affections or properties of curvilineal motions are of the moft extenfive ufe, and give an eafier folution of moft queftions than we obtain by the more ufual methods, and deferve to be kept in remembrance by fuch as engage much in the difcuffion of queftions of this kind.

Thus the inveftigation of the forces which regulate the planetary motions, is reduced to the tafk of difcovering the velocity of the planet in the different points of its orbit, and the curvature in thofe points, and the pofition of the deflective chords.

11 Phyfical fcience of aftronomy

The phyfical fcience of aftronomy muft confift in the difcovery of the general laws which can be affirmed with refpect to the exertion of thofe forces, whether with refpect to their direction or the intenfity of their action. If the mechanician can do more than this, and fhow that every motion that is obferved is an immediate or remote confequence of thofe general laws, he will have completed the fcience, and explained every appearance.

12 Completed by Newton and

This has accordingly been done by Sir Ifaac Newton and his followers. Sir Ifaac Newton has difcovered the general laws which regulate the exertions of thofe forces which produce the planetary motions, by reafoning from general phenomena which had been obferved with a certain precifion before his time; and has alfo fhown that certain confiderable deviations from the generality which he fuppofed to be perfect were neceffary confequences of the very univerfality of the phyfical law, although the phenomenon was not fo general as was at firft imagined. He has gone farther, and has pointed out fome other minute deviations which muft refult from the phyfical law, but which the art of obfervation was not then fufficiently advanced to difcover in the phenomena. This excited the efforts of men of fcience to improve the art of aftronomical obfervation; and not only have the intimations of Newton been verified by modern obfervation, but other deviations have been difcovered, and, in procefs of time, have alfo been fhown to be confequences of the fame general law of agency: And, at this prefent day, there is not a fingle anomaly of the planetary motions which has not been fhown to be a modification of one general law which regulates the action; and therefore characterifes the nature of that fingle force which actuates the whole fyftem of the fun, and his attending planets and comets.

13 His followers.

It was a moft fortunate circumftance that the conftitution of the folar fyftem was fuch that the deviations from the general law are not very confiderable. The cafe might have been far otherwife, although the law, or nature of the planetary force, were the fame, and the

the ſyſtem had been equally harmonious and beautiful. Had two or three of the planets been vaſtly larger than they are, it would have been extremely difficult to diſcover any laws of their motion ſufficiently general to have led to the ſuſpicion or the diſcovery of the univerſal law of action, or the ſpecific circumſtance in the planetary force which diſtinguiſhes it from all others, and characteriſes its nature. But the three laws of the planetary motions diſcovered by Kepler were ſo nearly true, at leaſt with reſpect to the primary planets, that the deviations could not be obſerved, and they were thought to be exact. It was on the ſuppoſition *that they were exact*, that Newton affirmed that they were only modifications of one law ſtill more general, nay univerſal.

We ſhall follow in order the ſteps of this inveſtigation.

14 The ſteps by which they proceeded.

Sir Iſaac Newton took it for granted, that the ſun and planets conſiſted of matter which reſembled thoſe bodies which we daily handle, at leaſt in reſpect of their mobility; and that the forces which agitate them, conſidered merely as moving forces, but without conſidering or attending to their mode of operation, were to be inferred, both as to their direction and as to their intenſity, from the changes of motion which were aſcribed to their agency. He firſt endeavoured to diſcover the *direction* of that tranſverſe force by which the planets are made to deſcribe curve lines. Kepler's firſt law furniſhed him with ample means for this diſcovery. Kepler had diſcovered, that *the right line joining the ſun and any planet deſcribed areas proportional to the times.* Newton demonſtrated, that if a body was ſo carried round a fixed point ſituated in the plane of its motion, that the right line joining it with that point deſcribed areas proportional to the times, the force which deflected it from an uniform rectilineal motion was continually directed to that fixed point. This makes the 2d propoſition of his immortal work *The Mathematical Principles of Natural Philoſophy*, and it is given in the article Astronomy of the Encyclopædia § 260.

Hence Sir Iſaac Newton inferred, that the primary planets were retained in their orbits by a force continually directed to the ſun; and, becauſe Kepler's law of motion was alſo obſerved by the ſecondary planets in their revolutions round their reſpective primary planets, this inference was extended to them.

15 Centripetal forces.

From the circumſtance that the planetary deflecting forces in the different points of the orbit are always directed toward one point as to a centre, they have been called centripetal forces.

16 Velocity of a planet in the different points of its orbit.

From this propoſition may be deduced a corollary which eſtabliſhes a general law of the motion of any planet in the different parts of its orbit, namely, that the velocity which a planet has in the different points of its path are inverſely proportional to the perpendiculars drawn from the ſun on the tangents to the orbit in thoſe points reſpectively. For, let AB, *ab* (fig. 3.) be two arches (extremely ſmall), deſcribed in equal times theſe arches muſt be ultimately proportional to the velocities with which they are deſcribed. Let SP, Sp be perpendicular to the tangents AP, ap. The triangles ASB, aSb are equal, becauſe equal areas are deſcribed by the *radii vectores* SA, Sa, in equal times: but in equal triangles, the baſes, AB, ab, are reciprocally as their heights SP, Sp, or AB : ab = Sp : SP.

This corollary gives us another expreſſion of the ratio of the centripetal forces in different points A and a of a curve. We ſaw by a former propoſition, that the force at A (fig. 2.) is to the force at a as $AC^2 \times ae$ to $ac^2 \times AE$, which we may expreſs thus: $F : f = V^2 \times c : v^2 \times C$. If we expreſs the perpendiculars SP, Sp (in fig. 3.) by the ſymbols P, p, we have $V^2 : v^2 = p^2 : P^2$, and therefore $F : f = p^2 \times c : P^2 \times C$. *The centripetal forces in different points of an orbit are in the ratio compounded of the inverſe duplicate ratio of the perpendiculars drawn to the tangents in thoſe points from the centre of forces, and the inverſe ratio of the deflective chords of the equicurve circles.* 17

Law of action of the centripetal force.

We are now in a condition to determine the law of action of the centripetal force by which a planet is retained in its orbit round the ſun, or the relation which ſubſiſts between the intenſity of its action and the diſtance of the planet from the ſun: for we know the elliptical figure of the orbit, and we can draw a tangent to it in any point, and a perpendicular from the ſun to that tangent.

Kepler's ſecond law or obſervation of the planetary motions was, that *each primary planet deſcribed an ellipſe, having the ſun in one focus.* It is eaſy to ſhow, even without any knowledge of the geometrical properties of the ellipſe, what is the proportion of the intenſities of the deflecting force at the aphelion and perihelion (ſee fig. 4.) At thoſe two points of the orbit, the motion of the planet is at right angles to the line joining it with the ſun. Therefore, ſince the areas deſcribed in equal times are equal, the arches deſcribed in equal times muſt be inverſely as the diſtances from the ſun; or the velocities muſt be inverſely as the diſtances from the ſun. But the curvature in the aphelion and perihelion is the ſame; and therefore the diameters of the equicurve circles in thoſe points are equal. But thoſe diameters are, in this particular caſe, what we called the deflective chords. Therefore, calling the aphelion and perihelion diſtances D and d, the velocities in the aphelion and perihelion V and v, let the common deflective chord be C. Then we have $F : f = V^2 \times C : v^2 \times C, = V^2 : v^2, = d^2 : D^2$. That is, the forces which deflect the planet in the aphelion and perihelion are inverſely as the ſquares of the diſtances from the ſun. A perſon almoſt ignorant of mathematics may ſee the truth of this by looking into a table of natural verſed ſines. He will obſerve, that the verſed ſine of one degree is quadruple the verſed ſine of half a degree, and ſixteen times the verſed ſine of a quarter of a degree; in ſhort, that the verſed ſines of ſmall arches are in the proportion of the ſquares of the arches. Now ſince the arches deſcribed in equal times are inverſely as the diſtances, their verſed ſines are inverſely as the ſquares of the diſtances. But theſe verſed ſines are the ſpaces through which the centripetal forces at the aphelion and perihelion deflect the planet from the tangent. Therefore, &c.

Thus we have found, that in the aphelion and perihelion the centripetal force acts with an intenſity that is proportional to the ſquares of the diſtances inverſely. As theſe are the extreme ſituations of a planet, and as the

the proportion of the aphelion and perihelion diſtances are conſiderably different in the different planets, and yet this law of action is obſerved in them all, it is reaſonable to imagine that it holds true, not in thoſe ſituations only, but in every intermediate ſituation. But a conjecture, however probable, is not ſufficient, when we aim at accurate ſcience, and it is neceſſary to examine whether this law of action is really obſerved in every point of the elliptical orbit.

18 Demonſtrated with reſpect to the earth,

For this purpoſe it is neceſſary to mention ſome geometrical properties of the ellipſe. Therefore let ADBE (fig. 4.) be the elliptical orbit of a planet or comet, having the ſun in the focus S. Let AB be the tranſverſe axis, and DE the conjugate axis, and C the centre. Let P be any point of the ellipſe. Draw PS through the focus. Draw the tangent PN, and SN from the focus, perpendicular to PN. Draw PQ perpendicular to PN, meeting the tranſverſe axis in Q. Draw QO parallel to PN, meeting PS in O. Alſo draw QR perpendicular to PS. Biſect PO in T.

It is demonſtrated in the treatiſes of conic ſections, that PO is one half of the chord of the equicurve or oſculating circle drawn through the point P. Therefore PO is one half of the deflective chord of the planetary orbit. It is alſo demonſtrated, that PR is one half of the parameter or *latus rectum* of the tranſverſe axis AB, or that it is the third proportional to AC and DC. Therefore PR or D r is of the ſame conſtant magnitude, in whatever part of the circumference the point P is taken.

It is evident that the triangles NSP, RPQ, and QPO, are all ſimilar, by reaſon of the parallels PN, QO, and the right angles SNP, PRQ, PQO. Therefore we have PR : PQ = PQ : PO. Therefore PR : PO = PR² : PQ², = SN² : SP². Therefore PR × SP² = PO × SN². But the *latus rectum* L is equal to twice PR, and the deflective chord C is equal to twice PO. Therefore L × SP² = C × SN². But we have ſeen, that when a curve is deſcribed by means of a centripetal force, ſo that areas are deſcribed proportional to the times, and therefore the velocities are reciprocally proportional to the perpendiculars drawn from the centre of forces to the tangents, the forces are inverſely proportional to C × SN². Therefore, in the elliptical motion of the planets, the forces are inverſely proportional to L × SP²; and ſince L is a conſtant quantity, the centripetal forces are inverſely proportional to SP², or to the ſquares of the diſtances from the ſun.

Thus it appears that, with reſpect to any individual planet, the centripetal force which continually deflects it from the tangent to its orbit diminiſhes in the inverſe

19 Obſerved in the motion of the moon &c.

duplicate ratio of the diſtance from the ſun. The ſame thing is obſerved to be very nearly true in the moon's motion round the earth, and in the motion of ſuch ſatellites of Jupiter and Saturn as deſcribe orbits which are ſenſibly elliptical. It is alſo obſerved in the motion of the comets, at leaſt in that which appeared in 1682 and in 1759.

It was therefore very natural for Sir Iſaac Newton to examine whether the like diminution of force obtained in the action of this force on different planets; that is, whether the deflection of the earth from the tangent of its orbit was to the ſimultaneous deflection of Jupiter as the ſquare of Jupiter's diſtance from the ſun to the ſquare of the earth's diſtance. This was very probable, but by no means certain. Its probability is very great indeed, when we know that a comet moves ſo in its orbit that its deflections in equal times are inverſely as the ſquares of its diſtances from the ſun, and that the comet paſſes through the orbits of all the planets; and when at the ſame diſtance from the ſun as any one of them, it ſuffers the ſame deflection with it. Newton therefore calculated the actual ſimultaneous deflections of the different planets, and found them agreeable to this law. But it was deſirable to obtain a demonſtration of this important propoſition in general terms. This was ſupplied by Kepler's third general obſervation of the motions, viz. that *the ſquares of the periodic times of the different planets were proportional to the cubes of their mean diſtances from the ſun.* The orbits of the planets are ſo nearly circular, that we may ſuppoſe them exactly ſo in the preſent queſtion, without any remarkable error. In this caſe, then, the deflective chords are the diameters of the orbits (for DS is equal to AC), and are proportional to the diſtances, which are their halves. The centripetal forces, being proportional to $\frac{v^2}{c}$, are proportional to $\frac{v^2}{d}$, when d is the radius of the orbit, or the mean diſtance from the ſun. But the velocity in a circular orbit is as the circumference directly, and as the time of a revolution inverſely. Therefore, inſtead of v^2, we may write $\frac{d^2}{t^2}$, and then the forces will be proportional to $\frac{d^2}{t^2\,d}$, or to $\frac{d}{t^2}$; that is, directly as the diſtances, and inverſely as the ſquares of the times of revolution. But, by Kepler's obſervation, t^2 is proportional to d^3. Therefore the centripetal forces are proportional to $\frac{d}{d^3}$, or to $\frac{1}{d^2}$; that is, inverſely as the ſquares of the mean diſtances from the ſun.

20 And demonſtrated in general terms.

But ſince the orbits of the planets are not accurate circles, this determination is but an approximation to the truth, and therefore inſufficient for the foundation of ſo important a propoſition; at any rate, it will not apply to the comets, whoſe orbits are very far from being circular. We muſt obtain a more accurate demonſtration.

Therefore draw SD (fig. 4.) to the extremity of the conjugate axis, and biſect it in t. About S, with the radius SD, deſcribe the circle DFG. Let D d, D δ be equal ſmall arches of the ellipſe and the circle. Join dS, δS. It is well known that DS is half of the chord of the equicurve circle at D, and therefore D t is one fourth part of it. It has been demonſtrated, that the velocity in any point D of a curve, deſcribed by means of a deflecting force, is that which the force in that point would communicate to it by uniformly impelling it along the fourth part of the deflective chord, that is, along D t. But if a body revolved round S in a circle DFG, its velocity in that circle would be that which the deflecting force would communicate to it by uniformly impelling it along one-fourth of the diameter, that is, along D t. Therefore the planet, if projected in the direction D δ, with the velocity which it has in the point D of the ellipſe, would deſcribe the circle DFG by the action of the centripetal force. Farther, it would deſcribe it in the ſame time that it deſcribes the ellipſe; for becauſe the velocities are equal, the areas

D S d,

D S d, D S δ are described in the same time. But the bases D d, D δ being equal, these areas are as their heights S n (or CD), and SD (or CA). But because the diameter of the circle is equal to AB, the area of the whole ellipse is to the area of the circle as CD is to CA; that is, as the area D S d to the area D S δ described in the same time. Therefore the elliptical and circular areas are similar portions of the ellipse and circle; and therefore the times of describing them are similar portions of the whole revolutions in the ellipse and in the circle. Therefore these revolutions are performed in equal times.

And thus it follows, that if all the planets and comets were projected, when at their mean distances from the sun, perpendicularly to the *radii vectores*, they would describe circles round the sun, and the squares of their periodic times would be proportional to the cubes of their mean distances from the sun, as Kepler has observed; and therefore the centripetal forces would be inversely as the squares of their distances from the sun.

21 All the planets retained in their respective orbits by one and the same force.

They are not different forces therefore which retain the different planets in their respective orbits, but one force, acting by the same law upon them all. We may either conceive it as an attractive force, exerted by the sun, or as a tendency in each planet; nay, nothing hinders us from conceiving it as a force external, both to sun and planets, impelling them towards the sun. It may be the impulse of a stream of fluid moving continually toward the sun. Sir Isaac Newton did not concern himself with this question, but contented himself with the discovery of the law according to which its action was exerted. The steps of this investigation showed him, that a body, projected in any direction whatever, and with any velocity whatever, and subjected to the action of a force directed to the sun, and inversely proportional to the square of the distance from the sun, will necessarily describe a conic section, having the sun in the focus. This will be a parabola, if the velocity of projection be that which the centripetal force in that place would communicate to the body by acting on it uniformly along a line equal to half its distance from the sun. If the velocity be greater than this, the path will be a hyperbola; if the velocity be less than this, the path will be an elliptical orbit, in which the body will revolve for ever round the sun.

The 3d Keplerean law is also observed in the revolutions of the satellites of Jupiter, Saturn, and the lately discovered planet; and we must infer from it, that they are retained in their orbits round their respective primary planets, by forces whose intensity decreases according to the same law of the distances. Also the elliptical motion of the moon round the earth, shows that the force by which she is retained in her orbit varies in the same proportion of the distances. But when we compare the motion of a satellite of Jupiter with that of one of the satellites of the other two planets, we find that the proportion does not hold. We shall find, that, at equal distances from Jupiter and Saturn, the force toward Jupiter is almost thrice as great as the force toward Saturn. We shall also find that the force toward Jupiter is three hundred times greater than the force which retains the moon in its elliptical orbit round the earth, when acting at the same distance.

Since a force directed to the sun, and inversely as the square of the distance, is thus found to pervade all the planetary orbits, it is highly improbable that it will not affect the secondary planets also. The moon accompanies the earth in its motion round the sun. It may appear sufficient for this purpose, that the moon be retained in its orbit by a force directed to the earth. Were the moon connected with the earth by a rope or chain, this would be true; for the earth could get no motion without dragging the moon along with it: but it is quite otherwise with bodies moving in free space, without any material connections. When a body that is moving uniformly in a straight line is accompanied by another which describes around it areas proportional to the times, the force which continually deflects this satellite is always directed to the moving central body.

22 The satellites of all the planets subjected to this solar action.

This is easily seen; for whatever be the mutual action of two bodies, and their relative motions in consequence of this action, if the same velocity be impressed at once on both bodies in the same direction, their mutual actions and relative motions will be the same as they would have been without this common impulse. Thus every thing is done in a ship that is sailing steadily in the same manner as if she were at rest. If therefore the moon be observed to describe areas round the earth, which are *precisely* proportional to the times, while the earth moves in an orbit round the sun, we must infer that the moon receives, in every instant, an impulse the same in every respect with what the earth receives at the same instant; or that the moon is acted on by a force parallel to the earth's distance from the sun, and proportional to the square of that distance inversely. Now this is very nearly true of the lunar motions; and we must infer that the moon is subjected to this solar action, or this tendency to the sun. The same must be affirmed of the satellites of the other planets.

But a force inversely proportional to the square of the earth's distance from the sun is not what the universality of the law requires: It must be inversely as the square of the moon's distance from the sun: and it must not be parallel to the earth's distance from the sun, but must be directed toward the sun; and therefore, in the quadratures, it must converge to the earth's *radius vector*. Therefore, since a force having the above mentioned conditions will allow the description of areas round the earth exactly proportional to the times, a force acting on the moon, inversely proportional to the square of her distance from the sun, and directed exactly to the sun, is incompatible with the accurate elliptical motion round the earth.

23 How the irregularity of the moon's motion

At new moon, her tendency to the sun exceeds the earth's tendency to him, and this excess will diminish her tendency to the earth, and her motion will be less incurvated, so that she will retire a little from the earth. At full moon, the earth's tendency to the sun exceeds the moon's tendency to him, and the earth will separate a little from the moon, so that the relative orbit will again be less incurvated. In the quadratures, the impulse on the moon is indeed equal to that on the earth, but not parallel, and tends to make the moon approach the earth, and increase the curvature of her orbit. In other situations of the moon, this want of equality and parallelism of the forces acting on the earth and moon, must produce other disturbances of the regular elliptical motion.

Newton

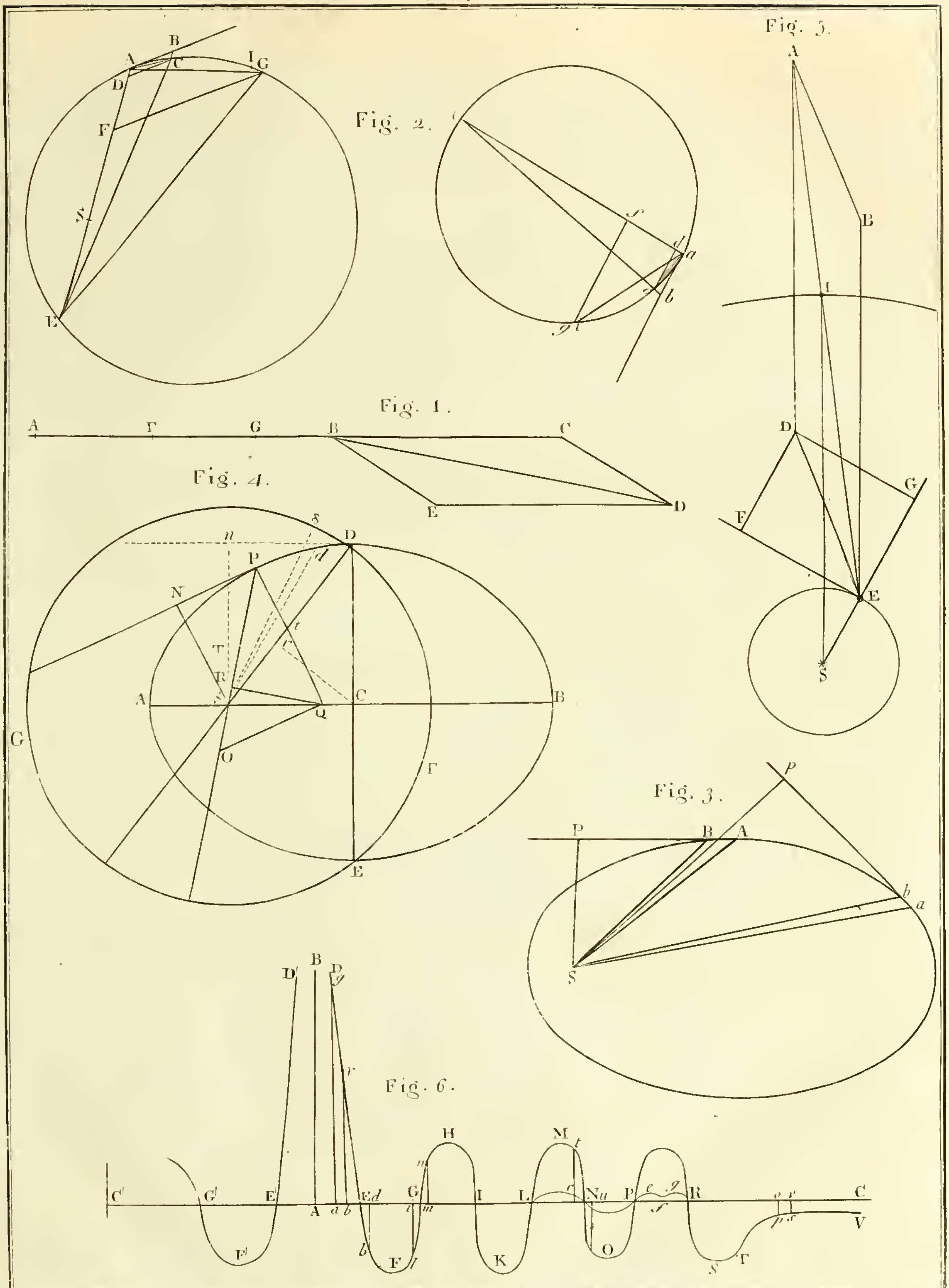


Fig. 1.
A F G B C E D
Fig. 2.
c f d a b g i
A B C I G D F S E
Fig. 3.
p P B A b a S
Fig. 4.
n δ D d P N t r T R S A C B Q O G Γ E
Fig. 5.
A B I D G F E S
Fig. 6.
D' B D g r H M t n C' G' E A a b E d G i m I L c N u P e g R o v C F' b F l K O f S T p s V

Newton ſaw this at once; and, to his great delight, he ſaw that the great deviations from regular motion, which had been diſcovered by Ptolemy and Tycho Brahé called the *Annual Equation*, the *Variation*, and the *Evection*, were ſuch as moſt obviouſly reſulted from the regular influence of the ſun on the moon. The firſt deviation from the regular elliptical motion is occaſioned by the increaſe of the ſun's diſturbing force as the earth approaches the perihelion; and it enlarges the lunar orbit, by diminiſhing the tendency to the earth, and increaſes the periodic time. The ſecond ariſes from the *direction* of the diſturbing force, by which it accelerates the moon's angular motion in the ſecond and fourth quadrants of her orbit, and retards it in the firſt and third. The laſt affects the eccentricity of the orbit, by changing the ratio of the whole or compound tendency of the moon to the earth in her perigee and apogee.

24 May be calculated with preciſion.

This ſucceſs incited him to an accurate examination of the conſequences of this influence. It is the boaſt of this diſcovery of the law of the planetary deflections that all its effects may be calculated with the utmoſt preciſion. The part of the moon's deflection toward the ſun, which is neither equal nor parallel to the ſimultaneous deflection of the earth, may be ſeparated from the part which is equal and parallel to it, and it may be called the ſun's diſturbing force. Its proportion to the moon's deflection towards the earth may be accurately aſcertained, and its inclination to the line of the moon's motion in every point of her orbit may be pointed out. This being done, the accumulated effect of this diſturbing force after any given time, however variable, both in direction and intenſity during this time, may be determined by the 39th and other propoſitions of the firſt book of the Mathematical Principles of Natural Philoſophy. And thus may the moon's motion, when ſo diſturbed, be determined and compared with her motion really obſerved.

All this has been done by Sir Iſaac Newton with the moſt aſtoniſhing addreſs and ſagacity, *ſua matheſi facem preferente*, partly in the Principia, and partly in his Lunæ Theoria. This inveſtigation, whether we conſider the complete originality of the whole proceſs, or the ingenuity of the method, or the ſagacity in ſeeing and clearly diſcriminating the different circumſtances of the queſtion, or the wonderful fertility of reſource, or the new and moſt refined mathematical principles and methods that he employed—muſt ever be conſidered as the moſt brilliant ſpecimen of human invention and reaſoning that ever was exhibited to the world.

In this inveſtigation Newton not only determined the quantity, the period, and the changes of thoſe inequalities, which had been ſo conſiderable and remarkable as to be obſerved by former aſtronomers, and this with an exactneſs far ſurpaſſing what could ever be attained by mere obſervation; but he alſo pointed out ſeveral other periodical inequalities, which were too ſmall, and too much implicated with the reſt, ever to be diſcovered or to be ſeparated from them. We do not ſay that he completed the theory of the lunar motions; but he pointed out the methods of inveſtigation, and he furniſhed all the means of proſecuting it, by giving the world the elements of a new ſpecies of mathematics, without which it would have been in vain to attempt it. Both this new mathematics, and the methods of applying it to ſuch queſtions, have been aſſiduouſly ſtudied and improved by the great mathematicians of this century; and the lunar theory has been carried to ſuch a degree of perfection, that we can compute her place in the heavens for any paſt age without deviating above one minute of a degree from the actual obſervation.

25 The ſecular equation of the moon's mean diſtance

There is one empirical equation of the moon's motion which the compariſon of ancient and modern eclipſes obliges the aſtronomers to employ, without being able to deduce it, like the reſt, *à priori*, from the theory of an univerſal force inverſely proportional to the ſquare of the diſtance. It has therefore been conſidered as a ſtumbling block in the Newtonian philoſophy. This is what is called *the ſecular equation of the moon's mean motion*. The mean motion is deduced from a compariſon of diſtant obſervations. The time between them, being divided by the number of intervening revolutions, gives the average time of one revolution, or the mean lunar period. When the ancient Chaldean obſervations are compared with thoſe of Hipparchus, we obtain a certain period; when thoſe of Hipparchus are compared with ſome in the 9th century, we obtain a period ſomewhat ſhorter; when the laſt are compared with thoſe of Tycho Brahé, we obtain one ſtill ſhorter; and when Brahé's are compared with thoſe of our day, we obtain the ſhorteſt period of all—and thus the moon's mean motion appears to accelerate continually; and the accelerations appear to be in the duplicate ratio of the times. The acceleration for the century which ended in 1700 is about 9 ſeconds of a degree; that is to ſay, the whole motion of the moon during the 17th century muſt be increaſed 9 ſeconds, in order to obtain its motion during the 18th; and as much muſt be taken from it, or added to the computed longitude, to obtain its motion during the 16th; and the double of this muſt be taken from the motion during the 16th, to obtain its motion during the 15th, &c. Or it will be ſufficient to calculate the moon's mean longitude for any time paſt or to come by the ſecular motion which obtains in the preſent century, and then to add to this longitude the product of 9 ſeconds, multiplied by the ſquare of the number of centuries which intervene. Thus having found the mean longitude for the year 1200, add 9 ſeconds, multiplied by 36, for ſix centuries. By this method we ſhall make our calculation agree with the moſt ancient and all intermediate obſervations. If we neglect this correction, we ſhall differ more than a degree from the Chaldean obſervations of the moon's place in the heavens.

The mathematicians having ſucceeded ſo completely in deducing all the obſerved inequalities of the planetary motions, from the ſingle principle, that the deflecting forces diminiſhed in the inverſe duplicate ratio of the diſtances, were fretted by this exception, the reality of which they could not conteſt. Many opinions were formed about its cauſe. Some have attempted to deduce it from the action of the planets on the moon; others have deduced it from the oblate form of the earth, and the tranſlation of the ocean by the tides; others have ſuppoſed it owing to the reſiſtance of the ether in the celeſtial ſpaces; and others have imagined that the action of the deflecting force requires time for its propagation to a diſtance: But their deductions have been proved unſatisfactory, and have by no means the preciſion and evidence that have been attained in the other queſtions of phyſical aſtronomy. At laſt M. de la la Place, of the Royal Academy of Sciences at Paris, has happily ſucceeded, and deduced the ſecular equation of the moon from the Newtonian law of planetary deflection. It is produced in the following manner.

26
Deduced from the Newtonian law of planetary deflection.

Suppoſe the moon revolving round the earth, undiſturbed by any deflection toward the ſun, and that the time of her revolution is exactly aſcertained. Now let the influence of the ſun be added. This diminiſhes her tendency to the earth in oppoſition and conjunction, and increaſes it in the quadratures: but the diminutions exceed the augmentations both in quantity and duration; and the exceſs is equivalent to $\frac{1}{179}$th of her tendency to the earth. Therefore this diminiſhed tendency cannot retain the moon in the ſame orbit; ſhe muſt retire farther from the earth, and deſcribe an orbit which is leſs incurvated by $\frac{1}{179}$th part; and ſhe muſt employ a longer time in a revolution. The period therefore which we obſerve, is not that which would have obtained had the moon been influenced by the earth alone. We ſhould not have known that her natural period was increaſed, had the diſturbing influence of the ſun remained unchanged; but this varies in the inverſe triplicate ratio of the earth's diſtance from the ſun, and is therefore greater in our winter, when the earth is nearer to the ſun. This is the ſource of the annual equation, by which the lunar period in January is made to exceed that in July nearly 24 minutes. The angular velocity of the moon is diminiſhed in general $\frac{1}{179}$, and this numerical coefficient varies in the inverſe ratio of the cube of the earth's diſtance from the ſun. If we expand this inverſe cube of the earth's diſtance into a ſeries arranged according to the ſines and coſines of the earth's mean motion, making the earth's mean diſtance unity, we ſhall find that the ſeries contains a term equal to $\frac{3}{2}$ of the ſquare of the eccentricity of the earth's orbit. Therefore the expreſſion of the diminution of the moon's angular velocity contains a term equal to $\frac{1}{179}$ of this velocity, multiplied by $\frac{3}{2}$ of the ſquare of the earth's eccentricity; or equal to the product of the ſquare of the eccentricity, multiplied by the moon's angular velocity, and divided by 119,33. ($\frac{2}{3}$ of 179). Did this eccentricity remain conſtant, this product would alſo be conſtant, and would ſtill be confounded with the general diminution, making a conſtant part of it: but the eccentricity of the earth's orbit is known to diminiſh, and its diminution is the reſult of the univerſality of the Newtonian law of the planetary deflections. Although this diminution is exceedingly ſmall, its effect on the lunar motion becomes ſenſible by accumulation in the courſe of ages. The eccentricity diminiſhing, the diminution of the moon's angular motion muſt alſo diminiſh, that is, the angular motion muſt increaſe.

During the 18th century, the ſquare of the earth's eccentricity has diminiſhed 0,000015325, the mean diſtance from the ſun being = 1. This has increaſed the angular motion of the moon in that time 0,00000001285. As this augmentation is gradual, we muſt multiply the angular motion during the century by the half of this quantity, in order to obtain its accumulated effect. This will be found to be 9″ very nearly, which exceeds that deduced, from a moſt careful compariſon of the motion of the laſt two centuries, only by a fraction of a ſecond!

As long as the diminution of the ſquare of the eccentricity of the earth's orbit can be ſuppoſed proportional to the time, this effect will be as the ſquares of the times. When this theory is compared with obſervations, the coincidence is wonderful indeed. The effect on the moon's motion is periodical, as the change of the ſolar eccentricity is, and its period includes millions of years. Its effect on the moon's longitude will amount to ſeveral degrees before the ſecular acceleration change to a retardation.

Thoſe who are not familiar with the diſquiſitions of modern analyſis, may conceive this queſtion in the following manner.

Let the length of a lunar period be computed for the earth's diſtance from the ſun for every day of the year. Add them into one ſum, and divide this by their number, the quotient will be the mean lunar period. This will be found to be greater than the arithmetical medium between the greateſt and the leaſt. Then ſuppoſe the eccentricity of the earth's orbit to be greater, and make the ſame computation. The average period will be found ſtill greater, while the medium between the greateſt and leaſt periods will hardly differ from the former. Something very like this may be obſerved without any calculation, in a caſe very ſimilar. The angular velocity of the ſun is inverſely as the ſquare of his diſtance. Look into the ſolar tables, and the greateſt diurnal motion will be found 3673″, and the leaſt 3433″. The mean of theſe is 3553″, but the medium of the whole is 3548″. Now make a ſimilar obſervation in tables of the motion of the planet Mars, whoſe eccentricity is much greater. We ſhall find that the medium between the greateſt and leaſt exceeds the true medium of all in a much greater proportion.

27
Certainty and utility of this law.

Thus has the patient and aſſiduous cultivation of the Newtonian diſcoveries explained every phenomenon, and enabled us to foreſee changes in them which no examination of the paſt appearances, unaſſiſted by this theory, could have pointed out, and which muſt have exceedingly embarraſſed future aſtronomers. This great but ſimple law of deflection repreſents every phenomenon of the ſyſtem in the moſt minute circumſtances. Far from fearing that future experience may overturn this law, we may reſt aſſured that it will only confirm it more and more; and we may confide in its moſt remote conſequences as if they were actually obſerved.

28
Reciprocal deflection of the earth and moon, and of the ſun and planets,

It is diſcovered by obſervation, that the deflection of the moon to the earth, and of the planets to the ſun, are accompanied by an equal and oppoſite deflection of the earth to the moon, and of the ſun to the planets.

The tendency of the earth to the moon is plainly indicated by the riſe of the waters of the ocean under the moon, and on the oppoſite ſide of the earth. Sir Iſaac Newton tried what ſhould be the reſult of a tendency of the water to the moon. His inveſtigation of this queſtion was very ſimilar to that in his lunar theory. We may conceive the moon to be one of many millions of particles of a fluid, occupying a globe as big as the lunar orbit. Each will feel a ſimilar diſturbing force, which will diminiſh its tendency to the earth in the neighbourhood of the place of conjunction and oppoſition, and will increaſe it in the neighbourhood of the quadratures. They cannot therefore remain in equilibrio in their ſpherical form; they muſt ſink in the quadratures, and riſe in the conjunction and oppoſition, till their greater height compenſates for the diminiſhed weight of each particle. In like manner, the waters of the ocean

29
Proved by the ebbing and flowing of the ſea,

ocean muſt ſink on thoſe parts of the earth where the moon is ſeen in the horizon, and muſt riſe in thoſe which have the moon in the zenith or nadir. All theſe effects are not only to be ſeen in general, but they may all be calculated, and the very form pointed out which the ſurface of the ocean muſt aſſume: and thus a tendency of every particle of the ocean to the moon, inverſely proportional to the ſquare of its diſtance from it, gives us a theory of the ebbing and flowing of the ſea. This is delivered in ſufficient detail in the article TIDE of the Encyclopædia, and therefore need not be inſiſted on in this place. The ſame inference muſt be drawn from the preceſſion of the equinoxes produced by the action of the moon on the protuberant matter of our equatoreal regions. See PRECESSION in the Encycl.

30 And by different computations of the ſun's place in the heavens.

But the mutual tendency of the earth and moon is clearly ſeen in a phenomenon that is much more ſimple. If we compute the ſun's place in the heavens, on the ſuppoſition that the earth deſcribes areas proportional to the times, we ſhall find it to agree with obſervation at every new and full moon: But at the firſt quarter the ſun will be obſerved about 9 ſeconds too much advanced to the eaſtward; and at the laſt quarter he will be as much to the weſtward of his calculated place. In all intermediate poſitions, the deviation of the obſerved from the computed place of the ſun will be 9 ſeconds, multiplied by the ſine of the moon's diſtance from conjunction or oppoſition. In ſhort, the appearances will be the ſame as if it were not the earth which deſcribed areas proportional to the times round the ſun, but that a point, lying between the earth and moon, and very near the earth's ſurface, were deſcribing the ellipſe round the ſun, while the earth and moon revolve round this point in the courſe of a lunation, having the point always in the line between them, in the ſame manner as if they were on the extremities of a rod which turns round this point, while the point itſelf revolves round the ſun.

This then is the fact with reſpect to the motions; and the earth in a month deſcribes an orbit round this common centre of the earth and moon. It cannot do this unleſs it be continually deflected from the tangent to this orbit: therefore it is continually deflected toward the moon: and the momentum of this deflection, that is, its quantity of motion, is the ſame with that of the moon's deflection, becauſe their diſtances from the common centre are as their quantities of matter inverſely.

Appearances perfectly ſimilar to theſe oblige us to affirm that the ſun is continually deflected toward the planets. Aſtronomical inſtruments, and the art of obſerving, have been prodigiouſly improved ſince Sir Iſaac Newton's time; and the moſt ſcrupulous attention has been paid to the ſun's motion, becauſe it is to his place in the univerſe that continual reference is made in computing the place of all the planets. He is ſuppoſed at reſt in the common focus of all their orbits; and the *obſerved* diſtance of a planet from the ſun is always conſidered as the *radius vector*. If this be not the caſe, the orbital motions contained in our tables are not the abſolute motions of the planets, nor the deflections from the tangents the real deflections from abſolute rectilineal motion; and therefore the forces are not ſuch as we infer from thoſe miſtaken deflections. Accordingly Sir Iſaac Newton, induced by certain metaphyſical conſiderations, aſſumed it as a law of motion, that every action of a body A on another body B, is accompanied by an equal and contrary action of B on A. We do not ſee the propriety of this aſſertion as a metaphyſical axiom. It is perfectly conceivable that a piece of iron will always approach a magnet when in its neighbourhood; but we do not ſee that this obliges us to aſſert that *therefore* the magnet will alſo approach the iron. Thoſe who explain the phenomena of magnetiſm by the impulſe of a fluid, muſt certainly grant that there is no metaphyſical neceſſity for another ſtream of fluid impelling the magnet toward the iron. And accordingly this, and the ſimilar reciprocity in the phenomena of electricity, have *always* been conſidered as deductions of experimental philoſophy; yet we obſerve the ſame reciprocity in all the actions of ſublunary bodies; and Newton's third law of motion is received as true, and admitted as a principle of reaſoning. But we apprehend that it was haſty in this great philoſopher, and unlike his ſcrupulous caution, to extend it to the planetary motions. He did, however, extend it, and aſſerted, that as each planet was deflected toward the ſun, the ſun was equally (in reſpect of momentum) deflected toward each planet, and that his real motion was the compoſition of all thoſe ſimultaneous deflections. He aſſerted, that there was a certain point round which the ſun and his attending planets revolved; and that the orbit of a planet, which our meaſurements determined by continual reference to the ſun as to a fixed body, was not the true orbit, but conſiſted of the contemporaneous orbits of that planet and of the ſun round this fixed point. Any little ſector of the apparent orbit was greater than the correſponding ſector of the planet's true orbit in abſolute ſpace, and the apparent motion was compounded of the true motion of the planet, and the oppoſite to the true motion of the ſun. After a moſt ingenious and refined inveſtigation, he ſhowed that, notwithſtanding this great difference of the Keplerean laws from the truth, the inference, with reſpect to the law of planetary deflection, is juſt, and that not only the apparent deflections are in the inverſe duplicate ratio of the diſtances from the ſun, but that the real deflections vary in the ſame ratio of the diſtances from the fixed point, and alſo from the ſun; for he ſhewed that the diſtances from the ſun were in a conſtant ratio to the diſtances from this point. He ſhewed alſo that the ſame forces which produced the contemporaneous revolution of a planet and the ſun round the centre of the ſyſtem, would produce a revolution of the planet in a ſimilar orbit round the ſun (ſuppoſed to be held faſt in his place) at the ſame diſtance which really obtains between them, with this ſole difference, that the periodic time will be longer, in the ſubduplicate ratio of the quantity of matter in the ſun to the quantity of matter of the ſun and planet together. Areas will be deſcribed proportional to the times, and the orbit will be elliptical; but the ratio of the ſquares of the periodic times will not be the ſame with the ratio of the cubes of the diſtances, unleſs all the planets are equal.

31 Obſervations on the third law of motion.

32 Newton's extenſion of that law

Thus was the attention of aſtronomers directed to a number of *apparent* irregularities in the motion of the earth, which muſt reſult from this derangement of the ſun, which they had imagined to remain ſtedfaſt in his place.

place. They were told what to expect, and on what positions of the planets the kind and quantity of every irregularity depended. This was a most inviting field of observation to a curious speculatist; but it required the nicest and most expensive instruments, and an uninterrupted series of long continued observations, sufficient to occupy the whole of a man's time. Fortunately the accurate determination of the solar and lunar motions were of the utmost importance, nay, indispensably necessary for solving the famous problem of the longitude of a ship at sea: and thus the demands of commercial Europe came in aid of philosophical curiosity, and occasioned the erection of observatories, first at Greenwich, and soon after at Paris and other places, with establishments for astronomers, who should carefully watch the motions of the sun and moon, not neglecting the other planets.

33
Confirmed by observation.

The fortunate result of all this solicitude has been the complete establishment of the Newtonian conjecture (for so we must still think it), and the verification of Newton's assertion, that action was accompanied, through the whole solar system, by an equal and contrary reaction. All the inequalities of the solar motion predicted by Newton have been observed, although they are frequently so complicated that they could never have been detected, had not the Newtonian theory directed us when to find any of them pretty clear of complication, and how to ascertain the accumulated result of them all in any state of combination.

But in the course of this attention to the motions of the sun and moon, the planets came in for a share, and considerable deviations were found, from the supposition that all their deflections were directed to the sun, and were in the inverse duplicate ratio of their distances. The nice observation shewed, that the period of Jupiter was somewhat shorter than Kepler's law required.

A slight reflection shewed that this was no inconsistency; because the common centre of the conjoined orbits of the Sun and Jupiter was sensibly distant from the centre of the sun, namely, about the 1100th part of the *radius vector*; and therefore the real deflection was about a 2200th part less than was supposed. It was now plain that the distances to which the Keplerean law must be applied, are the distances, not from the sun, but from the fixed point round which the sun and planets revolve. This difference was too small to be observed in Kepler's time; but the seeming error is only a confirmation of the Newtonian philosophy.

But there are other irregularities which cannot be explained in this manner. The planetary orbits change their position; their aphelia advance, their nodes recede, their inclination to each other vary. The mean motions of Saturn and Jupiter are subject to considerable changes, which are periodical.

34
Deflection of the planets towards each other.

Sir Isaac Newton had no sooner discovered the universality and reciprocity of the deflections of the planets and the sun, than he also suspected that they were continually deflected towards each other. He immediately obtained a general notion of what should be the more general results of such a mutual action. They may be conceived in this way.

Plate VI.

Let S (fig. 5.) represent the sun, E the earth, and I Jupiter, describing concentric orbits round the centre of the system. Make $IS : EA = EI^2 : SI^2$. Then, if IS be taken to represent the deflection of the sun toward Jupiter, EA will represent the deflection of the Earth to Jupiter. Draw EB equal and parallel to SI, and complete the parallelogram EBAD. ED will represent the disturbing force of Jupiter. It may be resolved into EF, perpendicular to ES, and EG in the direction of SE. By the first of these the earth's angular motion round the sun is affected, and by the second its deflection toward him is diminished or increased.

35
General result of such mutual action.

In consequence of this first part of the disturbing force, the angular motion is increased, while the earth approaches from quadrature to conjunction with Jupiter (which is the case represented in the figure), and is diminished from the time that Jupiter is in opposition till the earth is again in quadrature, westward of his opposition. The earth is then accelerated till Jupiter is in conjunction with the sun; after which it is retarded till the earth is again in quadrature.

The earth's tendency to the sun is diminished while Jupiter is in the neighbourhood of his opposition or conjunction, and increased while he is in the neighbourhood of his stationary positions. Jupiter being about 1000 times less than the sun, and 5 times more remote, IS must be considered as representing $\frac{1}{25000}$th of the earth's deflection to the sun, and the forces ED and EG are to be measured on this scale.

In consequence of this change in the earth's tendency to the sun, the aphelion sometimes advances by the diminution, and sometimes retreats by the augmentation. It advances when Jupiter chances to be in opposition when the earth is in its aphelion; because this diminution of its deflection towards the sun makes it later before its path is brought from forming an obtuse angle with the *radius vector*, to form a right angle with it. Because the earth's tendency to the sun is, on the whole, more diminished by the disturbing force of Jupiter than it is increased, the aphelion of the earth's orbit advances on the whole.

In like manner the aphelia of the inferior planets advance by the disturbing forces of the superior: but the aphelion of a superior planet retreats; for these reasons, and because Jupiter and Saturn are larger and more powerful than the inferior planets, the aphelia of them all advance while that of Saturn retreats.

In consequence of the same disturbing forces, the node of the disturbed planet retreats on the orbit of the disturbing planet; therefore they all retreat on the ecliptic, except that of Jupiter, which advances by retreating on the orbit of Saturn, from which it suffers the greatest disturbance. This is owing to the particular position of the nodes and the inclinations of the orbits.

The inclination of a planetary orbit increases while the planet approaches the node, and diminishes while the planet retires from it. 36

A peculiarity explained in the motions of Jupiter and Saturn.

M. de la Place has completed this deduction of the planetary inequalities, by explaining a peculiarity in the motions of Jupiter and Saturn, which has long employed the attention of astronomers. The accelerations and retardations of the planetary motions depend, as has been shown, on their configurations, or the relative quarters of the heavens in which they are. Those of Mercury, Venus, the Earth, and Mars, arising from their mutual deflections; and their more remarkable deflections to the great planets Jupiter and Saturn, nearly compensate each other, and no traces of them remain after a few revolutions: but the positions of the aphelia

lia of Saturn and Jupiter are ſuch, that the retardations of Saturn ſenſibly exceed the accelerations, and the anomaliſtic period of Saturn increaſes almoſt a day every century; on the contrary, that of Jupiter diminiſhes. M. de la Place ſhows, that this proceeds from the poſition of the aphelia, and the almoſt perfect commenſurability of their revolutions; five revolutions of Jupiter making 21,675 days, while two revolutions of Saturn make 21,538, differing only 137 days.

Suppoſing this relation to be exact, the theory ſhews, that the mutual action of theſe planets muſt produce mutual accelerations and retardations of their mean motions, and aſcertains the periods and limits of the ſecular equations thence ariſing. Theſe periods include ſeveral centuries. Again, becauſe this relation is not preciſe, but the odd days nearly divide the periods already found, there muſt ariſe an equation of this ſecular equation, of which the period is immenſely longer, and the maximum very minute. He ſhews that this retardation of Saturn is now at its maximum, and is diminiſhing again, and will, in the courſe of years, change to an acceleration.

This inveſtigation of the ſmall inequalities is the moſt intricate problem in mechanical philoſophy, and has been completed only by very ſlow degrees, by the arduous efforts of the greateſt mathematicians, of whom M. de la Grange is the moſt eminent. Some of his general reſults are very remarkable.

He demonſtrates, that ſince the planets move in one direction, in orbits nearly circular, no mutual diſturbances make any permanent change in the mean diſtances and mean periods of the planets, and that the periodic changes are confined within very narrow limits.

37 Oſcillation of the planetary ſyſtem.

The orbits can never deviate ſenſibly from circles. None of them ever has been or will be a comet moving in a very eccentric orbit. The ecliptic will never coincide with the equator, nor change its inclination above two degrees. In ſhort, the ſolar planetary ſyſtem oſcillates, as it were, round a medium ſtate, from which it never ſwerves very far.

This theory of the planetary inequalities, founded on the univerſal law of mutual deflection, has given to our tables a preciſion, and a coincidence with obſervation, that ſurpaſſes all expectation, and inſures the legitimacy of the theory. The inequalities are moſt ſenſible in the motions of Jupiter and Saturn; and theſe preſent themſelves in ſuch a complicated ſtate, and their periods are ſo long, that ages were neceſſary for diſcovering them by mere obſervation. In this reſpect, therefore, the theory has outſtripped the obſervations on which it is founded.

38 Authenticity of the Indian aſtronomy.

It is very remarkable, that the periods which the Indians aſſign to theſe two planets, and which appeared ſo inaccurate that they hurt the credit of the ſcience of thoſe ancient aſtronomers, are now found preciſely ſuch as muſt have obtained about three thouſand years before the Chriſtian era; and thus they give an authenticity to that ancient aſtronomy. The periods which any nation of aſtronomers aſſign to thoſe two planets would afford no contemptible mean for determining the age in which it was obſerved.

The following circumſtance is remarkable: Suppoſe Jupiter and Saturn in conjunction in the firſt degree of Aries; twenty years after, it will happen in Sagittarius; and after another twenty years, it will happen in Leo. It will continue in theſe three ſigns for 200 years. In the next 200 it will happen in Taurus, Capricornus, and Virgo; in the next 200 years, it will happen in Gemini, Aquarius, and Libra; and in the next 200 years, it will happen in Cancer, Piſces, and Scorpio: then all begins again in Aries. 39

Origin of the aſtrological diviſion of the heavens.

It is highly probable that theſe remarkable periods of the oppoſitions of Jupiter and Saturn, progreſſive for 40 years, and oſcillating during 160 more, occaſioned the aſtrological diviſion of the heavens into the four *trigons*, of fire, air, earth, and water. Theſe relations of the ſigns, which compoſe a trigon, point out the repetitions of the chief irregularities of the ſolar ſyſtem.

M. de la Place obſerves (in 1796,) that the laſt diſcovered planet gives evident marks of the action of the reſt; and that when theſe are computed and taken into the account of its bygone motions, they put it beyond doubt that it was ſeen by Flamſtead in 1690, by Mayer in 1756, and by Monnier in 1769. 40

Action of the comets.

We have hitherto overlooked the comets in our account of the mutual diſturbances of the ſolar ſyſtem. Their number is very great, and they go to all quarters of the univerſe: but we may conclude, from the wonderful regularity of the planetary motions, when all their own mutual actions are taken into account, that the quantity of matter in the comets is very inconſiderable. They remain but a ſhort time in the neighbourhood of the planets, and they paſs them with great rapidity. Some of them have come very near to Jupiter, but left no trace of their action in the motions of his ſatellites. They doubtleſs contribute, in general, to make the apſides of the planetary orbits advance. 41

They are affected by the planets.

On the other hand, the comets may be conſiderably affected by the planets. The very important phenomenon of the return of the comet of 1682, which was to decide whether they were revolving planets deſcribing ellipſes, or bodies which came but once into the planetary regions, and then retired for ever, cauſed the aſtronomers to conſider this matter with great care. Halley had ſhown, in a rough way, that this comet muſt have been conſiderably affected by Jupiter. Their motion near the aphelion muſt be ſo very ſlow, that a very ſmall change of velocity or direction, while in the planetary regions, muſt conſiderably affect their periods. Halley thought that the action of Jupiter might change it half a year. Mr Clairaut, by conſidering the diſturbing forces of Jupiter and Saturn through the whole revolution, ſhowed that the period then running would exceed the former nearly two years (618 days), and aſſigned the middle of April 1759 for the time of its perihelion. It really paſſed its perihelion on the 12th of March. This was a wonderful preciſion, when we reflect that the comet had been ſeen but a very few days in its former apparitions.

A comet obſerved by Mr Proſperin and others in 1771 has greatly puzzled the aſtronomers. Its motions appear to have been extremely irregular, and it certainly came ſo near Jupiter, that his momentary influence was at leaſt equal to the ſun's. It has not been recogniſed ſince that time, although there is great probability that it is continually among the planets. 42

Conſequence of a comet and planet meeting.

It is by no means impoſſible, nor highly improbable, that in the courſe of ages, a comet may actually meet one of the planets. The effect of ſuch a concourſe muſt be dreadful; a change of the axis of diurnal rotation muſt reſult from it, and the ſea muſt deſert its former bed

bed and overflow the new equatorial regions. The shock and the deluge must destroy all the works of man, and most of the race. The remainder, reduced to misery, must long struggle for existence, and all remembrance of former arts and events must be lost, and every thing must be invented anew. There are not wanting traces of such devastations in this globe: strata and things are now found on mountain tops which were certainly at the bottom of the ocean in former times; remains of tropical animals and plants are now dug up in the circumpolar regions. *Tempora mutantur, et nos mutamur in illis.*

It is plain, that when we know the direction and the intensity of the disturbing force, we can tell what will be the accumulated effect of its action for any time. The direction is easily determined by means of the distance: but how shall we determine the intensity? Since we see that the whole waters of the ocean are deflected toward the moon, and have such probable evidence that planetary deflection is mutual; it follows, that the moon is deflected towards *every* drop of water, and that *all* the matter in one body is deflected towards *all* the matter in another body; and therefore that the deflection towards the sun or a planet is greater or less in proportion to its quantity of matter. Newton indeed thought it unreasonable to suppose that a planet was deflected to the centre of the sun, which had no distinguishing physical property; and thought it more probable that the deflection of a planet to the sun was the accumulated deflection of every particle in the planet to every particle in the sun. But he was too scrupulous to take this for granted. He therefore endeavoured to discover what would be the sensible deflection of one sphere to another, when each consisted of matter, every particle of which was deflected to every particle of the other with an intensity inversely proportional to the square of the distance from it. By help of a most beautiful and simple process, he discovered, that the tendency of a particle of matter to a spherical surface, shell, or solid, of uniform density at equal distances from the centre, was the same as if all the particles in the surface, shell, or solid, were united in its centre: hence it legitimately followed, that the mutual tendency of spherical surfaces, shells, or solids, was proportional to the quantities of matter in the attracting body, and inversely as the square of the distance of their centres; and thus the law of attraction, competent to every particle of planetary matter, was the same with that which *was observed* among spherical bodies consisting of such matter. And it is remarkable, that the inverse duplicate ratio of the distances is the only law that will hold, both with respect to single particles and to globes composed of such particles. He also demonstrated, that a particle placed within a sphere was not affected by all the shell, which was more distant than itself from the centre, being equally attracted on every side, and that it tended toward the centre of a homogeneous sphere, on the surface of which it was placed, with a force proportional to its distance from the centre.

43 Tendency of spherical bodies towards each other, directly as the quantity of matter, and inversely as the square of the distance of their centres.

Newton saw a case in which it was possible to discover whether the tendency of the matter of which the planets consisted was directed to a mathematical centre void of any physical properties, or whether it was the result of its united tendency to all the matter of the planet. He demonstrated, that if the earth consisted of matter which tended to the centre, it behoved it to assume the form of an elliptical spheroid, in consequence of the centrifugal force arising from its diurnal motion, and that the polar axis must be to its equatorial diameter as 577 to 578; but if every particle tends to every other particle in the inverse duplicate ratio of the distance from it, the form must still be elliptical, but more protuberant, and the polar axis must be to the equatorial diameter as 230 to 231. Then only will a column of water from the pole to the centre balance a column from the equator to the centre. He also shewed what should be the vibrations of pendulums in different latitudes, on both suppositions. Mathematicians were eager therefore to make those experiments on pendulums, and to determine the figure of the earth by the measurement of degrees of the meridian in different latitudes. The result of their endeavours has been decidedly in favour of the mutual tendency of all matter. This has been farther confirmed by the observations of the mathematicians who measured the degrees of the meridian in Peru, and by Dr Maskelyne in Britain, who found that a pendulum suspended in the neighbourhood of a great and solid mountain, sensibly deviated from the true vertical, and was deflected toward the mountain.

44 Proportional quantities of matter in the sun and planets determined.

From a collective view of all these circumstances, Sir Isaac Newton concluded, with great confidence, that the deflection toward any planet was the united deflection toward every particle of matter contained in it.

This enabled him to determine the intensity of the planetary disturbing forces, by previously ascertaining the proportions of their quantities of matter. This proportion, the discovery of which seems above our reach, is easily ascertained in all those bodies which have others revolving round them: for the deflection of the revolving body, being occasioned by all the matter in the central body, will be proportional *(cæteris paribus)* to the quantity of matter in the central body, and therefore will give us a measure of that quantity. Would we compare the quantity of matter in Jupiter with the quantity of matter in the sun, we have only to suppose that a planet revolves round the sun at the distance of Jupiter's fourth satellite. Kepler's third law will tell us the time of its revolution. The distances, in this case, being the same, the centripetal forces, and consequently the quantities of matter in the central bodies, will be inversely as the squares of the periodic times of the revolutions around them. In this way have the quantities of matter been determined for the Sun, the Earth, Jupiter, Saturn, and the last discovered planet. If the quantity in the Earth be considered as the unit, we have,

The Earth	1
The newly discovered planet	17,75
Saturn	86,16
Jupiter	317,1
The Sun	338343.

Thus we see that the sun is incomparably bigger than any planet, having more than a thousand times as much matter as Jupiter, the most massy of them all. There is a considerable uncertainty, however, in the proportion to the sun, because we do not know his distance nearer than within $\frac{1}{100}$th part. The proportions of the rest to each other are more accurate. The quantities of matter in Mercury and Mars can only be guessed at: the quantity in Mercury may be called 0,1, and Mars may

may be called 0,12. Venus is fuppofed nearly equal to the Earth. This is concluded from the effect which fhe produces on the preceffion of the equinoxes and the equation of the fun's motion. The moon is fuppofed to be about $\frac{1}{60}$th of the earth, from the effect fhe produces on the tides and the preceffion of the equinoxes, compared with thofe produced by the fun.

45
Sun's place and the tranfit of a planet determined exactly.

When thefe quantities of matter are introduced into the computation of the planetary inequalities, and the intenfity of the difturbing forces affumed accordingly, the refults of the computations tally fo exactly with obfervation, that we can now determine the fun's place for any moment within two or three feconds of a degree, and are certain of the tranfit of a planet within one beat of the clock!

> *Jam dubios nulla caligine prægravat error;*
> *Queis fuperum penetrare domos atque ardua cœli*
> *Scandere fublimis genii conceffit acumen.*
>
> HALLEY.

Sir Ifaac Newton having already made the great difcovery of an univerfal and mutual deflection of all the matter in the folar fyftem, was one day fpeculating on this fubject, and comparing it with other deflections which he obferved among bodies, fuch as magnets, &c. He confidered terreftrial gravity as a force of this kind.

46
Progrefs of Newton's difcovery of

By the weight of terreftrial bodies they kept united with the earth. By its weight was the water of the ocean formed into a fphere. This force extended, without any remarkable diminution, to the tops of the higheft mountains. Might it not reach much farther? May it not operate even at the diftance of the moon? In the fame manner that the planetary force deflects the moon from the tangent to her orbit, and caufes her to defcribe an ellipfe, the weight of a cannon ball deflects it from the line of its direction, and makes it defcribe a parabola. What if the deflecting force which incurvates her path towards the earth be the fimple weight of the moon? If the weight of a body be the fame with the general planetary force, it will diminifh as the fquare of its diftance from the earth increafes. Therefore, faid he to himfelf, fince the diftance of the moon from the centre of the earth is about 50 times greater than the diftance of the ftone which I throw from my hand, and which is deflected 16 feet in one fecond, the weight of this ftone, if taken up to the height of the moon, fhould be reduced to the 2500th part, and fhould there deflect $\frac{1}{2500}$th of 16 feet in a fecond; and the moon fhould deflect as much from the tangent in a fecond. Having the dimenfions, as he thought, of the moon's orbit, he immediately computed the moon's deflection in a fecond; but he found it confiderably different from what he wifhed it to be. He therefore concluded that the planetary force was not the weight of the planet. For fome years he thought no more of it; but one day, in the Royal Society, he heard an account read of meafurements of a degree of the meridian, which fhowed him that the radius of the earth and the diftance of the moon were very different from what he had believed them to be. When he went home he repeated his computation, and found, that the deflection of a ftone was to the fimultaneous deflection of the moon as the fquare of the moon's diftance from the centre of the earth to the fquare of the ftone's diftance. Therefore the moon is deflected by its weight; and the fall of a ftone is juft a particular inftance of the exertion of the univerfal planetary force. This computation was but roughly made at firft; but it was this coincidence that excited the philofopher to a more attentive review of the whole fubject. When every circumftance which can affect the refult is taken into account, the coincidence is found to be moft accurate. The fall of the ftone is not the full effect of its weight; for it is diminifhed by the rotation of the earth round its axis: It is alfo diminifhed by the weight of the air which it difplaces: It is alfo diminifhed by its tendency to the moon. On the other hand, the moon does not revolve round the earth, but round a common centre of the earth and moon, and its period is about $\frac{1}{120}$th fhorter than if it revolved round the earth; and the moon's deflection is affected by the fun's difturbing force. But all thefe corrections can be accurately made, and the ratio of the full weight of the ftone to the full deflection of the moon afcertained. This has been done.

Terreftrial gravity therefore, or that power by which bodies fall or prefs on their fupports, is only a particular inftance of that general tendency by which the planets are retained in their orbits. Bodies may be faid to *gravitate* when they give indications of their being *gravis* or heavy, that is, when they fall or prefs on their fupports; therefore the planets may be faid to gravitate when they give fimilar indications of the fame tendency by their curvelineal motions. The general FACT, that the bodies of the folar fyftem are mutually deflected towards each other, may be expreffed by the verbal noun GRAVITATION. Gravitation does not exprefs a quality, but an event, a deflection, or a preffure.

The weight of a terreftrial body, or its preffure on its fupport, is the effect of the accumulated gravitation of all its particles; for bodies of every kind of matter fall equally faft. This has been afcertained with the utmoft accuracy by Sir Ifaac Newton, by comparing the vibrations of pendulums made of every kind of matter. 47
Therefore their united gravitation is proportional to their quantity of matter; and we have concluded, that every atom of terreftrial matter is heavy, and equally heavy. We extend this conclufion to the fun and planets, and fay, that the obferved gravitation of a planet is the united gravitation of every particle. Therefore Sir Ifaac Newton inferred, from a collective view of all the phenomena, that *all matter gravitates to* all matter with a force in the inverfe duplicate ratio of the diftance.

The univerfal law of gravitation,

But we do not think that this inference is abfolutely certain. We acknowledge that the experiments on pendulums, confifting of a vaft variety of terreftrial matter, all of which performed their ofcillations in equal times, demonftrate that the acceleration of gravity on thofe pendulums was proportional to their quantities of matter, and that equal gravitation may be affirmed of all terreftrial matter.

The elliptical motion of a planet is full proof that the accelerating power of its gravity varies in the inverfe duplicate ratio of the diftance; and the proportionality of the fquares of the periods to the cubes of the diftances, fhows that the whole gravitations of the planets vary by the fame law. But this third obfervation of Kepler might have been the fame, although the gravitation of a particle of matter in Jupiter had been equal to that of a particle of terreftrial matter, provided that all the matter in Jupiter did not gravitate. If

$\frac{1}{2}$th

$\frac{1}{25}$th of Jupiter had been ſuch gravitating matter, his deflection from the tangent of his orbit would have been the ſame as at preſent, and the time of his revolution would have been what we obſerve. In order that the third law of Kepler may hold true of the planetary motions, no more is required than that the accumulated gravitation of the planet be proportional to its quantity of matter, and thus the matter which does not gravitate will be compenſated by the ſuperior gravitation of the reſt.

But becauſe we have no authority for ſaying that there is matter which gravitates differently from the reſt, or which does not gravitate, we are entitled to ſuppoſe that gravity operates alike on all matter.

48 Which is the ultimatum of his philoſophy.

And this is the ultimatum of the Newtonian philoſophy, that the ſolar ſyſtem conſiſts of bodies compoſed of matter, every particle of which is, in fact, continually deflected by its weight towards every other particle in the ſyſtem; and that this deflection, or actual deviation, or actual preſſure, tending to deviation from uniform rectilineal motion, is in the inverſe duplicate ratio of the diſtance.

49 Objections to the law of gravitation ill-founded.

This doctrine has been called *the ſyſtem of univerſal gravitation*; and it has been blamed as introducing an unphiloſophical principle into ſcience. Gravitation is ſaid to be an occult quality; and therefore as unfit for the explanation of phenomena as any of the occult qualities of Ariſtotle. But this reproach is unfounded; gravitation does not expreſs any quality whatever, but a matter of fact, an event, an actual deflection, or an actual preſſure, producing an actual deflection of the body preſſed. Theſe are not occult, but matters of continual obſervation. True, indeed, Newton does not deny, although he does not poſitively ſay, that this deflection, preſſure, or gravitation, is an effect having a cauſe. *Gravity* is ſaid to be this cauſe. Gravity is the *being gravis or heavy*, and gravitation is the *giving indications of being heavy*. Heavineſs therefore is the word which expreſſes *gravitas*, and our notion of the cauſe of the planetary deflections is the ſame with our notion of heavineſs. This may be indiſtinct and unſatisfactory to a mind faſtidiouſly curious; but nothing can be more familiar. The planet is deflected, *becauſe it is heavy*. We are ſuppoſed to explain the fall of a ſtone through water very ſatisfactorily, and without having recourſe to any occult quality, when we ſay that it is heavier than the water; and we explain the riſe of a piece of cork, when we ſay that it is not ſo heavy as the water. The explanations of the mutual actions of the planets are equally ſatisfactory, founded on the ſame principles, and equally free from all ſophiſtry or employment of occult cauſes. The weight of a body is not its heavineſs, but the effect of its heavineſs. It is a gravitation, an actual preſſure, indicated by its balancing the ſuppoſed heavineſs of another body, or by its balancing the known elaſticity of a ſpring, or by balancing any other natural power. It is ſimilar to the preſſure which a magnet exerts on a piece of iron. This may perhaps be produced by the impulſe of a ſtream of fluid; ſo may the weight of a heavy body. But we do not concern ourſelves with this queſtion.

50 Our knowledge of that law ſatisfactory.

We gain a moſt extenſive and important knowledge by our knowledge of this univerſal law; for we can now explain every phenomenon, by pointing out how it is contained in this law; and we can predict the whole events of the ſolar ſyſtem with unerring exactneſs. This ſhould ſatisfy the moſt inquiſitive mind.

But, *nitimur in vetitum, ſemper cupimuſque negata.* There ſeems to be a fatal and ruinous diſpoſition in the human mind, a ſort of *priapiſm* of the underſtanding, that is irritated by every interdict of natural imperfection. We would take a microſcope to look at light; we would *know* what *knowing* is, and we would *weigh heavineſs*.

All who are acquainted with the writings of Ariſtotle have ſome notion of his whimſical opinions on this ſubject. He imagines that the planets are conducted in their orbits by a ſort of intelligences, ὥσπερ ψυχαί, which animate the orbs that wheel them round. 51

51 Vain attempts to account for it.

Although this crude conception met with no favour in later times, another, not more reaſonable, was maintained by Leibnitz, who called every particle of matter a *monad*, and gave it a perception of its ſituation in the univerſe, of its diſtance and direction from every other, and a power and will to move itſelf in conformity to this ſituation, by certain conſtant laws. This ὥσπερ ψυχή in the Monad is nothing but an aukward ſubſtitute for the principle of gravitation, which the learned inſiſted that Newton placed in every particle of matter as an innate power, and which they reprobated as unphiloſophical. But in what reſpect this perception and active propenſity is better, we do not perceive. It is more complex, and involves every notion that is reprehenſible in the other; and it offers no better explanation of the phenomena.

But Newton is equally anxious with other philoſophers not to aſcribe gravity to matter as an innate inherent property. In a letter to Dr Bently, he earneſtly requeſts him not to charge him with ſuch an abſurd opinion. It is an avowed principle, that nothing can *act* on any thing that is at a diſtance; and this is conſidered as an intuitive axiom. But it is ſurely very obſcure; for we cannot obtain, or at leaſt convey, clear notions of the terms in which it is expreſſed. The word *act* is entirely figurative, borrowed from animal exertions; it is therefore unlike the expreſſion of any thing intitled to the appellation of *intuitive*. If we try to expreſs it without figure, we find our confidence in its certainty greatly diminiſhed. Should we ſay that the condition of a body A cannot depend on another body B that is at diſtance from it, we believe that no perſon will ſay that he makes this aſſertion from perceiving the abſurdity of the contrary propoſition. In the demonſtration, as it is called, of the perſeverance of a body in a ſtate of reſt, the only argument that is offered is, that no cauſe can be aſſigned why it ſhould move in one direction rather than in another: but ſhould any one ſay that another body is near it, to the right hand, and that this is a ſufficient reaſon for its moving that way, we know no method by which this aſſertion can be ſhown to be falſe.

Such, however, has been the uniform opinion of philoſophers. *Nihil movetur* (ſays Leibnitz) *niſi a contiguo et moto.* The celebrated mathematician Euler having diſcovered, as he thought, the production of a preſſure, like gravity, from motion, ſays, "as motion may ariſe from preſſing powers, ſo we have ſeen that preſſing powers may ariſe from motion. We ſee that both exiſt in the univerſe. It is the buſineſs of a philoſopher to diſcover, by reaſon and obſervation, which is the origin of of the other. It is incompatible with reaſon, that bodies ſhould be poſſeſſed of inherent tendencies; much more that powers ſhould exiſt independently. Farther, that philoſopher muſt be reckoned to have aſſigned the true cauſes of phenomena, who demonſtrates that they ariſe from motion; for motion, once exiſting, muſt be preſerved for ever. In the preſent inſtance (a certain whimſical fact of a ball running round the inſide of a hoop) we ſee how a preſſing power may be derived from motion; but we cannot ſee how powers can exert themſelves, or be preſerved, without motion. Wherefore we may conclude that gravity, and all other powers, are derived from motion; and it is our buſineſs to inveſtigate from what motions of what bodies each obſerved power derives its origin."

Accordingly many attempts have been made to trace the planetary deflections to their origin in the motion of ſome impelling matter; but theſe attempts could not be ſucceſsful, becauſe they are all built on hypotheſes. It has been aſſumed, that there is a matter diffuſed through the celeſtial ſpaces; that this matter is in motion, and by its impulſe moves the planets: but the only reaſon that can be given for the exiſtence of this matter is the difficulty we find in explaining the planetary deflections without it. Even if the legitimate conſequences of this hypotheſis were conſiſtent with the phenomena, we have not advanced in our knowledge, nor obtained any explanation. We have only learned, that the appearances are ſuch as would have obtained had ſuch a matter exiſted and acted in this manner. The obſerved laws of the phenomena are as extenſive as thoſe of the hypotheſis; therefore it teaches us nothing but what we knew without it.

52 Inconſiſtency of ſome of theſe accounts with the phenomena.

But this is not all that can be ſaid againſt thoſe attempts; *their legitimate conſequences are inconſiſtent with the phenomena.* By legitimate conſequences we mean the laws of motion. Theſe muſt be admitted, and are admitted, by the philoſopher who attempts to explain the planetary motions by impulſe. It would be ridiculous to ſuppoſe a matter to fill the heavens, having laws of impulſe different from thoſe that are obſerved by common matter, and which laws muſt be *contrived* ſo as to anſwer the purpoſe. It would be more ſimple at once to aſſign thoſe *pro re nata* laws to the planets themſelves.

Yet ſuch was the explanation which the celebrated Deſcartes offered by his hypotheſis of vortices, in which

53 Vortices of Deſcartes

the planets were immerſed and whirled round the ſun. It is aſtoniſhing that ſo crude a conception ever obtained any partiſans; yet it long maintained its authority, and ſtill has zealous defenders. Till Sir Iſaac Newton ſaw the indiſpenſible neceſſity of mathematical inveſtigation in every queſtion of matter in motion, no perſon had taken the trouble of giving any thing like a diſtinct deſcription of thoſe vortices, the circumſtances of their motion, and the manner of their action; all determined with that preciſion that is required in the explanation: for this muſt always be kept in mind, that we want an explanation of the preciſe motions *which have been obſerved*, and which will enable us to predict thoſe which are yet to happen. Men were contented with ſome vague notion of a *ſort* of ſimilarity between the effects of ſuch vortices and the planetary motions in a few general circumſtances; and were neither at the trouble to conſider how theſe motions were produced, nor how far they tallied with the phenomena. Their account of things was only fit for careleſs chat, but unworthy of the attention of a naturaliſt. But ſince this explanation came from a perſon deſervedly very eminent, it was reſpected by Newton, and he honoured it with a ſerious examination. It is to this examination alone that we are indebted for all the knowledge that we have of the conſtitution of a fluid vortex, of the motions of which it is ſuſceptible, of the manner in which it can be produced, the laws of its circulation, and the effects which it can produce. We have this account in Sir Iſaac Newton's Principles of Natural Philoſophy; and it contains many very curious and intereſting particulars, which have been found of great ſervice in other branches of mechanical philoſophy. But the reſult of the examination was fatal to the hypotheſis; ſhewing that the motions which were poſſible in the vortices, and the effects which they muſt produce, are quite incompatible with the appearances in the heavens. We do not know one perſon who has acquired any reputation as a mechanician that now attempts to defend it; nor do we know of any other perſon beſides Newton who has attempted to explain mathematically how the circulation of a fluid can produce the revolution of a planet, if we except Mr Leibnitz, the celebrated rival of the Britiſh Philoſopher.

54 Examined by Newton.

55 Hypotheſis of Leibnitz.

This gentleman publiſhed in the Leipſic Review in 1689, three years after the publication of the *Principia*, an attempt to explain the elliptical motion of the planets, and the deſcription of areas proportional to the times by the impulſe of a vortex. It muſt not be paſſed over in this place, becauſe it acquired great authority in Germany, and many of that country ſtill affirm that Leibnitz is the diſcoverer of the law of planetary gravitation, and of the mechanical conſtitution of the ſolar ſyſtem. We cannot help thinking this explanation the moſt faulty of any, and a moſt diſingenuous plagiariſm from the writings of Newton.

Mr Leibnitz ſuppoſes a fluid, circulating round the ſun in ſuch a manner that the velocity of circulation in every part is inverſely as its diſtance from the ſun. (*N. B.* Newton had ſhown that ſuch a circulation was poſſible, and that it was the only one which could be generated in a fluid by an action proceeding from the centre). Leibnitz calls this *harmonical circulation.* He ſuppoſes that the planet adopts this circulation in every part of its elliptical orbit, obeying without any reſiſtance the motion of this fluid. He does not aſcribe this to the impulſe of the fluid, ſaying *expreſsly* that the planet follows its motion, *non abrepta tamen, ſed tranquilliter quaſi natante.* The planet therefore has no tendency to perſevere in its former ſtate of motion. Why therefore does it not follow this harmonic motion exactly, and deſcribe a circle *tranquilliter natans?* This is owing, ſays Leibnitz, to its centrifugal force, by which it perſeveres in a ſtate of rectilineal motion. It has no tendency to preſerve its former velocity, but it perſeveres in its former direction. The planet therefore is not like common matter, and has laws of motion peculiar to itſelf; it was needleſs therefore to employ any impulſe to explain its motions. But to proceed: This centrifugal force muſt be counteracted in every point of the orbit. Leibnitz therefore ſuppoſes that it is alſo urged toward the centre by a ſolicitation like gravity or attraction. He calls it the *paracentric force.* He computes what muſt be its intenſity in different parts of the orbit, in order to produce an elliptical motion, and he finds that it muſt be inverſely as the ſquare of the diſtance

diſtance from the centre (for this reaſon he is frequently quoted by Bernoulli, Wolff, and others, as the diſcoverer of the law of gravitation). But Leibnitz arrives at this reſult by means of ſeveral mathematical blunders, either ariſing from his ignorance at that time of fluxionary geometry, or from his perceiving that an accurate procedure would lead him to a concluſion which he did not wiſh: for we have ſeen (and the demonſtration is adopted by Leibnitz in all his poſterior writings of this kind), that if the ordinary laws of motion are obſerved, a body, actuated by this paracentric force alone, will deſcribe an ellipſe, performing both its motion of harmonic circulation, and its motion of approach to and receſs from the centre, without farther help. Therefore, if the harmonic circulation is produced by a vortex, a force inverſely as the ſquare of the diſtance from the centre, combined with the harmonic circulation, will produce a motion entirely different from the elliptical. It is demonſtrated, that the force which is neceſſary for deſcribing circles at different diſtances, with the angular velocity of the different parts of the orbit, is not in the inverſe duplicate, but in the inverſe triplicate, ratio of the diſtances. This muſt have been the nature of his paracentric force, in order to counteract the centrifugal force ariſing from the harmonic circulation. Therefore Leibnitz has not arrived at his concluſion by juſt reaſoning, nor can be ſaid to have diſcovered it. He ſays, *Video hanc propoſitionem innotuiſſe viro celeberrimo Iſaaco Newtono, licet non poſſim judicare quomodo ad eam pervenerit.* This is really ſomewhat like impudence. The *Principia* were publiſhed in 1686. They were reviewed at Leipſic, and the Review publiſhed in 1687. Leibnitz was at that time the principal manager of that Review. When Newton publiſhed, Leibnitz was living at Hanover, and a copy was ſent him, within two months of its publication, by Nicholas Facio, long before the Review. The language of the Review has ſeveral ſingularities, which are frequent in Leibnitz's own compoſition; and few doubt of its being his writing. Beſides, this propoſition in the *Principia* had been given to the Royal Society ſeveral years before, and was in the records before 1684. Theſe were all ſeen by Leibnitz when in England, being lent him by his friend Collins.

56 Diſingenuity of the author.

We think that the opinion which a candid perſon muſt form of the whole is, that Leibnitz knew the propoſition, and attempted to demonſtrate it in a way that would make it paſs for his own diſcovery; or that he only knew the enunciation, without underſtanding the principles. His harmonic circulation is a clumſy way of explaining the proportionality of areas to the times; and even this circulation is borrowed from Newton's diſſertation on the Carteſian vortices, which is alſo contained in the Leipſic Review above mentioned. Leibnitz was by this time a competitor with Newton for the honour of inventing the fluxionary mathematics, and was not guiltleſs of acts of diſingenuity in aſſerting his claim. He publiſhed at the ſame time, in the ſame Review, an almoſt unintelligible diſſertation on the reſiſtance of fluids, which, when examined by one who has learned the ſubject by reading the *Principia* of Newton, affords an enigmatical deſcription of the very theory publiſhed by Newton, as a neceſſary part of his great work.

But beſides all the above objections to Leibnitz's theory of elliptical motion, we may aſk, What is this paracentric force? He calls it like gravity. This is preciſely Newton's doctrine. But Leibnitz ſuppoſes this alſo to be the impulſe of a fluid. It would have been enough had he explained the action of this fluid, without the other circulating harmonically. He defers this explanation, however, to another opportunity. It muſt have very ſingular properties: it muſt impel the planet without diſturbing the other fluid, or being diſturbed by it. He alſo defers to another opportunity the explaining how the ſquares of the periodic times of different planets are proportional to the cubes of the mean diſtances; for this is quite incompatible with the harmonic circulation of his vortex. This would make the ſquares of the periods proportional to the diſtances. He has performed neither of theſe promiſes. Several years after this he made a correction of one of his mathematical blunders, by which he deſtroyed the whole of his demonſtration. In ſhort, the whole is ſuch a heap of obſcure, vague, inconſiſtent aſſumptions, and ſo replete with mathematical errors, that it is aſtoniſhing that he had the ignorance or the effrontery to publiſh it.

57 Hypotheſis of Le Sage.

There is another hypotheſis that has acquired ſome reputation. M. le Sage of Geneva ſuppoſes, that there paſſes through every point of the univerſe a ſtream of fluid, in every direction, with aſtoniſhing velocity. He ſuppoſes that, in the denſeſt bodies, the vacuity is incomparably more bulky than the ſolid matter; ſo that a ſolid body ſomewhat reſembles a piece of wire cage-work. The quantity of fluid which paſſes through will be incomparably greater than that of the intercepted fluid; but the impulſe of the intercepted fluid will be ſenſibly proportional to the quantity of ſolid matter of the body. A ſingle body will be equally impelled in every direction, and will not be moved; but another body will intercept ſome fluid. Each will intercept ſome from the other; and the impulſe on B, that is intercepted by A, will be nearly proportional to the matter in A, and inverſely proportional to the ſquare of its diſtance from B; and thus the two bodies will appear to tend toward each other by the law of gravitation.

M. le Sage publiſhed this in a work called *Chimie Mechanique*, and read lectures on this doctrine for many years in Geneva and Paris to crouded audiences. It is alſo publiſhed by Mr Prevoſt in the Berlin Memoirs, under the name of *Lucrece Newtonien*; and there are many who conſider it as a good explanation of gravitation: for our part, we think it inconceivable. The motions of the planets, with undiminiſhed velocity, for more than four thouſand years, appear incompatible with the impelling power of this fluid, be its velocity what it will. The abſolute preciſion of the law of gravitation which does not ſhow the ſmalleſt error during that time, is incompatible with an impulſe which cannot be *exactly* proportional to the quantity of matter, nor to the reciprocal of the ſquare of the diſtance, nor the ſame on a body moving with the rapidity of the comet of 1680 in its perihelion, as on the planet Saturn, whoſe motion is almoſt incomparably ſlower. What is the origin of the motion of this fluid? Why does it not deſtroy itſelf by mutual impulſe, ſince it is continually paſſing through every point? &c.

58 Ether of Newton ſolves no difficulties.

We have already obſerved that Newton expreſſed the ſame anxiety to avoid the ſuppoſition of action among bodies at a diſtance. *He* alſo *ſeemed* to ſhow ſome diſpoſition to account for gravitation by the action of a contiguous fluid. This is the ſubterfuge ſo much recurred

curred to by precipitate speculatists, by the name of the *ether of Sir Isaac Newton*. He supposes it highly elastic, and much rarer in the pores of bodies and in their vicinity than at a distance; therefore exceedingly rare in the sun, and denser as we recede from him. Being highly elastic, and repelled by all bodies, it must impel them to that side on which it is most rare; therefore it must impel them toward the sun. This is enough of its general constitution to enable us to judge of its fitness for Newton's purpose. It is wholly unfit; for since it is fluid, unequally dense and elastic, its particles are not in contact. Particles that are elastic, and in a state of compression, and in contact, cannot be fluid; they must be like so many blown bladders compressed in a box; therefore they are not in contact; therefore they are elastic by mutual repulsion; that is, by acting on each other at a distance. It is indifferent whether this distance is a million of miles, or the millionth part of a hair's breadth; therefore this fluid does not free Newton from the supposition which he wishes to avoid. Nay, it can be demonstrated, that in order to form a fluid which shall vary in density from the sun to the extremity of the solar system, there must be a mutual repulsion *extending to that distance*. This is introducing millions of millions of the very difficulties which Newton wished to avoid; for each particle presents the same difficulty with a planet.

We would now ask these atomical philosophers, why they have, in all ages, been so anxious to trace the celestial motions to the effects of impulse? They imagine that they have a clear perception of the communication of motion by impulse, while their perception of the production of it in any other way is obscure. Seeing, in a very numerous and familiar collection of facts, that motion *is* communicated by impulse, they think that it is communicated in no other way, and that impulse is the only moving power in nature.

59 Our notion of impulse not clearer than of gravitation.

But is it true that our notion of impulse is more clear than that of gravitation? Its being more familiar is no argument. A cause may be real, though it has exerted itself but once since the beginning of time. In no case do we *perceive* the exertion of the cause; we only perceive the change of motion. The constitution of our mind makes us consider this as an effect, indicating a cause which is inherent in that body which we always see associated with that change. Granting that our perception of the perseverance of matter in its state of motion is intuitive, it by no means follows that the body A in motion must move the body B by striking it. The moment it strikes B, all the metaphysical arguments for A's continuance in motion are at an end, and they are not in the least affected by the supposition that A and B should continue at rest after the stroke; and we may defy any person to give an argument which will prove that B will be moved; nay, the very existence of B may, for any thing we know to the contrary, be a sufficient reason for the cessation of the motion of A. The production of motion in B, by the impulse of A, must therefore stand on the same foundation with every other production of motion. It indicates a moving power in A; but this inherent power seems to have no dependence on the motion of A: (See what is contained in n° 81. of the article Physics, and n° 67. of Optics of the *Encycl.*) We see there a motion produced in B without impulse, and taken from A, similar in every respect to every case of impulse; and we see that the motion of A is necessary for producing such a motion in B as is observed in all cases of impulse, merely in order that the moving power, which is inherent in A, whether it be in rest or in motion, may act during a sufficient time. Our confidence in the communication of motion, in the case mentioned there, is derived entirely from experience, which informs us that A possesses a moving power totally different from impulse. Our belief of the impelling power of matter therefore does not necessarily flow from our intuitive knowledge of the perseverance of matter, although it gives us the knowledge of this perseverance. It is like a mathematical demonstration, a road to the discovery of the property of figure, but not the cause of that property. The impulsion of matter is merely a fact, like its gravitation, and we know no more of the one than of the other.

It is not a clearer perception, therefore, which has procured this preference of impulsion as the ultimate explanation of motion, and has given rise to all the foolish hypotheses of planetary vortices, ethers, animal spirits, nervous fluids, and many other crude contrivances for explaining the abstruse phenomena of nature.

Nor does it deserve any preference on account of its greater familiarity. Just the contrary: for one fact of undoubted impulse, we see millions where no impulse is observed. Consider the motion produced by the explosion of gunpowder. Where is the original impulse? Suppose the impulse of the first spark of fire to be immense, how comes it that a greater impulse is produced by a greater quantity of gunpowder, a greater quantity of quiescent matter? The ultimate impulse on the bullet should be less on this account. Here are plain exertions of moving powers, which are not reducible to impulse. Consider also the facts in animal motion. Reflect also, that there has been more motion, without any observed impulse, produced in the waters of a river since the beginning of the world, than by all the impulse that man has ever observed. Add to these, all the motions in magnetism, electricity, &c. Impulse is therefore a phenomenon which is comparatively rare. 60 Impulse rarely observed.

Have we ever observed motion communicated by pure impulse, without the action of forces at a distance? This appears to us very doubtful. Every one acquainted with Newton's discoveries in optics will grant, that the colours which appear between two object-glasses of long telescopes, when they are pressed together, demonstrate, that the glasses do not touch each other, except in the place where there is a black spot. It requires more than a thousand pounds to produce a square inch of this spot. Therefore every communication of motion between two pieces of glass, which can be produced by one of them striking the other, is produced without impulse, unless their mutual pressure has exceeded 1000 pounds on the square inch of the parts which act on each other. Nay, since we see that a black spot appears on the top of a soap bubble, in the middle of the coloured rings, we learn that there is a certain thickness at which light ceases to be visibly reflected; therefore the black spot between the glasses does not prove that they touch in that part; therefore we cannot say that any force whatever can make them touch. The ultimate repulsion may be insuperable. If this be the case, the production of motion by impulse is, in every instance, like the production of motion between the magnets in n° 81. of the article Physics in the Encycl.

and

and is of the ſame kind with the production of motion by gravity.

61 Intervening fluids multiply difficulties.

Therefore no explanation of gravitation can be derived from any hypotheſis whatever of intervening fluids. They only ſubſtitute millions of bodies for one, and ſtill leave the action *e diſtanti* the ſame difficulty as before. It is not in the leaſt neceſſary that we ſhall be able to conceive how a particle of matter can be influenced by another at a diſtance; if we have diſcovered in every inſtance the preciſe degree and direction of the effect of this influence, we have made a moſt important addition to our knowledge of nature; and our ſucceſs in the caſe of the power of gravity ſhould make us aſſiduous in our endeavours to diſcover, from the phenomena, the laws which regulate the other actions *e diſtanti*, which obſervation is daily finding out. A knowledge equally accurate of the law of magnetic and electric action may enable us to give theories of magnetiſm and electricity equally exact with the Newtonian theory of gravitation.

Having, we hope, evinced the truth of this theory, by following out the inveſtigations to which Newton was gradually led, we might proceed to conſider, in order, the complicated and ſubordinate phenomena which depend on it. The lunar and planetary inequalities are the ſubjects that naturally come firſt in our way; but they have already been explained in all the detail that this conciſe account will admit, as they occurred to Newton as teſts of the truth of his conjecture. If the law be ſuch as he ſuſpected, its conſequences muſt be ſo and ſo; if the celeſtial motions do not agree with them, the law muſt be rejected. We ſhall not repeat any thing therefore on this head, but confine our obſervations to ſuch applications of the theory of univerſal gravitation as newly diſcovered objects, or the improvement of aſtronomical obſervation and of fluxionary analyſis, have enabled us to make ſince the time of Newton.

The ſubſerviency of the eclipſes of Jupiter's ſatellites to geography and navigation had occaſioned their motions to be very carefully obſerved, ever ſince theſe uſes of them were firſt ſuggeſted by Galileo, and their theory is as far advanced as that of the primary planets. It has peculiar difficulties. Being very near to Jupiter, the great deviation of his figure from perfect ſphericity makes the relation between their diſtances from his centre and their gravitations toward it vaſtly complicated. But this only excited the mathematicians ſo much the more to improve their analyſis; and they ſaw, in this little ſyſtem of Jupiter and his attendants, an epitome of the ſolar ſyſtem, where the great rapidity of the motions muſt bring about in a ſhort time every variety of configuration or relative poſition, and thus give us an example of theſe mutual diſturbances of the primary planets, which require thouſands of years for the diſcovery of their periods and limits. We have derived

62 Eternal durability of the ſolar ſyſtem

ſome very remarkable and uſeful pieces of information from this inveſtigation; and have been led to the diſcovery of the eternal durability of the ſolar ſyſtem, a thing which Newton greatly doubted of.

Mr Pound had obſerved long ago, that the irregularities of the three interior ſatellites were repeated in a period of 437 days; and this obſervation is found to be juſt to this day.

247 revolutions of the firſt occupy		437 d.	3 h.	44′
123	ſecond	437	3	42
61	third	437	3	36
26	fourth	435	14	16

This naturally led mathematicians to examine their motions, and ſee in what manner their relative poſitions or configurations, as they are called, correſponded to this period: and it is found, that the mean longitude of the firſt ſatellite, *minus* thrice the mean longitude of the ſecond, *plus* twice the mean longitude of the third, always made 180 degrees. This requires that the mean motion of the firſt, added to twice that of the third, ſhall be equal to thrice the mean motion of the ſecond. This correſpondence of the mean motions is of itſelf a ſingular thing, and the odds againſt its probability ſeems infinitely great; and when we add to this the particular poſitions of the ſatellites in any one moment, which is neceſſary for the above conſtant relation of their longitudes, the improbability of the coincidence, as a thing quite fortuitous, becomes infinitely greater. Doubts were firſt entertained of the coincidence, becauſe it was not indeed accurate to a ſecond. The reſult of the inveſtigation is curious. When we follow out the conſequences of mutual gravitation, we find, that although neither the primitive motions of projection, nor the points of the orbit from which the ſatellites were projected, were *preciſely* ſuch as ſuited theſe obſerved relations of their revolutions and their contemporaneous longitudes; yet, if they differed from them only by very minute quantities, the mutual gravitations of the ſatellites would in time bring them into thoſe poſitions, and thoſe ſtates of mean motion, that would induce the obſerved relations; and when they are once induced they will be continued for ever. There will indeed be a ſmall equation, depending on the degree of unſuitableneſs of the firſt motions and poſitions; and this cauſes the whole ſyſtem to oſcillate, as it were a little, and but a very little way on each ſide of this exact and permanent ſtate. The permanency of theſe relations will not be deſtroyed by any ſecular equations ariſing from external cauſes; ſuch as the action of the fourth ſatellite, or of the ſun, or of a reſiſting medium; becauſe their mutual actions will diſtribute this equation as it did the original error.

This curious reſult came into view only by degrees, as analyſis improved and the mathematicians were enabled to manage more complicated formulas, including more terms of the infinite ſerieſes that were employed to expreſs the different quantities. It is to M. de la Grange that we are indebted for the completion of the diſcovery of the permanency of the ſyſtem in a ſtate very little different from what obtains in any period of its exiſtence. Although this required all the knowledge and addreſs of this great mathematician, in the management of the moſt complicated analyſis, the evidence of its truth may be perceived by any perſon acquainted with the mere elements of fluxionary geometry. The law of the compoſition of forces enables us to expreſs every action of the mutual forces of the ſun and planets by the ſines and coſines of circular arches, which increaſe with an uniform motion, like the perpetual lapſe of time. The nature of the circle ſhows, that the variations of the ſines and coſines are proportional to the coſines and ſines of the ſame arches. The variations of their ſquares, cubes, or other powers, are proportional to the ſines or coſines of the doubles or triples, or other multiplies of the ſame arches. Therefore ſince the infinite ſerieſes which expreſs thoſe actions of forces, and their variations, include only ſines and coſines, with their powers and fluxions, it follows, that all accumulated

lated forces, and variations of forces, and variations of variations, through infinite orders, are still expressible by repeated sums of sines or cosines, corresponding to arches which are generated by going round and round the circle. The analyst knows that these quantities become alternately positive and negative; and therefore, in whatever way they are compounded by addition of themselves, or their multiples, or both, we must always arrive at a period after which they will be repeated with all their intermediate variations. It may be extremely difficult, it may be impossible, in our present state of mathematical knowledge, to ascertain all those periods. It has required all the efforts of all the geniuses of Europe to manage the formulas which include terms containing the fourth and fifth powers of the eccentricities of the planetary orbits. Therefore the periods which we have already determined, and the limits to which the inequalities expressed by secular equations arrive, are still subjected to smaller corrections of incomparably longer periods, which arise from the terms neglected in our formulas. But the correction arising from any neglected term has a period and a limit; and thus it will happen that the system works itself into a state of permanency, containing many intervening apparent anomalies. The elliptical motion of the earth contains an anomaly or deviation from uniform circular motion; the action of Jupiter produces a deviation from this elliptical motion, which has a period depending on the configuration of the three bodies; Saturn introduces a deviation from this motion, which has also a period; and so on.

There is another accurate adjustment of motions which has attracted attention, as a thing in the highest degree improbable, in events wholly independent on each other. This is the exact coincidence of the period of the moon's revolution round the earth with that of her rotation round her own axis. The ellipticity or oval shape of the moon differs so insensibly from a sphere, that if the original rotation had differed considerably from the period of revolution, the pendular tendency to the earth could never have operated a change: but if the difference between those two motions was so small, that the pendular tendency to the line joining the centres of the earth and moon was able to overcome it after some time, the pole of the lunar spheroid would deviate a little from the line joining the earth and moon, and then be brought back to it with an accelerated motion; would pass it as far on the other side, and then return again, vibrating perpetually to each side of the mean position of the *radius vector*. The extent of this vibration would depend on the original difference between the motion of rotation and the mean motion of revolution. This difference must have been very small, because this *pendular vibration* is not sensible from the earth. The observed LIBRATION of the moon is precisely what arises from the inequality of her orbital motion. For the same reasons, the effects of the secular equations of the moon (which would, in the course of ages, have brought her whole surface into our view, had her rotation been strictly uniform) are counteracted by her pendular tendency, which has a force sufficient to alter her rotation by nearly the same slow and insensible changes that obtain in her mean motions. The same causes also preserve the nodes of her equator and of her orbit in the same points of the ecliptic. The complete demonstration of this is perhaps the most delicate and elegant specimen that has been given of the modern analysis. We owe it to M. de la Grange: and he makes it appear that the figure of the moon is not that which a fluid sphere would acquire by its gravitation to the earth; it must be the effect of a more considerable ellipticity, or internal inequality of density.

63 Depends on the law of planetary deflection,

This permanency of the system, within very narrow limits of deviation from its present state, depends entirely on the law of planetary deflection. Had it been directly or inversely as the distance, the deviations would have been such as to have quickly rendered it wholly unfit for its present purposes. They would have been very great, had the planetary orbits differed much from circles; nay, had some of them moved in the opposite direction. The selection of this law, and this form of the orbits, strikes the mind of a Newton, and indeed any heart possessed of sensibility to moral or intellectual excellence, as a mark of wisdom prompted by benevolence. But De la Place and others, infected with the *Theophobia Gallica* engendered by our licentious desires, are eager to point it out as a mark of fatalism. They say, that it is essential to all qualities that are diffused from a centre to diminish in the inverse duplicate ratio of the distance. But this is false, and *very false*: it is a mere geometrical conception. We indeed say, that the density of illumination decreases in this proportion; but who says that this is a quality? Whether it be considered as the emission of luminous corpuscles, or an undulation of an elastic fluid, it is not a quality emanating from a centre: and even in this estimation, it seems gratuitous, whether we shall consider the base of the luminous pyramid, or its whole contents, as the expression of the quantity. Nay, if all qualities must diminish at this rate, all action *e distanti* must do the same; for when the distances bear any great proportion to the diameters of the particles, their action deviates insensibly from this law, and is perceived only by the accumulation of its effects after a long time. It is only thus that the effects of the oblate figure of Jupiter are perceived in the motion of his satellites. The boasted sound philosophy which sees fatal necessity where the *most successful students of nature* saw moral excellence, has derived very little credit or title to the name of *wisdom*, by letting loose all those propensities of the human heart which are essentially destructive of social happiness.

64 And evinces the wisdom of the Creator.

These propensities were always known to lurk in the heart of man; and those surely were the wisest who laboured to keep them in check by the influence of moral principles, and particularly by cherishing that disposition of the human heart which prompts us to see contrivance wherever we see nice and refined adjustment of means to ends; and, from the admirable beauty of the solar system, to cry out,

"These are thy glorious works, Parent of good!
"Almighty, thine this universal frame,
"Thus wond'rous fair; thyself how wond'rous then!
"Unspeakable, who sitt'st above these heavens,
"To us invisible, or dimly seen
"In these thy lowest works; yet these declare
"Thy goodness beyond thought, and power divine."
Par. Lost, b. v.

"But wandering oft, with brute unconscious gaze,
"Man marks not THEE, marks not the mighty hand
"That, ever busy, wheels the silent spheres."
THOMPSON.

The

The moſt important addition (in a philoſophical view) that has been made to aſtronomical ſcience ſince the diſcovery of the aberration of light and the nutation of the earth's axis, is that of the rotation of Saturn's ring.

65 Saturn's ring.

The ring itſelf is an object quite ſingular; and when it was diſcovered that all the bodies which had any immediate connection with a planet were heavy, or gravitated toward that planet, it became an intereſting queſtion, what was the nature of this ring? what ſupported this immenſe arch of heavy matter without its reſting on the planet? what maintains it in perpetual concentricity with the body of Saturn, and maintains its ſurface in one invariable poſition?

The theory of univerſal gravitation tells us what things are poſſible in the ſolar ſyſtem; and our conjectures about the nature of this ring muſt always be regulated by the circumſtance of its gravitation to the planet. Philoſophers had at firſt ſuppoſed it to be a luminous atmoſphere, thrown out into that form by the great centrifugal force ariſing from a rotation: but its well defined edge, and, in particular, its being two very narrow rings, extremely near each other, yet perfectly ſeparate, rendered this opinion of its conſtitution more improbable.

66 Diſcovery of Dr Herſchel relating to it.

Dr Herſchel's diſcovery of brighter ſpots on its ſurface, and that thoſe ſpots were permanent during the whole time of his obſervation, ſeems to make it more probable that the parts of the ring have a ſolid connection. Mr Herſchel has diſcovered, by the help of thoſe ſpots, that the ring turns round its axis, and that this axis is alſo the axis of Saturn's rotation. The time of rotation is 10h. $32\frac{1}{4}'$. But the other circumſtances are not narrated with the preciſion ſufficient for an accurate compariſon with the theory of gravity. He informs us, that the radii of the four edges of the ring are 590 751, 774, 830, of a certain ſcale, and that the angle ſubtended by the ring at the mean diſtance from the earth is $46\frac{7}{4}''$. Therefore its elongation is $23\frac{1}{4}''$. The elongation of the ſecond Caſſinian ſatellite is 56″, and its revolution is 2d. 17h. 44′. This ſhould give, by the third law of Kepler, 17h. 10′ for the revolution of the outer edge of the ring, or rather of an atom of that edge, in order that it may maintain itſelf in equilibrio. The ſame calculation applied to the outer edge of the inner ring gives about 13h. 36′; and we obtain 11h. 16′ for the inner edge of this ring. Such varieties are inconſiſtent with the permanent appearance of a ſpot. We may ſuppoſe the ring to be a luminous fluid or vapour, each particle of which maintains is ſituation by the law of planetary revolution. In ſuch a ſtate, it would conſiſt of concentric ſtrata, revolving more ſlowly as they were more remote from the planet, like the concentric ſtrata of a vortex, and therefore having a relative motion incompatible with the permanency of any ſpot. Beſides, the rotation obſerved by Herſchel is too rapid even for the innermoſt part of the ring. We think therefore that it conſiſts of cohering matter, and of conſiderable tenacity, at leaſt equal to that of a very clammy fluid, ſuch as melted glaſs.

We can tell the figure which a fluid ring muſt have, ſo that it may maintain its form by the mutual gravitation of its particles to each other, and their gravitation to the planet. Suppoſe it cut by a meridian. It may be in equilibrio if the ſection is an ellipſe, of which the longer axis is directed to the centre of the planet, and very ſmall in compariſon with its diſtance from the centre of the planet, and having the revolution of its middle round Saturn, ſuch as agrees with the Keplerean law. Theſe circumſtances are not very conſiſtent with the dimenſions of Saturn's inner ring. The diſtance between the middle of its breadth and the centre of Saturn is 670, and its breadth is 161′, nearly one-fourth of the diſtance from the centre of Saturn. De la Place ſays, that the revolution of the inner ring obſerved by Herſchel is very nearly that required by Kepler's law: but we cannot ſee the grounds of this aſſertion. The above compariſons with the ſecond Caſſinian ſatellite ſhows the contrary. The elongation of that ſatellite is taken from Bradley's obſervations, as is alſo its periodic time. A ring of detached particles revolving in 10h. $32\frac{1}{4}'$ muſt be of much ſmaller diameter than even the inner edge of Saturn's ring. Indeed, the quantity of matter in it might be ſuch as to increaſe the gravitation conſiderably; but this would be ſeen by its diſturbing the ſeventh and ſixth ſatellites, which are exceedingly near it. We cannot help thinking therefore that it conſiſts of matter which has very conſiderable tenacity.

67 Its probable conſiſtency

An equatorial zone of matter, tenacious like melted glaſs, and whirled briſkly round, might be thrown off, and, retaining its great velocity, would ſtretch out while whirling, enlarging in diameter and diminiſhing in thickneſs or breadth, or both, till the centrifugal force was balanced by the united force of gravity and tenacity. We find that the equilibrium will not be ſenſibly diſturbed by conſiderable deviations, ſuch as unequal breadth, or even want of flatneſs. Such inequalities appear on this ring at the time of its diſparition, when its edge is turned to the ſun or to us. The appearances of its different ſides are then conſiderably different.

Such a ring or rings muſt have an oſcillatory motion round the centre of Saturn, in conſequence of their mutual action, and the action of the ſun, and their own irregularities: but there will be a certain poſition which they have a tendency to maintain, and to which they will be brought back, after deviating from it, by the ellipticity of Saturn, which is very great. The ſun will occaſion a nutation of Saturn's axis and a preceſſion of his equinoxes, and this will drag along with it both the rings and the neighbouring ſatellites.

The atmoſphere which ſurrounds a whirling planet cannot have all its parts circulating according to the third law of Kepler. The mutual attrition of the planet, and of the different ſtrata, ariſing from their different velocities, muſt accelerate the ſlowly moving ſtrata, and retard the rapid, till all acquire a velocity proportional to their diſtance from the axis of rotation; and this will be ſuch that the momentum of rotation of the planet and its atmoſphere remains always the ſame. It will ſwell out at the equator, and ſink at the poles, till the centrifugal force at the equator balances the weight of a ſuperficial particle. The greateſt ratio which the equatorial diameter can acquire to the polar axis is that of four to three, unleſs a coheſive force keeps the particles united, ſo that it conſtitutes a liquid, and not an elaſtic fluid like air; and an elaſtic fluid cannot form an atmoſphere bounded in its dimenſions, unleſs there be a certain rarity which takes away all elaſticity. If the equator ſwells beyond the dimenſion which makes the gravitation balance the centrifugal force, it muſt immediately diſſipate.

If we ſuppoſe that the atmoſphere has extended to this limit, and then condenſes by cold, or any chemical or other caufe different from gravity, its rotation neceffarily augments, preferring its former momentum, and the limit will approach the axis; becaufe a greater velocity produces a greater centrifugal force, and requires a greater gravitation to balance it. Such an atmofphere may therefore defert, in fucceffion, zones of its own matter in the plane of its equator, and *leave* them revolving in the form of rings. It is not unlikely that the rings of Saturn may have been furnifhed in this very way; and the zones, having acquired a common velocity in their different ftrata, will preferve it; and they are fufceptible of irregularities arifing from local caufes at the time of their feparation, which may afford permanent fpots.

68 And origin.

69 It may furnifh the means of difcovering the nature of light.

We think that the rotation of Saturn's ring affords fome hopes of deciding a very important queftion about the nature of light. If light be the propagation of elaftic undulations, its velocity depends entirely on the elafticity and denfity of the fluid; but if it be the emiffion of corpufcles, their velocity may be affected by other caufes. The velocity of Saturn's ring is $\frac{59}{63}$ of that of the earth in its orbit, and therefore about $\frac{1}{10000}$ of the velocity of light. The weftern extremity (to us in the northern regions) is moving from us, and the eaftern is moving toward us. If light, by which we fee it, be reflected like an elaftic ball from an elaftic body, there will be an excefs in the velocity of the light by which we fee the eaftern limb above the velocity of the light by which we fee the weftern limb. This excefs will be $\frac{1}{2500}$ of the mean velocity of light. This fhould be difcovered by a difference in the refraction of the two lights. If an acromatic prifm could be made to refract fourteen degrees, and if Saturn be viewed thro' a telefcope with this prifm placed before it, there fhould be a change of fhape amounting to fixteen feconds; if the axis of the prifm be parallel to the longer axis of the ring, it will diftort it prodigioufly, and give it an oblique pofition.

A fimilar effect will be produced by placing the prifm between the eye-glafs and the image in the focus of the object-glafs.

Our expectation is founded on this unqueftionable principle in dynamics, that when a particle of light paffes through the active ftratum of a tranfparent body which refracts light toward the perpendicular, the addition made to the fquare of its velocity by the refracting forces is equal to the fquare of the velocity which thofe forces would communicate to a particle at reft on the furface of this refracting ftratum of the tranfparent body. Therefore if the velocity of the incident light be increafed, the ratio of the fine of incidence to the fine of refraction will be diminifhed. It is confonant to common fenfe, that when the incident light has a greater velocity, it paffes more rapidly through the attracting ftratum, and a fmaller addition is made to the velocity. When the velocity of the incident light is 10000 times greater than that of the earth's annual motion, the fine of incidence is to the fign of refraction in glafs as 20 to 31, or as 10000 to 15500. If this be increafed $\frac{1}{2500}$, making it 10004, the ratio will be that of 10004 to 15502,62, or of 10000 to 15496.4. The difference between the refractions of the light from the eaftern and weftern extremities of the ring will be, to all fenfe, the fame, if the velocity of the one be diminifhed to 9998, and the other increafed to 10002.

We may juft add here, by the way, that the action of another body may confiderably change the conftitution of this atmofphere. Thus, fuppofing that the moon had originally an atmofphere, the limit will be that diftance from the moon where the centrifugal force, arifing from the moon's rotation, added to the gravitation to the earth, balances the gravitation to the moon. If the moon be $\frac{1}{39}$th of the earth, this limit will be about $\frac{1}{9}$th of the moon's diftance from the earth. If at this diftance the elafticity of the atmofphere is not annihilated by its rarefaction, it will be all taken off by the earth, and accumulate round it. This may be the reafon why we fee no atmofphere about the moon.

70 Probable reafon why we fee no atmofphere about the moon.

What has been faid in the article TIDE (Encycl.), will explain the trade-winds on the earth and in Jupiter and Saturn. On the earth they are increafed by the expanfion of the air by heat. This caufes it to rife in the parts warmed by the fun, and flow off toward the poles, where it is again cooled and condenfed. The under ftratum of colder and denfer air is continually flowing in from the poles. This having lefs velocity of circulation than the equatorial parts of the earth, muft have a relative motion contrary to that of the earth, or from eaft to weft, and this muft augment the current produced by gravitation.

THUS we fee that all the mechanical phenomena of the folar fyftem, whether relating to the revolutions round the various centres of gravitation, or to the figure of the planets and the ofcillations of the fluids which cover them, or to the rotations round their refpective axes—are neceffary confequences of one fimple principle of a gravitation in every particle, decreafing in the reciprocal duplicate ratio of the diftance. We fee that this, combined with a primitive projection, will produce every motion that we obferve. It was not neceffary, as Copernicus imagined, to imprefs three motions on the earth; one, by which it was made to revolve round the fun; a fecond, caufing it to turn round an axis inclined to that of its orbit; and a third, by which this axis defcribed that conic furface which forms the preceffion of the equinoxes. One impulfe, not paffing through the centre of the earth, nor in the plane of the ecliptic, will produce the two firft motions, and the protuberant matter produced by the rotation will generate the third motion, by the tendency of its parts to the other heavenly bodies. Without this principle, the elliptic motion of the planets and comets, their various inequalities, fecular or periodical, thofe of the moon and of the fatellites of Jupiter, the preceffion of the equinoxes, the nutation of the earth's axis, the figure of the earth, the undulations of its ocean—all would have been imperfectly known, as matters of fact, wholly different from each other, and folitary and unconnected. It is truly deferving admiration, that fuch an immenfe variety of important phenomena flow fo palpably from one principle, of fuch fimplicity, and fuch univerfality, that no phenomenon is now left out unexplained, and predicted with a certainty almoft equal to actual obfervation.

71 All the mechanical phenomena of the folar fyftem flow from one fimple principle.

Quæ toties animos veterum torfêre fophorum,
Quæque fcholas hodie rauco certamine vexant
Obvia confpicimus, nubem pellente Mathefi,
Surgite mortales, terrenas mittete curas,
Atque hinc cœligenæ vires dignofcite mentis,
A pecudum vitâ longe lateque remotæ.

A New

A New Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred;

Formed from Observations made in the Observatory at Gotha.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Ascension in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Ascension in Equat. Part.	Annual Variation in R. A.
			h ′ ″ 1/100	″ 1/1000	° ′ Nor. Sou.	° ′ ″ 1/100	″ 1/100
				+			+
1	88 γ Pegasus	2	0 2 56,79	3,063	14 4 N	0 44 11,85	45,95
2	8 ι Cetus	3	0 5 13,51	3,059	9 57 S	2 18 22,66	45,89
3	15 κ Cassiopea	4	0 21 45,12	3,301	61 50 N	5 26 16,75	49,51
4	17 ζ Cassiopea	4	0 25 53,93	3,262	52 49 N	6 28 29,01	48,93
5	31 δ Andromeda	3	0 28 39,02	3,161	29 45 N	7 9 45,31	47,42
6	18 α Cassiopea	3	0 29 14,40	3,311	55 26 N	7 18 35,95	49,66
7	16 β Cetus	2 3	0 33 31,83	3,001	19 5 S	8 22 57,40	45,01
8	24 η Cassiopea	4	0 37 1 44	3,389	56 46 N	9 15 21,64	50,83
9	63 δ Pisces	4	0 38 19,08	3,093	6 30 N	9 34 46,15	46,39
10	27 γ Cassiopea	3	0 44 44,75	3,505	59 38 N	11 11 11,29	52,58
11	71 ε Pisces	4	0 52 33,95	3,103	6 49 N	13 8 29,20	46,55
12	43 β Andromeda	2	0 58 34,23	3,297	34 33 N	14 38 33,38	49,46
13	33 θ Cassiopea	4	0 59 0,22	3,531	53 35 N	14 45 3,33	52,96
14	86 ζ Pisces	4	1 3 16,99	3,109	6 31 N	15 49 14,80	46,63
15	37 δ Cassiopea	3	1 12 50,58	3,761	59 11 N	18 12 38,70	56,42
16	98 μ Pisces	5	1 19 42,07	3,108	5 7 N	19 55 31,07	46,62
17	102 π Pisces	5	1 30 30,70	3,164	11 7 N	22 37 40,56	47,46
18	106 ν Pisces	4 5	1 31 1,77	3,107	4 28 N	22 45 26,62	46,61
19	110 ο Pisces	4 5	1 34 50,72	3,144	8 9 N	23 42 40,84	47,16
20	45 ε Cassiopea	3	1 40 10,01	4,155	62 41 N	25 2 30,15	62,33
21	55 ζ Cetus	3	1 41 36,69	2,953	11 20 S	25 24 10,33	44,30
22	2 α Triang. North.	3 4	1 41 42,74	3,379	28 36 N	25 25 41,15	50,68
23	5 γ¹ Aries	4	1 42 34,52	3,258	18 19 N	25 38 37,73	48,87
24	6 β Aries	3	1 43 36,77	3,277	19 50 N	25 54 11,48	49,15
25	9 λ Aries	5	1 46 48,86	3,315	22 37 N	26 42 12,83	49,73
26	57 γ Andromeda	2	1 51 41,05	3,615	41 22 N	27 55 15,76	54,23
27	* preced. α ♈	.	1 50 26,15	. . .	. . . . .	27 36 32,25	. . .
28	13 α ARIES	2	1 55 55,27	3,335	22 31 N	28 58 49,05	50 02
29	* sequ. α ♈	.	1 59 38,13	. . .	. . . . .	29 54 31,95	. . .
30	22 θ¹ Aries	5 6	2 7 1,64	3,308	18 58 N	31 45 24,55	49,62

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Afcenfion in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Afcenfion in Equat. Part.	Annual Variation in R. A.
			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
31	68 ο Cetus (Varia.)	0 2	2 9 14,70	3, 019	3 54 S	32 18 40,50	45, 29
32	42 π Aries	6	2 38 9,29	3, 321	16 38 N	39 32 19,32	49, 81
33	43 σ Aries	6	2 40 28,09	3, 285	14 15 N	40 7 1,39	49, 28
34	82 δ Cetus	3	2 29 14,17	3, 060	0 33 S	37 18 32,54	45, 90
35	83 ε Cetus	3	2 29 53,42	2, 884	12 44 S	37 28 21,37	43, 27
36	86 γ Cetus	3	2 32 57,18	3, 102	2 23 N	38 14 17,76	46, 53
37	89 π Cetus	3	2 34 36,02	2, 849	14 43 S	38 39 0,29	42, 74
38	39 ♈ Lilius North.	4	2 35 57,70	3, 521	28 25 N	38 59 25,49	52, 81
39	41 ♈ Lilius South.	4	2 38 14,43	3, 489	26 26 N	39 33 36,49	52, 34
40	40 ρ² Aries	6	2 44 35,65	3, 344	17 31 N	41 8 54,72	50, 16
41	46 ρ³ Aries	5 6	2 45 9,35	3, 340	17 13 N	41 17 20,19	50, 10
42	3 η Eridanus	3	2 46 39,72	2, 917	9 42 S	41 39 55,78	43, 75
43	48 ε Aries	5	2 47 48,01	3, 401	20 32 N	41 57 1,80	51, 01
44	23 γ Perfeus	3	2 50 24,42	4, 250	52 43 N	42 36 6,25	63, 75
45	92 α CETUS (Me.)	2	2 51 50,07	3, 119	3 18 N	42 57 31,06	46, 66
46	⁎ fequ. α Cetus	.	2 51 54,61	. . .	. . . .	42 58 39,15	. . .
47	26 β Perfeus	2 3	2 55 12,07	3, 846	40 11 N	43 48 1,04	57, 69
48	57 δ Aries	4	3 0 12,71	3, 393	18 58 N	45 3 10,59	50, 89
49	58 ζ Aries	5	3 3 25,98	3, 422	20 18 N	45 51 29,77	51, 33
50	13 ζ Eridanus	3	3 6 7,48	2, 904	9 34 S	46 31 52,20	43, 56
51	61 τ¹ Aries	7	3 9 42,36	3, 433	20 25 N	47 25 35,39	51, 49
52	33 α Perfeus	2	3 10 6,85	4, 203	49 8 N	47 31 42,77	63, 05
53	63 τ² Aries	6	3 11 16,37	3, 428	20 1 N	47 49 5,48	51, 42
54	65 Aries	7	3 12 55,52	3, 430	20 5 N	48 13 52,74	51, 45
55	5 *f* Taurus	5	3 19 54,65	3, 289	12 15 N	49 57 39,78	49, 33
56	18 ε Eridanus	3 4	3 23 31,52	2, 883	10 9 S	50 52 52,84	43, 24
57	39 δ Perfeus	3	3 28 44,93	4, 203	47 8 N	52 11 13,91	63, 05
58	25 η Lucida Pleïad.	3	3 35 37,17	3, 535	23 29 N	53 54 17,56	53, 03
59	44 ζ Perfeus	3	3 41 35,20	3, 734	31 17 N	55 23 48,00	56, 01
60	45 ε Perfeus	3	3 44 29,19	3, 977	39 25 N	56 7 17,87	59, 66

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Ascension in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Ascension in Equat. Part.	Annual Variation in R. A.
			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
61	34 γ Eridanus	2 3	3 48 42,25	2, 786	14 5 S	57 10 33,77	41, 79
62	37 *A* Taurus	5	3 52 53,46	3, 515	21 32 N	58 13 21,83	52, 72
63	54 γ Taurus	3	4 8 25,23	3, 387	15 8 N	62 6 18.48	50, 80
64	61 δ^1 Taurus	3 4	4 11 24,68	3, 432	17 4 N	62 51 10,26	51, 48
65	64 δ^2 Taurus	4	4 12 34,93	3, 431	16 58 N	63 8 43,89	51, 46
66	65 κ^1 Taurus	5	4 13 27,66	3, 545	21 50 N	63 21 54.93	53, 17
67	67 κ^2 Taurus	4 5	4 13 31,13	3, 543	21 44 N	63 22 47,02	53, 14
68	74 ε Taurus	3 4	4 16 56,98	3, 475	18 44 N	64 14 14.76	52, 12
69	77 θ^1 Taurus	5	4 17 9,30	3, 401	15 31 N	64 17 19,53	51, 02
70	78 θ^2 Taurus	5	4 17 19,53	3, 399	15 25 N	64 19 52,91	50, 99
71	* preced. α ♉	.	4 22 12,56	. . .	. . . .	65 33 8,40	. . .
72	87 ALDEBARAN.	1	4 24 27,29	3, 421	16 6 N	66 6 49,38	51, 31
73	* sequ. α ♉	.	4 26 43,44	. . .	. . . .	66 40 51,60	. . .
74	91 σ^1 Taurus	6	4 27 44,78	3, 406	15 24 N	66 56 11,77	51, 09
75	52 υ^1 Eridanus	3 4	4 27 47,26	2, 329	30 59 S	66 56 48,83	34, 94
76	92 σ^2 Taurus	6	4 27 50,67	3, 409	15 31 N	66 57 40,07	51, 13
77	54 Eridanus	3 4	4 31 43,15	2, 615	20 4 S	67 55 47,21	39, 23
78	102 ι Taurus	4	4 51 9,38	3, 565	21 18 N	72 47 20,75	53, 47
79	67 β Eridanus	3	4 58 2,38	2, 948	5 21 S	74 30 35 74	44, 22
80	69 λ Eridanus	4	4 59 34,73	2, 863	9 1 S	74 53 40 95	42, 95
81	* preced. α Auriga	.	5 1 39 44	. . .	. . . .	75 24 51,60	. . .
82	13 CAPELLA	1	5 1 56,16	4, 414	45 47 N	75 29 2,40	66, 21
83	* sequ. α Auriga	.	5 3 14 28	. . .	. . . .	75 48 34,20	. . .
84	* preced. β Orion	.	5 3 56,39	. . .	. . . .	75 59 5,85	. . .
85	19 RIGEL	1	5 4 55,54	2, 867	8 27 S	76 13 53,10	43, 01
86	* sequ. β Orion	.	5 8 24,57	. . .	. . . .	77 6 8,55	. . .
87	120 β TAURUS	2	5 13 39,38	3, 778	28 26 N	78 24 50,70	56, 67
88	24 γ Orion	2	5 14 24,54	3, 209	6 9 N	78 36 8,16	48, 13
89	9 β Lepus	3 4	5 19 41,09	2, 565	20 56 S	79 55 16,40	38, 47
90	34 δ Orion	2	5 21 47,38	3, 057	0 28 S	80 26 53,69	45, 86

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
91	11 α Lepus	3	5 23 54,94	2,639	17 59 S	80 58 44,13	39,59
92	123 ζ Taurus	3	5 25 42 41	3,575	21 0 N	81 25 36,14	53 62
93	46 ε Orion	2	5 26 4,15	3,037	1 20 S	81 31 2,19	45,55
94	50 ζ Orion	2	5 30 40,57	3,020	2 4 S	82 40 8,57	45,30
95	α Columba	2	5 32 25,03	2,167	34 11 S	83 6 15,45	32,50
96	13 γ Lepus	3 4	5 36 9,02	2,517	22 31 S	84 2 15,34	37,75
97	53 κ Orion	4	5 38 16 28	2,839	9 45 S	84 34 4,21	42,59
98	* preced. α Orion	.	5 41 27,74	. . .	. . . .	85 21 56,10	. . .
99	58 α ORION	1	5 44 20,57	3,239	7 21 N	86 5 8,55	48,59
100	* ſequ. α Orion	.	5 47 35,59	. . .	. . . .	86 58 23,85	. . .
101	34 β Auriga	2 3	5 44 51,68	4,398	44 55 N	86 12 55,22	65,97
102	1 H Gemi. (Prop.)	4 5	5 51 57,72	3,642	23 16 N	87 59 25,77	54,63
103	7 η Gemini	3 4	6 2 48 29	3,623	22 33 N	90 42 4,34	54,34
104	13 μ Gemini	3	6 10 51,44	3,624	22 36 N	92 42 51,64	54,36
105	1 ζ Cancer major	3	6 12 39,08	2,295	29 59 S	93 9 46 24	34,47
106	2 β Cancer major	2 3	6 13 53,76	2,638	17 52 S	93 28 26 33	39 57
107	18 ν Gemini	4	6 17 5,48	3,526	20 20 N	94 16 22,22	53,43
108	24 γ Gemini	2 3	6 26 9,35	3,463	16 34 N	96 32 20,32	51,95
109	27 ε Gemini	3	6 31 37,34	3,695	25 19 N	97 54 20,05	55,42
110	* preced. α Can. ma.	.	6 29 41,80	. . .	. . . .	97 25 27,00	. . .
111	9 SIRIUS	1	6 36 19,91	2,647	16 26 S	99 4 58,65	39,71
112	* ſequ. α Can maj.	.	6 41 26,68	. . .	. . . .	100 21 40,20	. . .
113	21 ε Cancer major	2 3	6 50 46,21	2,354	28 43 S	102 41 33,20	35,31
114	43 ζ Gemini	3 4	6 52 14,55	3,567	20 51 N	103 3 38,24	53,47
115	25 δ Cancer major	2 3	7 0 15,39	2,436	26 5 S	105 3 53,85	36,54
116	55 δ Gemini	3	7 8 10,06	3,594	22 20 N	107 2 30 94	52,91
117	3 β Cancer minor	3	7 16 18,01	3,261	8 41 N	109 4 30,21	48,92
118	* preced. α Gemini	.	7 16 13,65	. . .	. . . .	109 3 24 90	. . .
119	66 CASTOR	1 2	7 21 48,81	3,855	32 19 N	110 27 12,15	57,83
120	* ſequ. α Gemini	.	7 27 4,84	. . .	. . . .	111 46 12,60	. . .

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				+			+
121	69 υ Gemini	4 5	7 23 34,54	3, 715	27 21 N	110 53 38,04	55, 72
122	* preced. α Can. mi.	.	7 26 40,27	. . .	. . . .	111 40 4,05	. . .
123	10 PRCCYON	1 2	7 28 49,10	3, 137	5 44 N	112 12 16,50	47, 06
124	* sequ. α Can. min.	.	7 30 27,12	. . .	. . .	112 36 46,80	. . .
125	78 POLLUX	2	7 33 3,18	3, 687	28 30 N	113 15 47,70	55, 31
126	* sequ. β Gemini	.	7 35 28,78	. . .	. . . .	113 52 11,70	. . .
127	10 μ^2 Cancer	5	7 55 57,64	3, 545	22 9 N	118 59 24,55	53, 18
128	14 ψ^2 Cancer	4	7 58 23 25	3, 639	26 7 N	119 35 48,73	54, 58
129	17 β Cancer	3 4	8 5 39,37	3, 266	9 48 N	121 24 50,61	48, 99
130	31 ϑ Cancer	5 6	8 20 10,35	3, 441	18 46 N	125 2 35,31	51, 61
131	33 η Cancer	6 7	8 21 7,79	3, 491	21 6 N	125 16 56,87	52, 36
132	4 δ Hydra	4	8 27 3,04	3, 189	6 23 N	126 45 45,53	47, 83
133	43 γ Cancer	4	8 31 41,86	3, 499	22 10 N	127 55 27,85	52, 49
134	47 δ Cancer	4	8 33 18,11	3, 428	18 53 N	128 19 31,70	51, 42
135	11 ε Hydra	4	8 36 10,14	3, 199	7 8 N	129 2 32,03	47, 98
136	16 ζ Hydra	4 5	8 44 48,86	3, 187	6 42 N	131 12 12,84	47, 81
137	60 α^1 Cancer	4 5	8 44 59,39	3, 290	12 24 N	131 14 50,81	49, 35
138	65 α^2 Cancer	3 4	8 47 31,82	3, 292	12 37 N	131 52 57,26	49, 38
139	76 κ Cancer	4 5	8 56 54,33	3, 263	11 28 N	134 13 34,92	48, 95
140	66 ξ^1 Cancer	5 6	8 58 30,37	3, 472	22 51 N	134 27 35,48	52, 08
141	22 ϑ Hydra	4	9 3 54,80	3, 120	3 10 N	135 58 42,03	46, 80
142	1 κ Leo	4	9 12 58,32	3, 524	27 2 N	138 14 34,77	52, 86
143	30 ALPHARD	2	9 17 44,97	2, 935	7 48 S	139 26 14,55	44, 03
144	* sequ. α Hydra	.	9 23 9,19	. . .	. . . .	140 47 17,85	. . .
145	5 ξ Leo	4	9 21 9,26	3, 253	12 11 N	140 17 18,97	48, 80
146	14 ο Leo	4	9 30 27,65	3, 224	10 48 N	142 36 54,82	48, 36
147	17 ε Leo	3	9 34 28,29	3, 434	24 41 N	143 37 4,31	51, 51
148	24 μ Leo	3	9 41 21,84	3, 457	26 57 N	145 20 27,54	51, 85
149	27 ν Leo	4	9 47 26,92	3, 243	13 24 N	146 51 43,76	48, 65
150	29 π Leo	4	9 49 37,99	3, 183	9 0 N	147 24 29,89	47, 75

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
151	30 η Leo	3 4	9 52 24,60	3, 289	17 44 N	149 6 9,04	49, 33
152	32 REGULUS	1	9 57 42,02	3, 204	12 56 N	149 25 30,30	48, 06
153	* ſequ. α Leo	.	10 4 28,58	. . .	. . . .	151 7 8,70	. . .
154	36 ζ Leo	3	10 5 32,34	3, 361	24 25 N	151 23 5,16	50, 42
155	41 γ² Leo	2 3	10 8 55,22	3, 306	20 51 N	152 13 48,23	49, 60
156	34 μ Urſa major	3	10 10 21,35	3, 635	42 30 N	152 35 23,32	54, 52
157	47 ρ Leo	4	10 22 15,77	3, 170	10 20 N	155 33 56,49	47, 55
158	48 β Urſa major	2	10 49 39,53	3, 709	57 27 N	162 24 52,93	55, 63
159	7 α Crater	4	10 50 4 55	2, 943	17 14 S	162 31 8,25	44, 14
160	50 α Urſa major	1 2	10 51 15,84	3, 847	62 50 N	162 48 57,61	57, 70
161	11 β Crater	3 4	11 1 50,06	2, 933	31 44 S	165 27 30,97	44, 02
162	68 δ Leo	2 3	11 3 26,39	3, 199	21 37 N	165 51 35,91	47, 98
163	70 ϑ Leo	3	11 3 44,23	3, 165	16 31 N	165 56 3,49	47, 48
164	13 λ Crater	5 6	11 13 28,15	2, 981	17 17 S	168 22 2,21	44, 72
165	78 ι Leo	4	11 13 28,32	3, 125	11 38 N	168 22 4,85	46, 87
166	84 τ Leo	4	11 17 39,49	3, 085	3 57 N	169 24 52,34	46, 28
167	91 υ Leo	4	11 26 42,82	3, 069	0 17 N	171 40 42,29	46, 04
168	3 ν Virgo	5	11 35 34,11	3, 087	7 39 N	173 53 51,70	46, 31
169	* preced. β Leo	.	11 38 19,46	. . .	. . . .	174 34 51,90	. . .
170	94 DENEBOLA	1 2	11 38 50,49	3, 062	15 41 N	174 42 37,35	45, 93
171	5 β Virgo	3	11 40 16,38	3, 122	2 54 N	175 4 5,70	46, 83
172	64 γ Urſa major	2	11 43 14,22	3, 212	54 48 N	175 48 33,33	48, 18
173	1 α Corvus	4	11 58 6,94	3, 062	23 37 S	179 31 44,10	45, 93
174	2 ε Corvus	4	11 59 51,63	3, 067	21 30 S	179 57 54,47	46, 00
175	69 δ Urſa major	3	12 5 27,23	3, 021	58 9 N	181 21 48,42	45, 32
176	4 γ Corvus	3	12 5 32,31	3, 077	16 26 S	181 23 4,58	46, 16
177	15 η Virgo	3	12 9 40,74	3, 067	0 27 N	182 25 11,13	46, 01
178	9 β Corvus	3	12 23 54,39	3, 124	22 17 S	185 58 35,92	46, 86
179	5 κ Draco	3	12 24 47,65	2, 661	70 53 N	186 11 54,72	39, 91
180	29 γ¹ Virgo	3	12 31 33,85	3, 069	0 21 S	187 53 27,72	46, 03

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
181	77 ε Ursa major	2 3	12 45 12,58	2, 746	57 3 N	191 18 8,67	41, 19
182	43 δ Virgo	3	12 45 33,66	3, 047	4 29 N	191 23 24,93	45, 71
183	47 ε Virgo	3	12 52 13,33	3, 004	12 2 N	193 3 20,01	45, 06
184	51 θ Virgo	3 4	12 59 36,46	3, 095	4 28 S	194 54 6,97	46, 42
185	2 γ Hydra	3	13 8 4,31	3, 225	22 7 S	197 1 4,64	48, 38
186	✳ preced. α Virgo	.	13 9 13,00	. . .	. . . .	197 18 15,00	. . .
187	67 SPICA	1	13 14 40,11	3, 137	10 7 S	198 40 1,66	47, 06
188	79 ζ Ursa major	2	13 15 49,62	2, 425	55 59 N	198 57 24 26	36, 37
189	99 ι Virgo	4	13 16 10,79	3, 129	11 40 S	199 2 41,83	46, 93
190	79 ζ Virgo	3	13 24 30,65	3, 064	0 26 N	201 7 39,68	45, 96
191	4 τ Bootes	4	13 37 46,36	2, 884	18 27 N	204 26 35,35	43, 26
192	85 η Ursa major	2 3	13 39 38,85	2, 355	50 19 N	204 54 42,80	35, 88
193	8 η Bootes	3	13 45 9,21	2, 860	19 25 N	206 17 18,12	42, 90
194	11 α Draco	2 3	13 58 58,88	1, 628	65 20 N	209 44 43,24	24, 42
195	98 κ Virgo	4	14 2 14,87	3, 179	9 20 S	210 33 43,04	47, 68
196	16 ARCTURUS	1	14 6 32,21	2, 722	20 15 N	211 38 3,16	40, 83
197	✳ sequ. α Bootes	.	14 6 36,46	. . .	. . . .	211 39 6,90	. . .
198	100 λ Virgo	4	14 8 19,14	3, 223	12 27 S	212 4 47,16	48, 35
199	24 γ Bootes	3	14 24 1,50	2, 428	39 11 N	216 0 22,54	36, 42
200	30 ζ Bootes	3	14 31 35,56	2, 854	14 36 N	217 53 53,42	42, 81
201	36 ε Bootes	3	14 36 14,99	2, 622	27 56 N	219 3 44,80	39, 33
202	7 μ Libra	5	14 38 22,95	3, 268	13 18 S	219 35 44,22	49, 02
203	8 α¹ LIBRA	6	14 39 38,74	3, 299	15 9 S	219 54 41,10	49, 49
204	✳ preced. α² ♎	.	14 39 38,77	. . .	. . . .	219 54 41,55	. . .
205	9 α² LIBRA	2 3	14 39 49,97	3, 289	15 12 S	219 57 29,55	49, 34
206	7 β Ursa minor	3	14 51 27,55	−0,329	74 59 N	222 51 53,19	−4, 94
207	20 γ Scorpio	3	14 52 24,35	3, 482	24 29 S	223 6 5,22	52 23
208	42 β Bootes	3	14 54 24,99	2, 262	41 11 N	223 36 14,85	33, 93
209	43 ψ Bootes	5	14 55 52,50	2, 580	27 44 N	223 58 7,57	38, 70
210	27 β Libra	2 3	15 6 15,61	3, 215	8 38 S	226 33 54,21	48, 22

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
211	49 δ Bootes	3	15 7 26,62	2, 409	34 4 N	226 51 39,28	36, 13
212	1 ο Corona North	6	15 11 51,97	2, 487	30 21 N	227 57 59,55	37, 30
213	2 η Corona North.	5	15 14 56,05	2, 465	31 1 N	228 44 0,78	36, 97
214	3 β Corona North.	4	15 19 34,88	2, 483	29 48 N	229 53 43,13	37 24
215	13 γ^2 Ursa minor	2 3	15 2: 11,76	--0,209	72 33 N	230 17 56,39	--3 14
216	35 ζ^4 Libra	4	15 21 38,42	3, 365	16 10 S	230 24 36,26	50, 48
217	38 γ Libra	3 4	15 24 21,22	3, 328	14 7 S	231 5 18,34	49, 92
218	13 δ Serpens	3	15 25 15,84	2, 861	11 13 N	231 18 57,61	42, 91
219	5 GEMMA	2	15 26 13,29	2, 543	27 24 N	231 33 19,35	38, 15
220	43 κ Libra	4	15 30 27,12	3. 433	19 1 S	232 36 46 77	51, 49
221	24 α SERPENS	2	15 34 25,21	2, 936	7 4 N	233 36 18,00	44, 04
222	* sequ. α Serpens	.	15 36 23.53	. . .	. . . .	234 5 53,05	. . .
223	28 β Serpens	3	15 36 57,70	2, 756	16 4 N	234 14 25,47	41, 34
224	32 μ Serpens	4	15 39 10,30	3, 023	2 48 S	234 47 34,55	45, 35
225	37 ε Serpens	3 4	15 40 50,97	2, 969	5 6 N	235 12 44.51	44, 54
226	10 δ Corona North.	4	15 41 12,45	2, 515	26 42 N	235 18 6,71	37, 73
227	45 λ Libra	4	15 41 44,86	3, 457	19 33 S	235 26 12,93	51, 86
228	5 ρ Scorpio	3 4	15 44 33,34	3, 671	28 37 S	236 8 20,06	55, 06
229	6 π Scorpio	3	15 46 46,43	3, 600	25 31 S	236 41 36 48	54, 00
230	48 ψ Libra	4	15 47 0,91	3, 339	13 41 S	236 45 13,63	50, 09
231	41 γ Serpens	3	15 47 12.93	2, 740	16 21 N	236 48 13,98	41, 10
232	7 δ Scorpio	3	15 48 31,89	3, 521	22 2 S	237 7 58,38	52, 82
233	13 ε Corona North.	4 5	15 49 18.54	2, 483	27 28 N	237 19 38,04	37, 24
234	44 π Serpens	4	15 53 41,18	2 576	23 21 N	238 25 17,72	38, 64
235	8 β Scorpio	2	15 53 49,71	3, 465	19 15 S	238 27 25,65	51, 97
236	13 ϑ Draco	3 4	15 58 8,28	1, 142	59 6 N	239 32 4,27	17, 13
237	14 ν Scorpio	4	16 0 23,31	3, 465	18 56 S	240 5 49,60	51, 96
238	1 δ Ophiuchos	3	16 3 52,80	3, 132	3 10 S	240 58 11,95	46, 98
239	2 ε Ophiuchos	3 4	16 7 45,09	3, 154	4 12 S	241 56 16,31	47, 30
240	20 γ Hercules	3	16 13 5,83	2, 642	19 38 N	243 16 27,41	39, 63

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			h ′ ″ 1/100	″ 1/1000	° ′ Nor. Sou.	° ′ ″ 1/100	″ 1/100
				+			+
241	21 ANTARES	1	16 17 9,69	3, 645	25 58 S	244 17 25,35	54, 68
242	* α Scorpio	.	16 19 6,66	. . .	. . . .	244 46 39,90	. . .
243	8 φ Ophiuchos	4 5	16 19 43,03	3, 418	16 10 S	244 55 45,42	51, 27
244	14 η Draco	3 4	16 21 18,33	0, 785	61 58 N	245 19 34,92	11, 78
245	27 β Hercules	3	16 21 37,87	2, 579	21 56 N	245 24 28,08	38, 68
246	23 τ Scorpio	4	16 23 26,96	3, 709	27 47 S	245 51 44,36	55, 64
247	13 ζ Ophiuchos	2 3	16 26 9,55	3, 287	10 9 S	246 32 23,24	49, 30
248	40 ζ Hercules	3 4	16 33 45,64	2, 292	32 1 N	248 26 24,67	34, 38
249	44 η Hercules	3 4	16 36 3,14	2, 046	39 19 N	249 0 47,15	30, 69
250	58 ε Hercules	3	16 52 38,68	2, 292	31 16 N	253 9 40,16	34, 38
251	35 η Ophiuchos	2 3	16 58 55,15	3, 424	15 28 S	254 43 47,26	51, 36
252	* preced. α Hercules	.	17 5 12,70	. . .	. . .	256 18 10,50	. . .
253	64 α HERCULES	2 3	17 5 31,76	2, 726	14 38 N	256 22 56,40	40, 89
254	65 δ Hercules	3 4	17 6 49,41	2, 459	25 5 N	256 42 21,17	36, 88
255	42 θ Ophiuchos	3	17 9 44,25	3, 669	24 47 S	257 26 3,68	55, 04
256	35 λ Scorpio	3	17 20 2,64	4, 057	36 57 S	260 0 39,58	60, 85
257	* preced. α Ophiu.	.	17 24 45,90	. . .	. . . .	261 11 28,50	. . .
258	55 α OPHIUCHOS	2	17 25 38,97	2, 768	12 43 N	261 24 44,55	41, 52
259	* fequ. α Ophiuchos	.	17 29 11,02	. . .	. . . .	262 17 45,32	. . .
260	23 β Draco	3	17 25 55,99	1, 348	52 27 N	261 28 59,82	20, 22
261	60 β Ophiuchos	3	17 33 35,77	2, 959	4 40 N	263 23 56,54	44, 39
262	62 γ Ophiuchos	3	17 37 52,04	3, 003	2 48 N	264 28 0,56	45, 05
263	57 ζ Serpens	3 4	17 49 54,59	3, 153	3 40 S	267 28 38,87	47, 30
264	67 ο Oph. v. Taur. Poniatowfky	4	17 50 37,47	2, 999	2 57 N	267 39 21,99	44, 99
265	33 γ Draco	2 3	17 51 57,79	1, 389	51 31 N	267 59 26,85	20, 83
266	10 γ Sagittarius	3 4	17 52 58,05	3, 851	30 25 S	268 14 30,76	57, 77
267	. b Taur. Poniat.	.	18 0 41,10	2, 993	3 19 N	270 10 16,50	44, 90
268	13 μ^1 Sagittarius	4	18 1 48,37	3, 584	21 6 S	270 27 5,63	53, 76
269	15 μ^2 Sagittarius	4 6	18 3 16,90	3, 575	20 46 S	270 49 13,57	53, 62
270	20 ε Sagittarius	2 3	18 10 53,67	3, 984	34 28 S	272 43 25,11	59, 76

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
271	22 λ Sagittarius	4	18 15 37,66	3, 705	25 31 S	273 54 24,92	55, 57
272	* preced. α Lyra	.	18 28 40,12	. . .	. . . .	277 10 1,88	. . .
273	3 WEGA	1	18 30 9,89	1, 994	38 36 N	277 32 28,35	29, 91
274	* fequ. α Lyra	.	18 31 40,00	. . .	. . . .	277 54 50,00	. . .
275	27 φ Sagittarius	3 4	18 33 9,39	3, 747	27 11 S	278 17 20,84	56, 21
276	4 ε Lyra	5	18 37 42,87	1, 983	39 28 N	279 25 43,03	29, 74
277	32 ν^1 Sagittarius	4 5	18 42 5,41	3, 625	22 59 S	280 31 21,22	54, 38
278	10 β Lyra	3	18 42 41,86	2, 211	33 9 N	280 40 27,89	33, 16
279	34 σ Sagittarius	3	18 42 51,40	3, 724	26 32 S	280 42 50,99	55, 86
280	35 ν^2 Sagittarius	4 5	18 43 1,13	3, 623	22 54 S	280 45 16,99	54, 35
281	63 θ Serpens Dup.	3	18 46 16,82 / 18,32	2, 977	3 57 N	281 34 12,35 / 34,84	44, 66
282	12 δ Lyra	3 4	18 47 31,16	2, 095	36 39 N	281 52 47,43	31, 42
283	47 ο Draco	4	18 48 14,15	0, 880	59 9 N	282 3 32,20	13, 21
284	14 γ Lyra	3	18 51 27,04	2, 241	32 26 N	282 51 45,55	33, 61
285	39 ο Sagittarius	4	18 52 41,18	3, 595	22 1 S	283 10 17,72	53, 92
286	40 τ Sagittarius	4	18 54 26,45	3, 758	27 57 S	283 36 36,82	56, 37
287	16 λ Antinous	3 4	18 55 38,10	3, 186	5 10 S	283 54 31,55	47, 79
288	17 ζ Aquila	3	18 56 12,69	2, 755	13 35 N	284 3 10,37	41, 33
289	41 π Sagittarius	3 4	18 57 51,37	3, 574	21 20 S	284 27 50,57	53, 61
290	42 ψ Sagittarius	4 5	19 3 15,27	3, 685	25 35 S	285 48 49,04	55, 27
291	43 *d* Sagittarius	4 6	19 5 55,86	3, 517	19 18 S	286 28 57,90	52, 76
292	57 δ Draco	3	19 12 27,95	0, 033	67 19 N	288 6 59,21	0, 49
293	1 κ Cygnus	4	19 12 28,28	3, 383	52 58 N	288 7 4,19	20, 73
294	30 δ Aquila	3	19 15 24,12	1, 008	2 44 N	288 51 1,79	45, 12
295	6 β Cygnus	3	19 22 38,53	2, 415	27 33 N	290 39 37,97	36, 23
296	10 ι Cygnus	4 6	19 24 39,61	1, 511	51 19 N	291 9 54,19	22, 67
297	41 ι Antinous	3 4	19 26 22,16	3, 106	1 43 S	291 35 32,37	46, 59
298	13 θ Cygnus	4	19 31 5,16	1, 645	49 46 N	292 46 17,40	24, 68
299	5 α Sagitta	4	19 31 9,25	2, 678	17 34 N	292 47 18,74	40, 17
300	56 *f* Sagittarius	6	19 34 41,43	3, 520	20 14 S	293 40 21,39	52, 80

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Ascension in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Ascension in Equat. Part.	Annual Variation in R. A.
			h ′ ″ 1/100	″ 1/1000	° ′ Nor. Sou.	° ′ ″ 1/100	″ 1/100
				+			+
301	* preced. γ Aquila	.	19 35 12,50	. . .	. . . .	293 48 7,50	. . .
302	50 γ AQUILA	3	19 36 44,50	2, 837	10 8 N	294 11 7,50	42, 59
303	* sequ. γ Aquila	.	19 39 0,81	. . .	. . . .	294 45 12,16	. . .
304	18 δ Cygnus	3	19 38 43,09	1, 869	44 39 N	294 40 46,34	28, 02
305	* preced. α Aquila	.	19 38 35,87	. . .	. . . .	294 38 58,05	. . .
306	53 ATAIR	1 2	19 41 1,02	2, 918	8 21 N	295 15 15,30	43, 78
307	* sequ. α Aquila	.	19 42 52,37	. . .	. . . .	295 43 5,55	. . .
308	55 η Antinous	3 4	19 42 17,14	3, 058	0 30 N	295 34 17,08	45, 87
309	59 b Sagittarius	4 5	19 44 39,56	3, 699	27 41 S	296 9 53,46	55, 48
310	60 β AQUILA	3 4	19 45 28,97	2, 939	5 55 N	296 22 14,55	44, 08
311	65 θ Aquila	3	20 0 58,52	3, 097	1 24 S	300 14 37,75	46, 45
312	5 α¹ CAPRICOR.	3 4	20 6 32,79	3, 330	13 7 S	301 38 11,88	49, 95
313	* preced. α² Capricor.	.	20 5 17,48	. . .	. . . .	301 19 22,20	. . .
314	6 α² CAPRICOR.	3	20 6 56,48	3, 331	13 9 S	301 44 7,20	49, 96
315	* sequ. α² Capricor.	.	20 9 33,32	. . .	. . . .	302 23 19,80	. . .
316	prec. β Capr. N. 827 Mayer	.	20 9 31,35	3, 380	15 24 S	302 22 50,19	50, 70
317	8 ν Capricornus	6	20 9 33,69	3, 337	13 23 S	302 23 25,39	50, 06
318	9 β Capricornus	3	20 9 45,50	3, 380	15 24 S	302 26 22,54	50, 70
319	37 γ Cygnus	3	20 15 2,63	2, 148	39 38 N	303 45 39,39	32, 22
320	11 ρ Capricornus	6	20 17 26,45	3, 438	18 28 S	304 21 36,72	51, 57
321	4 ζ Delphinus	4 5	20 25 57,50	2, 801	14 0 N	306 29 22,44	42, 01
322	6 β Delphinus	3	20 28 10,32	2, 804	13 55 N	307 2 34,74	42, 06
323	9 α Delphinus	3	20 30 20,76	2, 780	15 13 N	307 35 11,37	41, 70
324	50 DENEB.	1 2	20 34 36,68	2, 034	44 34 N	308 39 10,20	30, 51
325	* sequ. α Cygnus	.	20 40 28,55	. . .	. . . .	310 7 8,25	. . .
326	2 ε Aquarius	4 5	20 36 50,38	3, 255	10 13 S	309 12 35,72	48, 83
327	* preced. γ Delphi.	.	20 37 21,94	. . .	. . . .	309 20 29,08	. . .
328	12 γ Delphinus	3	20 37 22,96	2, 783	15 25 N	309 20 44,34	41, 75
329	53 ε Cygnus	3	20 38 6,70	2, 393	33 13 N	309 31 40,56	35, 89
330	6 μ Aquarius	4 5	20 41 51,17	3, 243	9 43 S	310 27 47,61	48, 65

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Ascension in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Ascension in Equat. Part.	Annual Variation in R. A.
			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
331	7 Aquarius	6	20 46 4,59	3, 255	10 28 S	311 31 8,80	48, 82
332	23 ϑ Capricornus	5 4	20 54 39,75	3, 384	18 1 S	313 39 56,25	50, 76
333	13 ν Aquarius	5	20 58 41,24	3, 274	12 10 S	314 40 18,64	49, 11
334	8 α Equuleus	4	21 5 48,78	2, 997	4 26 N	316 27 11,73	44, 96
335	32 ι Capricornus	5	21 11 5,67	3, 355	17 41 S	317 46 25,00	50, 33
336	4 β Equuleus	6	21 12 57,71	2, 981	5 58 N	318 14 25,62	44, 72
337	18 Aquarius	6	21 13 14,77	3, 286	13 44 S	318 18 41,53	49, 29
338	5 α Cepheus	3	21 13 46,85	1, 427	61 45 N	318 26 42,69	21, 40
339	22 β Aquarius	3	21 21 1,12	3, 165	6 27 S	320 15 16,74	47, 48
340	39 ε Capricornus	4	21 25 52,29	3, 379	20 21 S	321 28 4,34	50, 68
341	8 β Cepheus	3	21 26 1,18	0, 821	69 41 N	321 30 17,76	12, 32
342	40 γ Capricornus	3 4	21 28 59,14	3, 329	17 33 S	322 14 47,15	49, 93
343	43 κ Capricornus	5	21 31 27,98	3, 360	19 46 S	322 51 59 74	50, 40
344	8 ε Pegasus	3	21 34 21,53	2, 943	8 58 N	323 35 22,99	44, 15
345	80 π¹ Cygnus	4	21 34 59,63	2, 116	50 17 N	323 44 54,38	31, 74
346	49 δ Capricornus	3	21 35 58,68	3, 310	17 1 S	323 59 40,25	49, 65
347	⁕ preced. α Aquarius	.	21 55 8,21	. . . .	. . . .	328 47 3,15	. . .
348	34 α AQUARIUS	3	21 55 29,75	3, 067	1 17 S	328 52 26,25	46, 00
349	48 γ Aquarius	3	22 11 18,89	3, 094	2 23 S	332 49 43,29	46, 41
350	52 π Aquarius	4 5	22 15 4,00	3, 065	0 22 N	333 45 59,98	45, 97
351	55 ζ Aquarius	4	22 18 31,68	3, 079	1 2 S	334 37 55,26	46, 18
352	57 σ Aquarius	5	22 20 2,99	3, 186	11 42 S	335 0 44 84	47, 79
353	7 Lacerta	4	22 23 7,61	2, 431	49 16 N	335 46 54,14	36, 46
354	62 η Aquarius	4	22 25 4,59	3, 079	1 9 S	336 16 8,78	46, 19
355	63 κ Aquarius	5	22 27 23 38	3, 117	5 14 S	336 50 50,67	46, 76
356	42 ζ Pegasus	3	22 31 29,06	2, 981	9 48 N	337 52 15,89	44, 72
357	44 η Pegasus	3	22 33 37,87	2, 792	29 11 N	338 24 27,91	41, 88
358	69 τ¹ Aquarius	5	22 37 4,70	3, 197	15 7 S	339 16 10,57	47, 96
359	71 τ² Aquarius	5 6	22 38 59,29	3, 190	14 39 S	339 44 49,41	47, 85
360	73 λ Aquarius .	4	22 42 10,52	3, 137	8 38 S	340 32 37,87	47, 05

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N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Ascension in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Ascension in Equat. Part.	Annual Variation in R. A.
			h ′ ″ 1/100	″ 1/1000	° ′ Nor. Sou.	° ′ ″ 1/100	″ 1/100
				+			+
361	32 ι Cepheus	4	22 42 35,33	2, 109	65 9 N	340 38 49.95	31, 63
362	76 δ Aquarius	3	22 44 1,80	3, 201	16 53 S	341 0 27,06	48, 02
363	* prec. α Pisc. South.	.	22 40 17,35	. . .	. . . .	340 4 20,25	. . .
364	24 FOMALHAUT	1	22 46 33,60	3, 330	30 41 S	341 38 24,00	49, 95
365	* sequ. α Pisc. South.	.	22 48 38,04	. . .	. . . .	342 9 30,60	. . .
366	53 β Pegasus	2	22 54 5,50	2, 874	27 0 N	343 31 22,47	43, 11
367	54 MARKAB	2	22 54 47,99	2, 964	14 8 N	343 41 59,85	44, 46
368	* sequ. α Pegasus	.	22 55 35,64	. . .	. . . .	343 53 54,60	. . .
369	90 φ Aquarius	4 5	23 3 57,39	3, 109	7 7 S	345 59 20,79	46, 64
370	91 ψ¹ Aquarius	5	23 5 23,05	3, 125	10 10 S	346 20 45,68	46, 88
371	6 γ Pisces	5	23 6 46,42	3, 057	2 12 N	346 41 36,37	45, 85
372	95 ψ³ Aquarius	3	23 8 32,63	3, 125	10 42 S	347 8 9,48	46, 88
373	16 Pisces	6	23 26 11,40	3, 065	1 0 N	351 32 50,96	45, 97
374	18 λ Pisces	5	23 31 51,01	3, 066	0 40 N	352 57 45,08	45, 99
375	19 Pisces	5 6	23 36 10,88	3, 062	2 23 N	354 2 43,18	45, 93
376	28 ω Pisces	5	23 49 2,88	3, 061	5 46 N	357 15 43,16	45, 92
377	* prec. α Andromeda	.	23 55 45,47	. . .	. . . .	358 56 22,05	. . .
378	* prec. α Andromeda	.	23 56 15,28	3, 060		359 3 49,19	45, 90
379	21 α ANDROMED.	2	23 58 4,32	3, 065	27 59 N	359 31 4,95	45, 97
380	* sequ. α Andromeda	.	0 1 32,98	. . .	. . . .	0 23 14,70	. . .
381	11 β Cassiopea.	2 3	23 58 34,32	3, 051	58 3 N	359 38 34,75	45, 76

ASTROTHEMATA, the places or positions of the stars, in an astrological scheme of the heavens.

ASTROTHESIA, is used by some for a constellation or collection of stars in the heavens.

ASTRUM, or ASTRON, a constellation or assemblage of stars: in which sense it is distinguished from *Aster*, which denotes a single star. Some apply the term, in a more particular sense, to the Great Dog, or rather to the large bright star in his mouth.

ASYMMETRY, the want of proportion, otherwise called *incommensurability*, or the relation of two quantities which have no common measure, as between 1 and $\sqrt{2}$, or the side and diagonal of a square.

ASYMPTOTES, (see Encycl.) are, by some, distinguished into various orders. The asymptote is said to be of the first order, when it coincides with the base of the curvilinear figure; of the second order, when it is a right line parallel to the base; of the third order, when it is a right line oblique to the base; of the fourth order, when it is the common parabola, having its axis perpendicular to the base; and, in general, of the $n+2$ order, when it is a parabola whose ordinate is always as the n power of the base. The asymptote is oblique to the base, when the ratio of the first fluxion of the ordinate to the fluxion of the base approaches to an assignable ratio, as its limit; but it is parallel to the base, or coincides with it, when this limit is not assignable.

ATTAR OF ROSES. See *Roses, Otter of*, both in the Encyclopædia and in this Supplement.

AVANT-FOSS, or *Ditch of the Counterscarp*, in fortification, is a wet ditch surrounding the counterscarp on the outer side, next to the country, at the foot of the glacis. It would not be proper to have such a ditch if it could be laid dry, as it would then serve as a lodgment for the enemy.

AVALON, a peninsula at the S. E. corner of the island of Newfoundland, which is joined to the island by a narrow neck of land, that has Placentia Bay on the S. and Trinity Bay on the N. The E. part of this peninsula is encompassed by the Great Bank, and has, besides the two former bays, the bay of Conception on the N. and the bay of St Mary's and Trepassy bay on the S. It contains several excellent harbors, bays and capes, among which are St Mary's, Pine, Race, Ballard, St Francis, &c.—*Morse*.

AUBIGNE. See STUART in this supplement.

AVES, or *Bird's Island*, in the West Indies, situated in N. lat. 15. 30. W. long. 63. 15. named so from the great number of birds that breed there, yet is without a tree, which obliges them to lay their eggs in the sand. A shoal runs from hence to the islands of Saba, St Eustatius, and St Christophers; which is about 2 leagues broad, and from 10 to 20 fathom soundings.

There is another island of this name, among the Little Antilles, between the coast of St Jago de Leon, in Terra Firma, and the island of Bonaire.—*Morse*.

AUGUSTA *Co.* in Virginia, has Albemarle co. on the E. Part of it lies E. and part W. of the North Mt. a ridge of the Allegany. The soil is fertile, and the county contains 10,886 inhabitants, including 1567 slaves.

Here is a remarkable cascade, called the *Falling Spring*. It is a branch of the James, where it is called Jackson's River rising in the mountains 20 miles S. W. from the *Warm Spring*, or *Hot Spring*, which lies in N. lat. 38. 9. W. long. 80. 6. At the *Falling Spring*, the water falls 200 feet; which is about 50 feet higher than the fall of Niagara. Between the sheet of water and the rock below, a man may walk across dry. The sheet of water is only 12 or 15 feet wide above and somewhat wider below. It is broken in its breadth in two or three places, but not at all in its height.—*ib.*

AUGUSTA, in the Upper District of Georgia, was till lately the seat of government. It is situated on a fine plain in Richmond co. on the S. W. bank of Savannah R. where it is nearly 500 yards broad, at a bend of the river, 127 miles N. W. from Savannah; from Washington S. E. by E. and from Louisville S. westerly, 50 miles; and 934 miles S. W. from Philadelphia.

At the first settlement of the colony, Gen. Oglethorpe erected a fort here, for protecting the Indian trade, and holding treaties with the natives. In 1739, about 600 people separated themselves from the maritime settlements, and removed to its neighbourhood to carry on a peltry trade with the Indians. There were, however, but 3 or 4 houses in the town of Augusta in 1780, and in 1787 it contained 200. The country round it has an excellent soil, which with its central situation between the upper and lower countries, will bring it fast into importance. N. lat. 33. 19. W. long. 80. 46.—*ib.*

AUMIL, in Bengal, a native collector or manager of a district on the part of government.

AVON, a river of Nova-Scotia, which empties into the Atlantic Ocean a little eastward of Halifax. It is navigable as far as Fort Edward for vessels of 400 tons, and for vessels of 60 tons 2 miles higher. A river called St Croix runs into the Avon, whose source is in lakes and springs, about 7 miles from its entrance, where it is crossed by a bridge on the road leading to Windsor. It is navigable for vessels of 60 tons 3 miles, and for large boats 7 miles.—*Morse*.

AURELIUS, a military township in New-York, in Onondaga co. on Owasco Lake having the Cayuaga Reservation Lands W. and Marcellus E. and 9 miles E. of the ferry on Cayuaga Lake. By the state census of 1796, 213 of the inhabitants are electors.—*ib.*

AUTENIQUA, a large and beautiful country in Africa, lying to the east of the Cape of Good Hope, and inhabited, part of it, by Dutch colonists. The word *Auteniqua* signifies, in the Hottentot language, "a man loaded with honey;" a name which is not improperly given to the country, since, as you enter it from the Cape, you cannot proceed a step without seeing a thousand swarms of bees. The flowers on which they feed spring up in myriads; and your attention is engaged, and your course suspended, by the mixed odours which exhale from them, by their colours and variety, and by the pure cool air which you breathe. Nature has made these enchanting regions like fairy land. The calyxes of all the flowers abound with excellent juices, from which the bees extract the honey that they every where deposit in hollow rocks and trees.

This country was visited in 1782 by M. Vaillant, who calls it the most delightful region in the universe;

Auteniqua. and says, that, as he approached it, he beheld, from the top of a very high mountain, an immense valley, adorned with agreeable hills, variegated in an infinite number of shapes, and extending in an undulating manner as far as the sea; whilst enamelled meads, and the most beautiful pastures, still added to the magnificent scene. It abounds with small rivulets, which, flowing down from the mountains, run into the sea through an hundred different channels. The water of these rivulets has the colour of Madeira wine, and a ferruginous taste; but our traveller did not examine whether this taste and colour proceed from their flowing through some mine in their passage, or from the roots and leaves of trees which they carry along with them.

The whole of Auteniqua, from the chain of mountains which divides it from the country of that race of Hottentots called *Gonaquas* to the sea, is inhabited by several planters, who rear a number of cattle, make butter, cut down timber, and collect honey; all of which they transport to the Cape: but it appears that they make not the most of their situation. "Can it be believed (says M. Vaillant), that the directors of the Company, for their own use, should order ships to be sent every year from Amsterdam, loaded with planks and boards of every kind, whilst in this country there are immense forests, and the most beautiful trees in the world? This absurdity, however, is not at all astonishing. The Company gratuitously furnishes the governor and all the officers with whatever wood they have occasion for; and it is delivered to them at their houses without any expence. The governor therefore has no *personal* interest to extend his views to this part of the administration, and to abolish an abuse so prejudicial to the colony."

But the colonists themselves must be a very indolent and stupid kind of people; since, if our traveller deserves credit, they neglect advantages with which the personal interest of the governor cannot possibly interfere. "I was filled with indignation (says M. Vaillant) to see people, who have wood within their reach, employ it in commerce, and not have the courage to build for themselves habitable houses. They live in wretched hovels, constructed of wicker-work, daubed over with clay; the skin of a buffalo, fixed at the four corners to as many stakes, serves them for a bed; and the door, which is at the same time a window, is shut by a mat; while two or three mutilated chairs, a few pieces of plank, a kind of table, and a pitiful box of two feet square, form all the furniture of these colonial habitations. Thus is the picture of the most profound misery contrasted with the charms of this terrestial paradise; for the beauties of these regions extend even beyond Auteniqua. The people, however, though their houses be bad, live well. They have game and salt-water fish in abundance; and enjoy exclusively, over all the other cantons of these colonies, the advantage of having, for the whole year without interruption, vegetables of every kind in their gardens. For this they are indebted to the excellence of the soil, and to its being naturally watered by small streams, which cross each other in a thousand different directions, and, as one may say, lay the four seasons under contribution to fertilize Auteniqua. These streams, which frequently overflow their banks, but never dry up, proceed from a cause well known; the high mountains towards the east, which are covered with forests, stop the clouds and the fogs carried from the sea, and this occasions very abundant rains." Auteniqua.

In these mountainous regions, which, as well as the plain, our author comprehends under the denomination of *Auteniqua*, there are multitudes of elephants, buffaloes, panthers, hyenas, and antelopes of every species; and all these animals are hunted and killed by the natives, as well for food as for the protection of their flocks and herds from such of them as are beasts of prey. Our author has eaten the flesh of every one of them except the hyena; and declares, that the foot of an elephant, baked after the Hottentot manner, is one of the most delicious morsels that he ever tasted. He gives directions for hunting them all; but warns his readers from attacking elephants when he finds them in droves, for then, he says, they are invincible. He even thinks it exceedingly dangerous for one man, however well armed, to attack a single elephant in the plain. The buffalo he describes, contrary to most other travellers, as a timid animal, which never resists till his situation becomes desperate; and he thinks that there would be no difficulty in training him, if caught when a calf, to the yoke like the bullocks of Europe.

The kites and vultures of this country, our traveller represents as in the highest degree voracious and fierce, insomuch that it is hardly possible to fright them from their prey. He had on one occasion killed two buffaloes, which he ordered to be cut into very small pieces, that they might be more easily salted, and exposed afterwards to the air and the sun. His waggons, as well as the bushes and trees which surrounded him and his people, were loaded with the bloody fragments of these two animals, and they had begun their operation of salting: but on a sudden, while they were not expecting it, they found themselves attacked by flights of kites and vultures, which, without exhibiting the least symptoms of fear, perched in the midst of them. The kites were above all the most impudent. They seized upon the morsels of flesh, and even contended furiously with his people. "When they had each carried away (says he) a pretty large piece, they retired to some branch, at the distance of ten paces from us, and devoured it before our eyes. Though we fired our fusees they were not frightened, but returned incessantly to the charge; so that finding our powder wasted in vain, we resolved to keep them off with large poles until our provisions should be quite dry. This manœuvre, which for a long time harrassed my people, did not prevent us from being plundered without mercy; but had we not employed it, nothing would have remained to us of our two buffaloes."

This battle with the kites took place on the confines of the Dutch settlements; but when M. Vaillant had with difficulty passed over the mountains which bound them, the prospects became more magnificent, the soil seemed to be more fruitful and rich, nature appeared to be more majestic and grand, and the lofty mountains presented on all sides more charming and delightful points of view than any that he had ever before met with. These scenes, contrasted with the dry and parched fields of the Cape, made him exclaim, he says, in ecstacy, "What! shall these superb regions be eternally inhabited by tygers and lions? What speculator, with the sordid view only of establishing a kind of centre for commerce, Auteniqua. commerce, could have preferred the ſtormy Table Bay to the numberleſs roads and commodious harbours which are to be found on the eaſtern coaſts of Africa? Thus (continues he) was I reflecting within myſelf, whilſt I was climbing the mountain, and forming vain wiſhes for the conqueſt of this beautiful country, which the indolent policy of the European nations will perhaps never gratify."

If his deſcription of its beauties and fertility be not greatly exaggerated, it is indeed wonderful that either the Dutch or ſome other maritime power of Europe has not long ago taken poſſeſſion of it. After he had paſſed the mountain, one could not, he ſays, chooſe a more agreeable or advantageous ſpot than that upon which he then was for eſtabliſhing a thriving colony. The ſea advances through an opening of about a thouſand paces in breadth, and penetrates into the country to the diſtance of more than two leagues and a half. The baſon which it forms is more than a league in extent (he does not ſay whether in breadth or in circumference); and the whole coaſt, both on the right and the left, is bordered with rocks, which intercept all communication with it. The land is watered by limpid and refreſhing ſtreams, which flow down on all ſides from the eaſtern mountains; and theſe mountains, crowned with majeſtic woods, extending as far as the baſon, and winding round it with a number of ſinuoſities, exhibit a hundred groves, which are naturally variegated, and each more agreeable than another.

The author proceeding forwards about two days journey, arrived at a bay known to navigators by the name of the Bay of *Agoa*, but called by the coloniſts *Blettenberg's* Bay, from its having been viſited ſome time before by a Governor Blettenberg, who ordered his name, together with the year and day of his arrival, to be engraven on a ſtone column. This bay is a little beyond the limits of the country called Auteniqua; but it is not foreign from the purpoſe of this article to inſert in this place our traveller's account of it, and of the country around it.

The bay itſelf, he ſays, is very ſpacious, and has a ſufficient depth of water for the largeſt veſſels. The anchoring ground is ſure, and boats can ſail to a beautiful part of the ſhore, which is not confined by the rocks, as they are all there detached from one another. By advancing a league along the coaſt, the crews would arrive at the mouth of a conſiderable river called the *Queur-Boom*, where they would find water. Refreſhments might be procured from the inhabitants of the environs; and the bay would ſupply them with excellent fiſh, with which it abounds.

This bay is one of thoſe places where government might eſtabliſh warehouſes and repoſitories for timber; and it is for this reaſon that we have introduced it to notice in this article. The foreſts around it, ſays M. Vaillant, are everywhere magnificent, and the trees could be more eaſily cut down than anywhere elſe; for it is not to ſteep mountains that one muſt go for wood, as at Auteniqua; it is here ready at hand; and during the fine monſoon might be tranſported to the Cape with little trouble and no riſk. The inexhauſtible and fertile lands in the neighbourhood of the bay, if once cultivated, would produce abundant crops, and draw together a great number of intelligent planters, on account of the ready communication which they would have with the Cape. In a word, the Company, continues he, have nothing to do ſo much for their own intereſt as to form here a proper eſtabliſhment. To the general profits of ſuch an inſtitution, would be added thoſe of individuals, which could not fail to be of great importance. They might, for example, cut down a certain tree called *ſtinking wood*, and export it to Europe, where it would undoubtedly be ſoon preferred to mahogany and every other kind of wood employed by cabinet makers.

Auteniqua ‖ Automaton.

The Hottentots, who in ſcattered *kraals* inhabit this delightful country, our author deſcribes as a faithful, gentle, and rather timid race. He affirms, that they have no religious impreſſions whatever, nor any notion of ſuperior powers who govern the world. But this, if not a wilful falſehood dictated by the philoſophy of France, is probably a miſtake ariſing from his ſcanty knowledge of their language, and total ignorance of the meaning of their religious ceremonies. His great maſter, as well as the maſter of his ſect, *Lucretius*, might have taught him, that fear, if not a better principle, will generate the notion of ſuperior beings in the minds of ſavages; and from fear, by his own account, the inhabitants of Auteniqua are far from being free. He likewiſe affirms, and ſeems to conſider it as much to their credit, that this race of gentle beings, ſo far from being a prey to the paſſion of jealouſy (as other travellers have repreſented the Hottentots in general), are ſo obliging, as to lend their wives to travellers who viſit them, and that they actually accommodated his Hottentots in this way. Auteniqua, as laid down in M. Vaillant's map, lies between 33° 30 and 34° 50′ of ſouth latitude, and between 20° and 23° 40′ of eaſt longitude; and his rout through the country was from ſouth-weſt to north-eaſt, or nearly ſo.

AUTOMATON. Under this title and that of ANDROIDES full credit was allowed in the *Encyclopædia* to the ſtory of M. de Kempell's mechanical *cheſs-player*, and a detail at ſome length was given of the feats of that figure, as well as of ſome other ſurpriſing *automata*. No man more readily admits the powers of the ſkilful mechanician than the writer of this ſhort article; but having many years ago detected the impoſition which was practiſed on the public in ſome parts of Scotland by a circumferaneous mountebank, who exhibited a figure apparently capable of writing a certain number of words, he has ever ſince ſuſpected impoſture in all automata which appear to have the power of varying their motions according to circumſtances. With reſpect to the *cheſs-player*, there is now ſufficient evidence that his ſuſpicions were well founded.

In the deſcription of this figure (*Encycl.* Vol. I. p. 787.), "it is ſaid, that the automaton could not play unleſs M. de Kempell or his ſubſtitute was near it to direct its moves. A ſmall box during the game was frequently conſulted by the exhibiter; and herein conſiſted the ſecret, which he ſaid he could in a moment communicate." The ſecret was indeed ſimple: "A well taught boy, very thin and ſmall of his age, was concealed in this box almoſt immediately under the cheſs-board, and agitated the whole machine." This we learn from Thomas Collinſon, Eſq. who was let into the ſecret at Dreſden by a gentleman of rank and talents, named *Joſeph Freidrick Freyhere*, by whom the *vitality* and *ſoul* of the cheſs-playing figure had ſome time before been completely discovered. Mr Collinson, finding that Dr Hutton had given the same credit with us to the reality of mechanical chess-playing, undeceived his friend, by communicating the discovery of Freyhere in a letter, which the Doctor has with great propriety published in the *Addenda* to his Mathematical Dictionary. Mr Collinson adds, and we doubt not with truth, that, "even after this abatement of its being strictly an automaton, much ingenuity remains to the contriver." This was in some degree true of the mechanism of the writing figure, of which the compiler of this article detected the bungling imposture of the two exhibiters. The figure itself, with all the principles of its motion, was very ingeniously constructed; but the two men who exhibited it were ignorant and aukward, and could not conceal from a scrutinizing eye, that the automaton wrote sometimes well and sometimes ill, and never wrote at all when they were both present to the company. It was by insisting upon seeing them both together, and threatening to expose the cheat to the whole town, that the present writer prevailed upon him who appeared to be the principal exhibiter, to confess in private that his companion was concealed behind a screen, and to show how, from thence, he directed the movements of the figure.

Conjugate AXIS, or *Second Axis*, in the ellipse and hyperbola, is the diameter passing through the centre, and perpendicular to the transverse axis; and is the shortest of all the conjugate diameters.

Transverse Axis, in the ellipse and hyperbola, is the diameter passing through the two foci and the two principal vertices of the figure. In the hyperbola it is the shortest diameter, but in the ellipse it is the longest.

B.

BAAL's *River* and *Bay*, in West Greenland, lie between Bear Sound on the S. E. and Delft's Point on the N. W. and opposite the mouth of Hudson's Strait.—*Morse*.

BABAHOYO, a village and custom house on Guayaquil River, in Peru, being the landing place from the city of Guayaquil. Here the merchandize from Peru and Terra Firma, and their respective provinces, are landed.—*ib*.

BABOPAS, a town in the interior parts of New Albion, eastward of the long range of mountains which extend northward from the head of the peninsula of California. N. lat. 37. 45. W. long. 114. 25. —*ib*.

BAFFIN's *Bay*, is the largest and most northern gulf, or bay, that has yet been discovered in N. America; and lies between the 70th and 80th degrees of N. lat. It opens into the Atlantic ocean through Baffin's and Davis's straits, between Cape Chidley on the Labrador coast, and Cape Farewell on that of West Greenland; both of which are in about the 60th degree of N. lat. It abounds with whales; and on the S. W. side of Davis's straits has a communication with Hudson's Bay, through a cluster of islands. It was discovered by the navigator whose name it bears, in the year 1662. Some maps shew a communication with Hudson's Bay, in the 70th degree of N. lat. and in the 70th of W. long.—*ib*.

BAHAMA *Islands*, (See Encycl.) The first discovery of the New World, by Columbus, began October 11, 1492, at Guanahani, or Cats Island, one of the Bahamas. They were then full of people; who were simple, mild and lived happy in the midst of plenty. These unfortunate people were transported to the mines of St Domingo, after the cruel Spaniards had exterminated the numerous inhabitants of that large island; 14 years after the discovery of these islands, not one person remained in any of the Bahamas. At this time Charles II. granted the Bahamas to the proprietors of Carolina. They sent several governors, and built the town of Nassau, which is now the seat of government in the Island of Providence. The island of Providence afterwards became an harbour for pirates, who, for a long time, infested the American navigation. In 1718, Capt. Woods Rogers was sent out to dislodge the pirates, and form a settlement. This the captain effected; and the islands have been improving since by a slow progress. In time of war, the people gain considerably by the prizes condemned there; and in the course of the present war between Great-Britain and France, numbers of American vessels, carrying provisions and stores to French ports, have been carried in and condemned; and at all times they profit by the wrecks which are frequent in this labyrinth of rocks and shoals. The Spaniards and Americans captured these islands during the last war; but they were retaken April 7, 1783. The Bahamas are said to be 500 in number; some of them only rocks, others very low and narrow, or little spots of land on a level with the water's edge; but 12 of them are large and fertile, some indeed rocky and barren. Five of them only are inhabited, viz. *Providence*, *Harbor*, *Eleuthera*, *Cat*, and *Exuma*; *Turk*'s islands have about 500 men in the salt season, but at other times half of them return to Bermuda.

The principal island which has given its name to the whole cluster is *Great Bahama*, in the *Northern Bank*, called the *Little Bank of Bahama*, whose situation is E. and W. about 20 leagues from the coast of Florida. At a little distance to the E. is *Lucayoneque*, of nearly the same size, whose situation is N. and S. To the N. of both is *Lucayo*, which lies E. and W. A channel

channel of 8 or 10 leagues feparates the Little Bank, from the Great Bank, in which is *Providence I.* with the great ifland of *Alabafter*, which has *Harbor I.* on the N. Cape. *Andros* iflands are on the S. W. of Providence, which take up a fpace of 30 leagues long and 5 broad. Towards the S. E. are *Stocking*, *Exuma*, and *Yuma*, or Long Ifland. *Guanahani*, or Cats I. the firft difcovered in America, lies E. of the Great Bank, and is feparated from it by Exuma Sound.

The climate of thefe iflands is temperate and the air healthy. On the coafts is found ambergrife; and the inhabitants catch great quantities of green turtle. The only article cultivated for exportation is cotton; of which the medium export is 1,500 bags of 2 cwt. each. In 1787, there were 4,500 acres in cotton. In 1785, 1786, and 1787, which were favorable years, each acre produced about 112lb. It is very liable to be deftroyed by the worms; between Sept. and March, 1788, no lefs than 280 tons were deftroyed. Thefe iflands alfo produce a great quantity of dying woods, and fome lignumvitæ and mahogany; and lie between 22. and 27. N. lat. and 73. and 81. W. long. In 1773, there were 2052 white, and 2241 black, inhabitants; but of late years there has been a confiderable emigration from North America, fo that the precife number cannot be given.—*ib.*

BAHIA DE CHETUMEL, called by the Britifh Hanover Bay, lies on the E. fide of the peninfula of Yucatan in the fea of Honduras, and into which falls Honde River. It has the Logwood Country on the S. At its mouth are two large iflands and a number of iflots. The largeft ifland is Ambergrife Key, which runs along the mouth of the bay, and is 70 miles long.—*ib.*

BAHRDT (Dr Carl Friedirich) was fo deeply concerned in a combination of philofophers formed, as they faid, for the advancement of fcience and virtue, that an account of his life muft be interefting, if it were only to fhow the effects of this philofophic culture on his own morals. We truft therefore that our readers will be pleafed, perhaps improved, by the following narrative, taken from documents the moft authentic, by a man * whofe communications on other fubjects do credit to this volume.

* See Profeffor Robifon of Edinburgh's *Proofs of a Confpiracy againft all the Religions and Governments of Europe.*

Carl Friedirich Bahrdt was, in 1741, born at Leipfig, where his father, then a parifh minifter, and afterwards profeffor of theology, died in 1775. It is natural to fuppofe that fuch a parent would be at due pains to inftil into the mind of his fon the principles of piety, virtue, and patriotifm, which is indeed a branch of virtue; but if fo, he lived to fee that his labour had been in vain. While yet at college, where the courfe of his ftudies was calculated to fit him for the important office of preaching the gofpel, the young man enlifted as a huffar in the Pruffian fervice; but being bought off, he returned to the univerfity, where, in 1761, he was admitted to the degree of M. A. Soon afterwards he became catechift in his father's church, was a popular preacher, and in 1765 publifhed fermons, and fome controverfial writings, which evinced that he poffeffed both learning and genius. Neither learning nor genius, however, nor both united, could attach him to the caufe of virtue, or make him obferve even the common rules of decorum; for immediately after this publication he began to indulge in conviviality, and to give fcope to his refentments in anonymous pafquinades, in the higheft degree bitter and offenfive. From the fhafts of his malice no perfon was fafe. Profeffors, magiftrates, and clergymen, had indeed his chief notice; but he condefcended occafionally to attack ftudents, and fpared not even his own comrades or his friends.

Whilft he was thus labouring to make enemies of all to whom he was known, unfortunately, for his own character, his temperament was what the atomical philofophers (who can explain every thing by ethers and vibrations) call fanguine; and he was, as he himfelf acknowledged, a paffionate admirer of the ladies. Coming home from his midnight revels, he frequently met in his way a young girl neatly dreffed in a rofe coloured filk jacket and train, and a coftly fable bonnet; and one evening, after having, as he fays, indulged freely in fome old Rhenifh, he faw her home to her lodgings. Some time after this interview, the miftrefs of the houfe (a Madam Godfchufky) came into his room, and faid that the poor *maiden* whom he had debauched was pregnant. This was a misfortune *which he could not help*; but as it would ruin his character if known, he gave to the old lady a bond for 200 dahlers (about L. 40 fterling), to be paid by inftalments of twenty-five, to keep the matter fecret. "The girl (he fays) was *fenfible* and *good*; and as her converfation, for which he had already paid, was agreeable, he did not difcontinue his acquaintance."

It could not be fuppofed that fuch vifits, by a clergyman, would pafs unobferved, however cautioufly made, in the midft of a town, of which the inhabitants had been the indifcriminate objects of his fatire; and he could hardly be furprifed when told by a friend, that one Bel, a magiftrate whom he had lampooned, was acquainted with the whole affair, and would bring it into a court of juftice, unlefs the bond was immediately retired.

This bond was the only evidence which could be produced againft Bahrdt, but it was fufficient to blaft his character in Leipfig, and muft therefore by any means be removed out of the way. To accomplifh this, however, was a matter of fome difficulty; for neither he nor his friend could raife the money. In this dilemma they fell upon a contrivance worthy of themfelves. They invited Madam Godfchufky to meet them in another houfe to receive the 200 dahlers due to her by Bahrdt; but when fhe was ufhered into the room, and found no perfon waiting for her but Bahrdt's friend, fhe could not be prevailed upon to produce the bond till the money fhould be put into her hands, together with a prefent to herfelf. The *Gentleman* tried to intimidate her. He drew his fword; fhowed her how men fence; made pufhes at the wall and then at her; but finding that fhe could not be frightened out of her fenfes, he threw away his fword, and endeavoured to take the bond from her by force. It was fome time before he prevailed; but at laft getting the paper out of her pocket, he tore it in pieces, opened the door of a clofet in which Bahrdt was concealed, and faid, "There, you b——; there is the honourable fellow whom you and your whore have bullied; but it is with me you have now to do, and you know that I can bring you to the gallows."

Bahrdt, from whofe memoirs of himfelf this ftory is taken, admits that there was a great fquabble on the occafion;

Bahrdt. occafion; but he went home, comforting himfelf with the belief that he fhould now have no farther trouble from Madam Godfchufky or her girl. He chanced, however, to be miftaken. The magiftrate Bel had fome how been made acquainted with this nefarious tranfaction, and brought it into court on the day that our hero was to make fome very reverend appearance at church. The cafe of Bahrdt was now hopelefs; for after fome unfuccefsful attempts of his poor father to fave him, he was obliged to give in his gown and band, and to quit Leipfig.

To a parent the public difgrace of a child is one of the fevereft calamities to which human nature is liable; but for this calamity the father of Bahrdt muft have been long prepared, as his fon appears to have been remarkably undutiful. Of this we have one memorable inftance recorded by himfelf. His father, he fays, was fevere, and his own temperament hafty, fo that he fometimes forgot himfelf. "One day (continues he) I laid a loaded piftol on the table, and told him that he fhould meet with that if he went on fo; but I was then only SEVENTEEN!"

On his being obliged to leave the place of his nativity, the friends of Bahrdt, and in particular Semler, an eminent theological writer, who had formed a very favourable opinion of his talents, were affiduous in their endeavours to procure an eftablifhment for him elfewhere; but his high opinion of himfelf, his impetuous and precipitant temper, and that fatirical habit which he had fo freely indulged in his outfet in life, made their endeavours long ineffectual. At laft he got a profefforfhip at Erlangen, then at Erfurth, and in 1771 at Gieffen. But in each of thefe places he was no fooner fettled than he got into difputes with his colleagues and with the eftablifhed church; for he was a ftrenuous partizan of the innovations then attempted to be made in the doctrines of Chriftianity. In his publications, which were generally anonymous, he did not truft to rational difcuffion alone, but had recourfe to ridicule and perfonal anecdotes, and indulged in the moft cutting farcafms and grofs fcurrility.

His love for convivial company continuing, his income was infufficient for the craving demand. Finding therefore that anecdote and flander always procured readers, and poffeffing a wonderful activity and facility in writing, he never ceafed from publifhing lampoons and fatires, in which he fpared neither friends nor foes. But it was impoffible to prevent thefe publications from being traced to their author; and his avowed theological writings being fuch as could not be fuffered in a profeffor of divinity, the hoft of enemies which he had been at fo much pains to raife againft himfelf, were furnifhed with fufficient grounds for fubjecting his conduct to legal cognizance; even the very ftudents at Gieffen were fhocked at fome of his liberties.

The confequence of all this was, that, after much wrangling in the church judicatories, he was juft about to be difmiffed from his profefforfhip, when he got an invitation to Marfchlins in Switzerland to fuperintend an academy.

To Marfchlins he went about the year 1776, and began his new career by forming the feminary after the model of an academy which had fome time before been fet up in the principality of Anhalt Deffau by one Bafedow, a man of talents and learning, who gave to it the appellation of PHILANTHROPINE. The plan of this academy was very different from thofe of the univerfities; for its author profeffed to confider languages, fciences, and the ornamental exercifes, as mere acceffories, his aim being to form the young mind to the love of mankind and of virtue, by a courfe of moral education certainly fpecious, and apparently unexceptionable. To make this novel inftitution the more extenfively ufeful, the rules by which the education was to be conducted were framed in fuch a manner as, it was thought, would remove from the minds of Catholics, Lutherans, and Calvinifts, all uneafinefs refpecting the faith of their children, as it related to thofe particular tenets which feparated them into different communions. It was even propofed to banifh from the philanthropine all *pofitive* religion whatever, and to inftruct the youth educated there in the principles only of natural, or, as it was called, *philofophical religion*.

This plan was peculiarly fuited to Bahrdt's tafte, becaufe it left him at liberty to introduce into his academy any fyftem of religious or irreligious opinions that he pleafed; a liberty of which he refolved to avail himfelf, and, though now a doctor in theology, to outftrip, in licentioufnefs, even the founder of the philanthropine, who was not in orders. By meditating on the workings of his own mind, he had by this time formed his theory of human nature, which was indeed very fimple. "The leading propenfities of the human mind (he fays) are three; inftinctive liberty, inftinctive activity, and inftinctive love." By thefe expreffions we fuppofe he means, "innate *love* of liberty, inftinct prompting to action, and the fexual appetite:" and he immediately adds, that "if a man is obftructed in the gratification of any of thefe propenfities, he fuffers an injury. The bufinefs therefore of a good education is to teach us how they are to be gratified in the higheft degree."

That fuch an education would be approved of by the uncorrupted natives of Switzerland was hardly to be expected; and Bahrdt foon found his fituation at Marfchlins as uncomfortable as it had been at Gieffen. "The Grifons (he fays) were a ftrong inftance of the immenfe importance of education. They knew nothing but their handicrafts; and their minds were as coarfe as their perfons." He quarrelled with them all, and was obliged to abfcond after lying fome time in prifon.

From Marfchlins he went to Durkheim, a town in the palatinate, where his father had been minifter, and where his literary talents were well known. After fome little time he got an affociation formed for erecting and fupporting a *Philanthropine* or houfe of education. A large fund was collected; and he was enabled to travel into Holland and England to engage pupils, and was furnifhed with proper recommendations.

In London he gained the friendfhip of a clergyman, whom he reprefents as a perfon in the higheft degree accomplifhed. "With found judgment (fays Bahrdt), great genius, and correct tafte, he was perfectly a man of the world. He was my friend, and the only perfon who warmly interefted himfelf for my inftitution. To his earneft and repeated recommendations I owe all the pupils that I got in England, and many moft refpectable connections; for he was univerfally efteemed as a man of learning and of the moft unblemifhed character. He was my friend, my conductor, and I may fay my preferver;

Bahrdt. preserver; for when I had not bread for two days, he took me to his houfe, and fupplied all my wants."

For fo much kindnefs the reader doubtlefs fuppofes that the heart of Bahrdt overflowed with gratitude; but if fuch be his opinion, he is a ftranger to the principles of thofe who have on the continent of Europe affociated for the purpofe of enlightening the world. This amiable man, whofe character is here fo juftly drawn, was afterwards depicted by the monfter whom he had faved from perifhing by hunger, as a wretch loft to all fenfe of fhame and decency, as an apoftate from the Chriftian faith, and as a notorious frequenter of the London brothels! Fortunately he was able to vindicate his character completely from this flanderous abufe, and to convict Bahrdt of having publifhed what *could not poffibly be true*.

This ungrateful liar returned from England, and carried into execution his plan of the Philanthropine. The caftle of Count Leining Hartzburgh at Heidefheim, having gardens, park, and every handfome accommodation, had been fitted up for it; and in 1778 it was confecrated by a folemn religious feftival. But his old misfortunes purfued him. He had indeed no colleagues with whom he could quarrel; but his *avowed* publications became every day more obnoxious; and when any of his *anonymous* pieces had a great run, he could not fo far ftifle his vanity as to conceal that he was the author. Of thefe pieces fome were fhocking to decency, and others fo horribly injurious to the characters of the moft refpectable men in the ftate, that he was continually under the correction of the courts of juftice. It was hardly poffible for a man of letters to be in his company, and not fuffer by it; for it was his conftant practice to attribute every ftep which he took towards atheifm, to the force of the arguments urged by fome of his friends.

To be his friend, or to obtain his applaufe, was indeed fo great a misfortune, that when the reader fees any perfon celebrated by Dr Bahrdt, in the beginning of a book, for found fenfe, profound judgment, accurate reafoning, or praifed for acts of friendfhip to himfelf, he may be affured, that before the clofe of the book this man fhall be reprefented as having in private converfation convinced the author, that fome doctrine, cherifhed and venerated by all Chriftians, is a piece of knavifh fuperftition.

Dr Bahrdt had married, while at Gieffen, a woman with a fmall fortune: but fuch a ftranger was he to the delicacies of wedded love, fo loft indeed to all fenfe of decency, that he contrived one day to entice his wife *naked* into the bath in the garden of his Philanthropine, where, in the water, he, being alfo *naked*, toyed with her in the fight of all his pupils. It was his boaft that he held his opinions independent of all mankind, and was indifferent whether they procured him praife or reproach: but it appears from this fact, that he was, equally regardlefs of the praife or cenfure which might be attached to his actions; for furely the groffeft hog that ever before him battened in the Epicurean fty would not have prefented fuch an exhibition to boys.

The confequence of all this was, that he was obliged to fly from Heidefheim, leaving his fureties in the Philanthropine to pay about 14,000 dahlers, befides debts without number to his friends. He was imprifoned at Dienheim; but being foon releafed, he fettled at Halle, where he funk to be the keeper of a tavern and billiard-table. His houfe became of courfe the refort and the bane of the ftudents in the univerfity, and he was obliged to leave the city. He had fome how got money fufficient to purchafe a little vineyard, pleafantly fituated in the neighbourhood. This he fitted up with every accommodation that could invite the ftudents, and called it *Bahrdt's Ruhe* (Bahrdt's repofe) where he lived for two years, directing the operations of a fecret fociety called the GERMAN UNION, FOR ROOTING OUT SUPERSTITION AND PREJUDICES, AND FOR ADVANCING TRUE CHRISTIANITY.

With Bahrdt's qualifications for advancing the interefts of genuine Chriftianity, the Chriftian reader is already fufficiently acquainted: but he will not wonder at his appointment to this high office, when he is informed that the GERMAN UNION is nothing more than a fpawn of the fecret fociety of *Illuminati* (fee ILLUMINATI in this Supplement); and that its object is to abolifh the religion of the gofpel, and to teach in its ftead the fatalifm of the Stoics. With this view Chriftianity is confidered in the UNION as a myftical fociety, and its Divine Founder as the grand mafter of a lodge! The apoftles Peter, James, John, and Andrew, were the ELECT, brethren of the *third* degree, and initiated into all the myfteries. The remaining apoftles were only of the *fecond* degree; and the feventy-two, of the *firft*: a degree into which ordinary Chriftians may be admitted, and prepared for farther advancement. The great myftery is, that J—— C—— was a NATURALIST, and taught the doctrine of a fupreme mind, the fpectator but not the governor of the world.

To propagate thefe impious and abfurd notions, Bahrdt publifhed many books of the moft antichriftian tendency, and fome of them calculated to make their readers fhake off all moral obligation. But the labours of the fociety were not confined to religion: it inculcated on its members the moft dangerous maxims of civil conduct: for, as we learn from Bahrdt himfelf, the objects at which the Union aimed were—*Advancement of fcience—a general intereft and concern for arts and learning—excitement of talents—check of fcribbling—good education*—LIBERTY—EQUALITY—*hofpitality*—DELIVERY OF MANY FROM MISFORTUNES—*union of the learned—and at laft—perhaps—Amen.*

What the meaning of this enigmatical conclufion is we can only guefs; and we agree with the real philofopher from whom we have taken this account, that our conjectures cannot be favourable. Bahrdt was a villain, and could be affociated only with villains, whofe affairs he managed with the help of an old man, who lived at bed and board in his houfe for about fix fhillings a week, and difcharged the office of fecretary to the UNION.

When he had toiled in this caufe near two years, fome of the fecrets of the Union tranfpired; his former conduct and his conftant imprudence made him fufpected; his affociated friends lodged informations againft him; his papers were feized; and he himfelf was fent to prifon, firft at Halle and then at Magdeburg. After fomething more than a year's confinement, he was fet at liberty, and returned to his *Ruhe*, not, alas! to live at eafe, or to exhibit fymptoms of repentance, but to lie down on a fick-bed, where, after many months fuffering of increafing pain, he died on the 23d of April 1793, 1793, the moſt wretched and loathſome victim of unbridled ſenſuality.

Such were the fruits of the German Union, and of that illumination which was to refine the heart of man, and bring to maturity the ſeeds of native virtue, which are choaked in the heart by ſuperſtition and deſpotiſm. Dr Bahrdt affected to be the enlightner and reformer of the world; and affirmed, that all the evils of life originated from deſpotiſm and ſuperſtition. "In vain (ſays he) do we complain of the inefficacy of religion. All poſitive religion is founded on injuſtice. No prince has a right to preſcribe or ſanction any ſuch ſyſtem; nor would he do it, were not the prieſts the firmeſt pillars of his tyranny, and ſuperſtition the ſtrongeſt fetters for his ſubjects. He dares not ſhow Religion as ſhe is, pure and undefiled—ſhe would charm the eyes and the hearts of mankind, would immediately produce true morality, would open the eyes of free born man, would teach him what are his rights and who are his oppreſſors, and princes would vaniſh from the face of the earth."

Therefore, without troubling ourſelves with the truth or falſehood of his religion of nature, and aſſuming it as an indiſputable point, that Dr Bahrdt has ſeen it in this natural and ſo effective purity, it is ſurely a very pertinent queſtion, "Whether has the ſight produced on his mind an effect ſo far ſuperior to the acknowledged faintneſs of the impreſſion of Chriſtianity on the bulk of mankind, that it will be prudent to adopt the plan of the German Union, and at once put an end to the diviſions which ſo unfortunately alienate the minds of profeſſing Chriſtians from each other?" The account here given of Dr Bahrdt's life ſeems to decide the queſtion.

But it will be ſaid that we have only related ſo many inſtances of the quarrels of prieſts and their ſlaviſh adherents with Dr Bahrdt. Let us view him in his ordinary conduct, not as the champion and martyr of illumination, but as an ordinary citizen, a huſband, a father, a friend, a teacher of youth, a clergyman.

When Dr Bahrdt was a pariſh-miniſter, and preſident of ſome inferior eccleſiaſtical diſtrict, he was empowered to take off the cenſures of the church from a young woman who had borne a baſtard child. By violence he again reduced her to the ſame condition, and eſcaped cenſure by the poor girl's dying of a fever before her pregnancy was far advanced, or even legally documented. On the night of the ſolemn farce of conſecrating his Philanthropine, he debauched the maid-ſervant, who bore twins, and gave him up for the father. The thing was not judicially proved, but was afterwards made ſufficiently evident by letters found among his papers, and publiſhed by one of his friends in the UNION. Having ſupported theſe infants, in a pitiful manner, for little more than a year, he cauſed them to be taken away from their mother, during night, ſome time in the month of February 1780; and they were found expoſed, the one at Uſſtein, and the other at Worms, many miles diſtant from each other, and almoſt frozen to death.

So much for the purity of his morals and his religion, as he appears in the character of a father and of a clergyman. His *decency* as a huſband, and his gratitude to his friend, we have already ſeen; and we ſhall now ſee his kindneſs and fidelity. After waſting the greateſt part of his wife's little fortune, he was ſo provoked becauſe her brother would not give him up the remainder, amounting to about L. 110, that he ever afterwards treated her with the greateſt cruelty, and exhibited her to contempt and ridicule in two infamous novels. At Halle he brought a miſtreſs into the houſe, and committed to her the care of his family, confining his wife and daughter to their own apartment; and the laſt thing which he did was to ſend for a bookſeller, who had publiſhed ſome of his vileſt pieces, and, without a thought of his injured wife, recommend his ſtrumpet and her children to his protection.

"Think not, indignant reader (ſays Arbuthnot), that this man's life is uſeleſs to mortals." It ſhows in a ſtrong light the falſity of all his declamations in favour of his ſo much praiſed natural religion and univerſal kindneſs and humanity. No man of the party writes with more perſuaſive energy, and, though his petulance and precipitant ſelf-conceit lead him frequently aſtray, no man has occaſionally put all the arguments of theſe philoſophers in a clearer light; yet we ſee that all is falſe and hollow. He is a vile hypocrite, and the real aim of all his writings is to make money, by foſtering the ſenſual propenſities of human nature, although he ſees and feels that the completion of the plan of the German Union would be an event more deſtructive and lamentable than any that can be pointed out in the annals of ſuperſtition. We will not ſay that all the partiſans of illumination are hogs of the ſty of Epicurus like this wretch; and it would be extremely unjuſt to conſider his vices as the effects of his illumination. He was ſenſual, ungrateful, and profane, before he was admitted into the order of the *Illuminati;* but had the views of that order been ſuch as were held out to the world at large, its ſagacious founder would not have initiated a wretch ſo notoriouſly profligate as Dr Bahrdt. Their views, however, being to govern mankind thro' the medium of their ſenſual appetites, and to reign in hell, rather than ſerve in heaven, they could not have employed a better inſtrument. Dr Bahrdt was a true diſciple of illumination; and though his torch was made of the coarſeſt materials, and ſerved only to diſcover ſights of woe, the horrid glare darted into every corner, rouſing hundreds of filthy vermin, and directing their flight to the rotten carrion, where they could beſt depoſit their poiſon and their eggs. Whilſt the more decent members of the Union laboured to pervert the refined part of mankind by declamations on the rights of man and the bleſſings of liberty, Bahrdt addreſſed himſelf to readers of all deſcriptions, and aſſailed at once the imagination and the appetites. He taught them, that religion is an impoſture; that morality is convenience; and, with blaſphemy peculiar to himſelf, that he and his order, by their licentious doctrines, were to *complete the plan and aim of* J —— C ——.

BAILLY (Jean-Sylvian), who made ſuch a figure during the firſt years of the French revolution, was born at Paris on the 15th of September 1736, of a family which had been diſtinguiſhed painters during four ſucceſſive generations. He was bred to the ſame profeſſion, but ſhowed an early taſte for poetry and the belles lettres. Chancing, however, to become acquainted with the geometer La Caille, this circumſtance decided his genius, and he thenceforth devoted himſelf to the cultivation of ſcience. He calculated the orbit of the comet of 1759; and on the 29th of January 1763 was received

Bailly.

received into the Academy of Sciences. In that year he publiſhed an uſeful and laborious compilation, being the reduction of the obſervations made by La Caille in 1760 and 1761, on the zodiacal ſtars. He likewiſe began to conſider the theory of Jupiter's ſatellites, and, in the competition for this prize queſtion of 1764, had a formidable rival in La Grange, who already promiſed to become the firſt mathematician in Europe. The reſults of his inveſtigations were collected into a treatiſe publiſhed in 1766, containing alſo the hiſtory of that part of aſtronomy. In 1771 he gave a moſt curious and important memoir on the light of the ſatellites, and introduced a degree of accuracy till then unknown in the obſervations of their ellipſes.

His ſtudies were not confined to the abſtract ſciences; for he cultivated letters with ſucceſs. His elogies of Charles V. of Corneille, of Leibnitz, of Moliere, and afterwards thoſe of Cook, La Caille, and Greſſet, were much admired. His eloquence pointed him out as a proper perſon to fill the charge, vacant in 1771, of ſecretary to the Academy of Sciences; and, under the patronage of Buffon, he ſtood candidate for that enviable place. He failed: but it was the high birth and promiſing talents of the young Condorcet, joined to the active influence of D'Alembert, that carried the prize.

In 1775 appeared the firſt volume of the Hiſtory of Aſtronomy, which indeed ſtrews the path of ſcience with flowers, and in every reſpect is a moſt valuable work—full of animated deſcription, of luminous narrative, and intereſting detail. His very peculiar ideas concerning the early ſtate of Upper Aſia gave riſe to an ingenious correſpondence and diſcuſſion with the veteran philoſopher Voltaire, the ſubſtance of which ſoon appeared in two volumes, intitled, "Letters on the Origin of Sciences," and "Letters on the Atlantide of Plato." If imagination ſhone forth in theſe eſſays, erudition was no leſs conſpicuous in a great work compoſed in the year 1781 and 1782, on the fables and religious creeds of antiquity; which ſtill exiſts in manuſcript, and the publication of which would aſſuredly extend the fame of its author and gratify the learned world. His opinions on ſome points happening to coincide with the theories of Buffon, he contracted with that celebrated naturaliſt a cloſe friendſhip, which was diſſolved by Bailly's uncourtly oppoſition to the election of the Abbé Maury into the *Academie Françaiſe*. Of that academy he had been choſen ſecretary in 1784; and he was admitted, in the following year, into the Academy of Inſcriptions and Belles Lettres; the only inſtance, ſince Fontenelle, of the ſame perſon being at once a member of all the three academies. In the meantime, the other volumes of the Hiſtory of Aſtronomy ſucceſſively appeared, and that capital work was completed in 1787 by the Hiſtory of the Indian and Oriental Aſtronomy; a production of ſingular acuteneſs, reſearch, and nice calculation.

In 1784 he made an elegant report to the Academy of Sciences on the animal magnetiſm of Meſmer; and in 1786 another report, which diſplays the judgment and humanity of its author, on a project for a new *hotel dieu* or infirmary.

We now approach the eventful period which ſummoned Bailly from his retirement, to enter on a political career, that was full of difficulty and danger, and for which his habits and ſtudies appear not to have fitted him. He had ſeen, as others ſaw, the defects of the old government of France. His heart panted for civil and eccleſiaſtical liberty; but unfortunately, like many other philoſophers both in his own country and in this, he had formed notions of that bleſſing which experience ſhould have taught him can never be realiſed among beings ſo imperfect as the bulk of mankind. When the ſtates-general were ſummoned to meet, he was on the 26th of April 1789 nominated ſecretary by the electors of Paris, and then appointed one of the deputies. He was choſen preſident of the *Tiers Etat;* and when that chamber was conſtituted the National Aſſembly, he continued in the chair, and concurred in all the levelling decrees which laid the foundation of the preſent miſery of his country, as well as of moſt other countries of Europe.

After the taking of the Baſtile, when the king was removed to Paris on the 15th of July, Bailly was called by public acclamation to the head of that city, with the title of *Mayor*. In his ſeveral functions he acted with integrity, courage, and moderation. He reached the ſummit of glory:—but how mutable, alas! is human grandeur! That middle courſe of conduct, the *aurea mediocritas*, at which virtue aims, is fitted to pleaſe neither of the contending parties in the midſt of revolutions: and ſuch proved the ruin of Bailly. His popularity began to decline, and was at length changed into inveterate enmity by an unfortunate accident. On the 17th of July 1791, the populace having collected tumultuouſly to demand the abolition of monarchy, Bailly was ordered by the National Aſſembly to diſperſe the mob. He was obliged to proceed to the Champ-de-Mars at the riſk of his life; and, in ſpite of all his exertions and forbearance, ſome ſhots were fired by the ſoldiery. It was no longer deſirable to hold his perilous charge, and on the 16th of November following he gave way to the aſcending reputation of Petion. The impaired ſtate of his health, too, rendered it expedient to retire from the focus of turbulence. He ſpent the year 1792 and part of 1793 in travelling through different provinces of France. During this period he wrote memoirs of the events which he had witneſſed, and in which he had often been a principal actor. Theſe come down only to the 2d of October 1789, but would make a large quarto volume; and La Lande, from whoſe *Eloge de Bailly* this article is taken, gives us hopes, that the manuſcript will be publiſhed. He was adviſed by his friends to withdraw from France, but he choſe rather, like Socrates, to ſubmit to the injuſtice and ingratitude of his country. At the nod of a vulgar tyrant he was arreſted, ſummarily condemned by a ſanguinary tribunal, and on the 15th of November 1793 was delivered over to appeaſe the vengeance of an incenſed and indiſcriminate populace. His ſufferings were ſtudiouſly protracted, but he bore them with the calmneſs and magnanimity of a ſage. Nature recoils at the recital of ſuch barbarities.

In 1787 M. Bailly married the widow of one who had been during 25 years his intimate friend; a woman more qualified by her age and condition to inſpire reſpect than the paſſion of love. He was tall in his perſon, of a ſerious deportment, and joined firmneſs to ſenſibility. Never did philoſopher diſtinguiſh himſelf in ſo many different lines, nor acquire ſuch deſerved reputation in them all. His diſintereſtedneſs was pure and unaffected;

unaffected; and during his magistracy he spent a part of his fortune in relieving the wants of the poor. His virtue remained as untainted in his various public stations as in the sweet retirement of domestic life.

Such is the encomium passed upon this philosopher and statesman by no less a man than the celebrated astronomer M. DE LA LANDE; but to those who are not infected with the *mania* of freedom, it will doubtless appear greatly exaggerated. That M. Bailly was a man of eminence in the republic of letters, is known to all the learned of Europe; that in his political conduct he meant to promote the good of his country, it would certainly be presumptuous in us to deny; and that he suffered unjustly, is incontrovertible: But let it be remembered, that he suffered in a storm, which he exerted all his abilities to raise; and that he set an example of injustice, when he concurred in the degradation of the privileged orders, and in the violent confiscation of the property of the church.

BAIRDSTOWN, or *Beardstown*, in Nelson co. Kentucky, is a flourishing town, of 216 inhabitants, situated on the head waters of Salt river, 50 miles S. E. from Louisville, and nearly the same distance S. W. from Danville.—*Morse.*

BAKERSFIELD, a newly settled township in Franklin co. Vermont, formerly in Chittenden co. In 1790 it had only 13 inhabitants.—*ib.*

BAKERSTOWN, in Cumberland co. District of Maine, contains 1276 inhabitants; 162 miles N. E. from Boston.—*ib.*

BALD EAGLE, or *Warrior Mountains*, lie about 200 miles W. of Philadelphia, in Bedford co. Pennsylvania, and forms the western boundary of Bald Eagle Valley.

Bald Eagle is likewise the name of a river which runs a N. E. course 44 miles and falls into the W. branch of Susquehanna River. The head water of Huron River which falls into Lake Erie, is called Bald Eagle Creek.—*ib.*

BALD EAGLE VALLEY, or, as it is commonly called, *Sinking Spring Valley*, lies upon the frontiers of Bedford co. in Pennsylvania, about 200 miles W. from Philadelphia. It has on the E. a chain of high, rugged mountains, called the *Canoe Ridge*, and on the W. the *Bald Eagle*, or Warrior Mountains. This is a pleasant vale, of limestone bottom, 5 miles in extent where widest; and in the vicinity are great quantities of lead ore. It contained, in 1779, about 60 or 70 families, living in log-houses, who formed, in the space of 7 or 8 years, several valuable plantations, some of which are remarkably agreeable on account of their situation.

During the late war with Great Britain, lead was much wanted, and very difficult to be procured, which induced a company, under the promises of the state, to settle here, and establish a regular set of works. A fort of logs was erected for the protection of the miners; and a considerable quantity of ore was produced, from which lead enough was made, to give a competent idea of the real value of the mines in general. The danger of the situation, however, while an Indian war continued, occasioned the failure of the undertaking.

The lead ore was of many kinds; some in broad flakes, and others of the steely texture. Several regular shafts were sunk to a considerable depth; one of which was on the hill, upon which the fort was erected, and from which many large masses of ore were procured; but, not forming a regular vein, it was discontinued, and another opened about a mile from the fort, nearer to Frank's Town. Here the miners continued until they finally relinquished the business. When they first began, they found in the upper surface or vegetable earth, several hundred weight of cubic lead ore, clean and unmixed with any substance whatever, which continued as a clue, leading them down through the different strata of earth, marl, &c. until they came to the rock, which is here in general of the limestone kind.

Among other curiosities of this place, is that called *the Swallows*, which absorb several of the largest streams of the valley, and after conveying them several miles under ground, in a subterraneous course, return them again upon the surface. These subterraneous passages have given rise to the name, *Sinking Spring Valley*. Of these the most remarkable is called the *Arch Springs*, and run close upon the road from the town to the fort. It is a deep hollow, formed in the limestone-rock, about 30 feet wide, with a rude natural stone arch hanging over it, forming a passage for the water, which it throws out with some degree of violence, and in such plenty as to form a fine stream, which at length buries itself again in the bowels of the earth. Some of these pits are near 300 feet deep; the water at the bottom seems in rapid motion; and is apparently as black as ink; though it is as pure as the finest springs can produce. Many of these pits are placed along the course of this subterraneous river, which soon after takes an opportunity of an opening at a declivity of the ground, and keeps along the surface among the rocky hills for a few rods, then enters the mouth of a large cave, whose exterior aperture would be sufficient to admit a shallop with her sails full spread. In the inside it keeps from 18 to 20 feet wide. The roof declines as you advance, and a ledge of loose, rugged rocks, keeps in tolerable order, on one side, affording means to scramble along. In the midst of this cave is much timber, bodies of trees, branches, &c. which being lodged up to the roof of this passage, shews that the water is swelled up to the very top during freshes. This opening in the hill continues about 400 yards, when the cave widens, after you have got round a sudden turning (which prevents its being discovered till you are within it) into a spacious room, at the bottom of which is a vortex, the water that falls into it whirling round with amazing force; sticks, or even pieces of timber, are immediately absorbed, and carried out of sight, the water boiling up with excessive violence, which subsides by degrees, until the experiment is renewed.

From the top of the Bald Eagle Mountains is a fine prospect of those of the Alleghany, stretching along until they seem to meet the clouds. Much slate is found here, with strong signs of pit coal. Such as visit these parts must cross the Juniata river 3 or 4 times from Standing Stone or Huntington, to the fort; from which it is computed to be about 22 miles distance.—*ib.*

BALIOL (John), the competitor with Bruce for the crown of Scotland, was not (as he is said to have been

been in the *Encyclopædia)* the brother of King Alexander, but the great grandson of David Earl of Huntington, third son of King David I.

BALLISTIC Pendulum, an ingenious machine invented by Benjamin Robins, for ascertaining the velocity of military projectiles, and consequently the force of fired gunpowder. It consists of a large block of wood, annexed to the end of a strong iron stem, having a cross steel axis at the other end, placed horizontally, about which the whole vibrates together like the pendulum of a clock. The machine being at rest, a piece of ordnance is pointed straight towards the wooden block or ball of this pendulum, and then discharged: the consequence is this; the ball discharged from the gun strikes and enters the block, and causes the pendulum to vibrate more or less according to the velocity of the projectile or the force of the blow; and by observing the extent of the vibration, the force of that blow becomes known, or the greatest velocity with which the block is moved out of its place, and consequently the velocity of the projectile itself which struck the blow and urged the pendulum.

Hutton's Dictionary.

BALTIMORE *Co.* in Maryland, lies between Patapsco and Gunpowder rivers, the former dividing it from Ann Arundel co. on the S. and S. W. Gunpowder and Little Gunpowder separating it from Harford co. on the E. and N. E. It has Frederick co. on the W. and N. W. Pennsylvania on the N. and Chesapeak Bay on the S. E. Besides the rivers which bound it, and their branches, this county has Back and Middle rivers, between the two former, but they are rather arms of Chesapeak bay, than rivers. Back river, 4 or 5 miles E. of Patapsco, receives two small streams; the N. westernmost is called Herring Run. Middle river has little or no supply of fresh water. There are numerous iron works in this county; and it contains 25,434 inhabitants, including 5,877 slaves. Its chief town is Baltimore.—*Morse.*

Baltimore, (See Encycl.) From the head of Elk river at the head of the bay to Baltimore, is about 60 miles. The town is built around what is called the bason, reckoned one of the finest harbors in America. The water rises 5 or 6 feet at common tides. It is divided into what is called the town and Fell's Point, by a creek; over which are two bridges: but the houses extend, in an irregular manner, from the one to the other. At Fell's Point the water is deep enough for ships of burden, but small vessels only go up to the town.

The situation is low, and was formerly thought unhealthy, but, by its rapid increase, improvements have taken place, which have corrected the dampness of the air, and it is now judged to be tolerably healthy. In 1787, it contained 1955 dwelling houses; of which 1200 were in the town, and the rest at Fell's Point. It then contained 152 stores. The number of the inhabitants of the town and precincts, in 1791, were 13,503, including 1,255 slaves. The number of houses and inhabitants have been greatly increased since.

Before the emigration of the French people from Cape François and other islands, the houses had increased to 2,300. Those unfortunate people, flying from their merciless countrymen, who had burned and pillaged their cities and towns, and murdered their relations and friends, found here an hospitable asylum, after sufferings hardly paralleled in the annals of history.

Here are 9 places of public worship, which belong to Roman Catholics, German Calvinists and Lutherans, Episcopalians, Presbyterians, Baptists, Methodists, Quakers, and Nicolites, or New Quakers, who all live together in peace. It is inhabited by people from most parts of Europe. The principal street is Market Street, which runs nearly E. and W. a mile in length, parallel with the water. This is crossed by a number of other streets, which run from the water; a number of which, particularly Calvert and Gay streets, are well built. N. and E. of the town, the land rises, and presents a noble view of the town and bay. In 1790, this city owned 27 ships, 1 snow, 31 brigantines, 34 schooners, and 9 sloops—Total 102; tonnage 13,564. The exports in the same year amounted to 2,027,770, and the imports to 1,945,899 dollars. The exports in July, August, and Sept. in 1790, amounted only to 343,584 dollars; but in these months in 1795, they amounted to 1,675,748 dollars. The affairs of the town are managed by a board of town commissioners, a board of special commissioners, and a board of wardens; the first board fills its own vacancies, and is perpetual; the two last are appointed by electors, chosen every 5th year by the citizens. It is 53 miles S. W. from Elktown, 176 N. E. from Richmond in Virginia; 50 N. E. from the city of Washington, and 103 S. W. from Philadelphia. N. lat. 39. 21. W. long. 77. 48.—*ib.*

BANGOR, a township in Hancock co. District of Main, on the western side of Penobscot river, 25 miles from its mouth at Belfast Bay; 65 N. W. by W. from Machias; 63 N. E. from Hallowell, and 280 N. E. from Boston.—*ib.*

BANKA (see Banca, *Encycl.*) is noted throughout Asia for its tin mines. It lies opposite to the river Palambang, in the island of Sumatra, on which the sovereign of Banka, possessor also of the territory of Palambang, keeps his constant residence. This prince maintains his authority over his own subjects, and his independence of the neighbouring sovereigns, chiefly by the assistance of the Dutch, who have a settlement and troops at Palambang, and enjoy the benefit of a contract with the king of Banka for the tin which his subjects procure from that island. Such at least was the case in 1793, when Lord Macartney touched at Banka on his way to China. At that period the sovereign compelled his subjects, and probably does so at present, to deliver the tin to him at a low price, and sold it to the Dutch at a small advance, pursuant to his contract. Those miners, from long practice, have arrived at great perfection in reducing the ore into metal, employing wood as fuel in their furnaces, and not fossile coal, or *coak*, which is seldom so free from sulphur, as not to affect the malleability of the metal. It is sometimes preferred therefore to European tin at the Canton market; and the profit upon it to the Dutch company was, at the period mentioned above, supposed to have long been not less than L. 150,000 a year. Into whose hands this trade has now fallen we know not; probably it is in a great degree neglected.

BANTAM, the capital of a kingdom of the same name in the island of Java, is, in the *Encyclopædia*, said to be a large town with a good harbour and fortified castle. Sir George Staunton, however, who visited Bantam since that article was published, gives a very different account both of the town and of its harbour. Once indeed it was a place of considerable consequence, being the great mart for pepper and other spices, whence they were distributed to the rest of the world. The chief factory of the English as well as Dutch East India Company was settled there. The merchants of Arabia and Hindostan resorted to it. Its sovereigns were so desirous of encouraging trade, by giving security to foreign merchants against the violent and revengeful disposition of the natives, that the crime of murder was never pardoned when committed against a stranger, but might be committed by a foreigner for a fine to the relations of the deceased. This place flourished for a considerable time; but the Dutch having conquered the neighbouring province of Jacatra, where they since have built Batavia, and transferred their principal business to it, and the English having removed to Hindostan and China, and trade in other respects having taken a new course, Bantam was reduced to a poor remnant of its former opulence and importance. Other circumstances have accelerated its decline. The bay is so choked up with daily accessions of new earth washed down from the mountains, as well as by coral shoals extending a considerable way to the eastward, that it is inaccessible at present to vessels of burden; even the party who went there from the Lion, the ship which carried Lord Macartney to China, was obliged to remove from her pinnace into a canoe, in order to reach the town. With the trade of Bantam the power of its sovereign declined. In his wars with other princes of Java he called in the assistance of the Dutch; and from that period he became in fact their captive. He resides in a palace, built in the European style, with a fort garrisoned by a detachment from Batavia, of which the commander takes his orders not from the king of Bantam, but from a Dutch chief or governor, who lives in another fort adjoining the town, and nearer to the seaside. His Bantamese majesty is allowed, however, to maintain a body of native troops, and has several small armed vessels, by means of which he maintains authority over some parts of the south of Sumatra. His subjects are obliged to sell to him all the pepper they raise in either island, at a low price, which he is under contract with the Dutch to deliver to them at a small advance, and much under the marketable value of that commodity. The present king joins the spiritual to the temporal power, and is high priest of the religion of Mahomet; with which he mingles, indeed, some of the rites and superstitions of the aboriginal inhabitants of Java; adoring, for instance, the great banyan, or Indian fig-tree, which is likewise held sacred in Hindostan, and under which religious rites might be conveniently performed; in like manner, as all affairs of state are actually transacted by the Bantamese under some shadowing tree by moonlight. To complete the ruin of Bantam, a fire some time ago destroyed most of the houses, and few have been since rebuilt.

BANYAN TREE. See Ficus, *Encycl.*

British BARILLA, is the name given by Mr James King of Newcastle upon Tyne, to a material invented by him to supply the place of Spanish barilla in the making of crown window-glass, broad window-glass, and glass bottles, as also in the manufacturing of soap and alum. For these purposes he affirmed that it answered much better than any other material then in use; and in consequence of that affirmation he obtained a patent for his invention, dated March 4, 1780.

Though we can hardly allow to this invention all the merit claimed for it by its fond author, yet as it *may* be of use to different manufacturers, we shall lay before our readers his method of making the British barilla. It is as follows: "Take a certain quantity of ashes obtained by burning the loppings or branches of ash, oak, beech, elm, alder, or any other kind of green wood or bramble: Take an equal quantity of the ashes obtained by burning the green vegetables known by the name of fern, brecon, bean and pea-straw, whins, common field and high-way thistles, the stalks of rape or mustard-seed, or the bent or rushes that grow by the sea shore." Though we know not in what qualities the ashes obtained from the former substances differ from those obtained from the latter, the author, as if the difference was very great, directs these equal quantities to be mixed together, sifted through a fine sieve, and laid upon a boarded floor, where a quantity of soapers waste-ashes, equal to the whole compound mass, is to be added to it, and well mixed with it by means of a shovel or other instrument. To this mixture of vegetable ashes and soapers waste-ashes is to be added a quantity of fine quick-lime, in the proportion of one hundred weight to twelve hundred of the blended ashes, and the lime and ashes are to be well mixed together. After this the whole is to be put into an iron pan, into which is to be poured a quantity of sea water sufficient, says the author, to dissolve the ashes and lime; and the whole is to be stirred with an iron rake till it incorporate. This being done, a coal fire is to be lighted up under the pan, and kept burning for two days and two nights without intermission, additional quantities of sea water being constantly supplied to impregnate the materials with saline matter sufficient for calcination in a reverberating furnace or calcar. In this calcar the saline mass, which was boiled in the pan, is by intense heat to be dissolved, and kept in a state of fusion for the space of an hour; during which time the volatile part flies off, and leaves remaining a fixed alkaline salt, which, cooled in iron pans, is the British barilla, and has the appearance of Spanish barilla. See Barilla, *Encycl.*

BARNEGAT, the name of a small village of 8 or 10 houses, on the east bank of Hudson river, 5 miles S. of Poughkeepsie, and 75 N. of N. York. The sole business of the few inhabitants of this place, is burning lime, from the vast quantities of lime stone which are found here. Their lime is marketed in N. York, whither they carry it in great quantities annually.—*Morse.*

BARNET, a township in Caledonia co. Vermont, formerly in Orange co. containing 477 inhabitants, and 112 miles N. E. from Bennington. The lower bar of the 15 mile falls in Connecticut River is situated at the N. E. corner of this township. Into that river it sends Stephens River which rises in Peachum, the adjoining town on the W.—*ib.*

BARNSTABLE, the *Mattacheese*, or *Mattacheeset* of the ancient Indians, is a port of entry and post town, and is the shire town of Barnstable co. It extends across the peninsula, and is washed by the sea on the N. and S. having Sandwich, and the district called Marshpee or Mashpee on the W. is about 5 miles

miles broad, and 9 long; 67 miles S. easterly from Boston. Sandy Neck, on the N. shore, runs E. almost the length of the town, and forms the harbor, embosoming a large body of salt marsh. The harbor is about a mile wide, and 4 long; in which the tide rises from 8 to 14 feet. It has a bar running off N. E. from the Neck several miles, which prevents the entrance of large ships; but small vessels may pass any part of it at high water; and where it is commonly crossed, it seldom has less than 6 or 7 feet at low water.

There is another harbor on the S. called *Lewis's Bay*. Its entrance is within Barnstable, and it extends almost 2 miles into Yarmouth. It is commodious and safe, and is completely land locked; and has 5 feet water at a middling tide.

A mile or two to the westward, and near the entrance of Lewis's Bay, lies *Hyanis Road*. It is formed principally by an island, joined by a beach to Yarmouth, which together, make the outside of the bay before mentioned. The S. head of this island is called Point Gammon. Oyster Bay, near the S. W. limit of the town, admits small vessels; and which, with Lewis's Bay, has in years past produced excellent oysters, in great quantities; though they are now much reduced.

There are about 20 or 30 ponds in Barnstable. The land here produces about 25 bushels of Indian corn to an acre, and rye and other grain in proportion. Wheat and flax are cultivated; the latter with success. From 12 to 18,000 bushels of onions are raised for the supply of the neighboring towns. Upwards of 100 men are employed in the fishery, which is yearly increasing. Whales seldom come into Massachusetts Bay now, and that fishery is discontinued. No quarrels with the ancient natives of the country are recorded in the accounts of this town, where the English settlers of New-England first landed, Nov. 11, 1620. The people, 2610 in number, are generally healthy; and many instances of longevity are to be met with. Numbers of the farmers are occasionally seamen; and this town has afforded, and continues to furnish many masters of vessels and mariners who sail from other ports. N. lat. 41. 43.—*Morse.*

BARNSTEAD, a township in Stafford co. New-Hampshire, containing 807 inhabitants; 22 miles N. W. of Portsmouth, and 16 E. by S. from Canterbury, on Connecticut river.—*ib.*

BARRE', a township in Worcester co. Massachusetts, containing 1613 inhabitants, 24 miles N. W. of Worcester, and 66 W. of Boston, deriving its name from Col. Barré, a British senator, who on the eve of the late war, plead the cause of America, in the British house of commons, with great, but unsuccessful energy. This town has good pastures, and here are fatted multitudes of cattle; and it is supposed, more butter and cheese is carried from hence to the market, annually, than any other town of the same size in the State. —*ib.*

Barre', a township in Huntingdon co. Pennsylvania.—*ib.*

BARRELL's *Sound*, on the N. W. Coast of America, called by the natives *Conget-hoi-toi*, is situated about 6 leagues from the southern extremity of Washington, or Charlotte islands, in a N. W. direction, about N. lat. 52. W. long. 131. from Greenwich. It has two inlets; one on the E. the other W. side of the island; the latter is the best, the other is dangerous. The shores are of a craggy black rock; the banks lined with trees of various kinds, as pines, spruce, hemlock, alder, &c. Mr Hoskins, in the summer of 1791, measured one of these trees, which was *ten fathoms* in circumference. On one side of it a hole had been cut, large enough to admit a man; within was a spacious and convenient room, which had apparently been dug and burnt out with much labor. Mr Hoskins concluded that it must have been occasionally inhabited by the natives; as he found in it a box, fireworks, dried wood, and several domestic utensils. This sound was named after Joseph Barrell, Esq. of Charlestown, *(Mass.)* and was first visited by Capt. Gray, in the Washington, in 1789.—*Morse.*

BARREN *Creek*, rises in the N. W. corner of Delaware state, runs about 9 miles S. westerly, and empties into Nanticoke river. A triangular tract of land in the N. part of Somerset co. Maryland, is enclosed between this creek on the S. Delaware state E. and Nanticoke river on the W. and N. W.—*ib.*

BARRINGTON, a township in Queen's co. Nova-Scotia, on the S. side of the bay of Fundy; settled by Quakers from Nantucket Island.—*ib.*

Barrington, a township in Stafford co. N. Hampshire, about 30 miles N. W. from Portsmouth, incorporated in 1722, containing 2470 inhabitants. Allum is found here; and the first ridge of the *Frost Hills*, one of the three inferior summits of Agamenticus, is continued through this town. Its situation is very healthy; *e. g.* 14 of the first settlers in 1732, were alive in 1785, who were between 80 and 90 years old. —*ib.*

Barrington, a township in Bristol co. Rhode-Island, on the S. western side of the N. W. branch of Warren river, little more than 2½ miles N. W. of Warren, and about 7 S. E. from Fox Point, in the town of Providence. It contains 683 inhabitants, including, 12 slaves.—*ib.*

Barrington, Great, is the second township in rank in Berkshire co. Massachusetts. It contains 1373 inhabitants, and lies 140 miles W. from Boston, and south of Stockbridge, adjoining.—*ib.*

BARTHELEMI (Jean Jacques), the Nestor of French literature, was a man so eminent for his knowledge of antiquities, that every classical reader must be interested in his fate. He was born, we believe, at Paris about the latter end of the year 1715; and being educated for the service of the church, he became prior of Courcay, keeper of the medals and antiques in the French king's cabinet, and in 1747 was elected a member of the Academy of Inscriptions. From that period his life was wholly devoted to letters; and in recording the principal events of it, we can only enumerate, in their order, his various publications.

A dissertation of his on the river Pactolus was read 1748 *(Hist. de l'Acad.* X. 29.); Reflections on a Medal of Xerxes, King of Arsamata *(Mem. de l'Acad.* XXXVII. 171.), found, or said to be found, by Fourmont in the temple of Apollo Anycleus (XXXIX. 129.); Essay on Numismatic Palæography, *ib.* 223; Dissertation on two Samaritan Medals of Antigonus King of Judea, *ib.* 257; Remarks on some Inscriptions published

Barthelemi

published by different authors, XLV. 99; Dissertation on Arabic Coins, *ib.* 143; by which it appears that the Mohammedan princes copied the heads of Greek and Roman ones on their coins, and gave Arabic inscriptions of their own names on the reverse. On the Ancient Alphabet and Language of Palmyra, *ib.* 179; on the Ancient Monuments of Rome, the result of a tour in Italy to collect medals for the royal cabinet, to which he added 300, XLIX. 151; on some Phœnician Monuments, and the Alphabets formed from them, LIII. 23. The characters on the written mountains, which he here cites, have been proved of no value; and he illustrates the conformity between the Phœnician and the Egyptian characters from the latter on the bandages of the mummies. Explanation of the Mosaic Pavement of the Temple of Præneste, *ib.* 149; of which there have been four engravings since its first discovery in 1650, and which Barthelemi refers to the voyage of Adrian into Egypt. It may be of that date, but there is no reason to suppose that it represents any thing more than an Egyptian landscape. The form of letters determines the date in the judgment of the learned Abbé. On the Relations of the Egyptian, Phœnician, and Greek Languages, LVII. 383; on some Medals published by different authors, LIX. 270; Explanation of an Inscription under a Bas-relief in the Bishop of Carpentras's Library, 1767, *ib.* 365; on the Number of Pieces represented in one Day on the Theatre at Athens, LXXII. 286; three Comedies, as many Tragedies, a Satire, and a Petite Piece; Remarks on some Medals of the Emperor Antoninus struck in Egypt, LXXX. 484. 1775 (A).

His interpretation of the Phœnician inscription at Malta, LIII. 23, was controverted by our learned linguist, Mr Swinton, in Philos. Transact. LIV. art. xxii. p. 119; in farther remarks, *ib.* art. lxx. p. 393.

In 1792 he published a dissertation on an ancient Greek inscription, containing an account of expences of the public feasts under the archontate of Glaucippus, 410 years before Christ.

The intimate acquaintance which he had cultivated with classical antiquity, enabled him, in the close of a long life, to compose that *chef-d'œuvre*, the "Travels of the Younger Anacharsis into Greece" in the middle of the fourth century before the vulgar era. In representing the curiosity of a Scythian savage (for we cannot consider in any other light the man who put music and the excesses of the table on the same level), he takes occasion to interweave very curious and instructive details on the laws, religion, manners, customs, and general spirit, of a great nation, as well as its progress in arts and sciences. The epoch which he has chosen is that of letters and arts, combining the age of Pericles with that of Alexander, the revolution which changed the appearance of Greece, and soon after overturned the empire of Persia. The introduction comprehends the 1250 years elapsed from the age of Cecrops to the supposed era of Anacharsis, in two intervals; the first reaching to the commencement of the Olympiads, the second to the capture of Athens by the Lacedemonians. The history of the Athenians commences about 150 years after the first Olympiad, including the age of Solon, or that of legislation; that of Themistocles and Aristides, or that of glory, of luxury, and arts. In the second, speaking of war, his observation, that "the example of one nation, that prefers death to slavery, is too important and too instructive to be passed in silence," should have preserved him from the horrors of a long confinement in an advanced age, from which he was delivered only to die. But arts, sciences, and literature, are alike forgotten and overwhelmed in France. In the third interval, speaking of the corruption of manners introduced by Pericles to support his power, he has this observation, applicable to every state: "Corrupted morals are not restored but by the loss of liberty, which brings that poverty inconsistent with softness, and inseparable from abstemiousness, if not that rigid principle of a healthy mind, which is properly called *virtue*." In this period, though the arts were encouraged, philosophy was neglected.

In this diversified undertaking, where the picture of ancient Greece in its minutest parts, both of public and private use, is brought before our eyes, the Abbé is frequently more brilliant than solid, and occasionally loses the substance of a reflection in pursuit of something ingenious to add to it. The plans, views, and maps, are executed with great spirit and accuracy by Mr Barber, a young man of very promising talents; and to the charts many useful tables are added. The beauties of the classics are diffused in a very pleasing manner, and interspersed with anecdotes little known.

Such was the man whom the French government detained in prison for months, and released on the fall of Robespierre. As he concurred in the revolution, we know of no cause for his imprisonment but the mildness of his disposition, and the jealousy of that tyrant, which pursued, with relentless cruelty, every man suspected of being a friend to peace. Of the persecution of Barthelemi, in the extremity of old age, the convention itself seemed to be ashamed; for it unanimously voted him a pension as some recompence for his sufferings. But, alas! the recompence came too late: the old man lived but a few months after his liberation, having died at Paris on the 4th of May 1795; and the day after the following tribute was paid to his memory by Dussaulx, in the national convention:

"Legislators, your liberality conferred honour on the latter days of the life of our respectable fellow citizen, Barthelemi. Our successors, I have no doubt, will consecrate his memory so soon as the period fixed by the law shall permit them. May his old friend, however, be permitted, in a few words, to point out the rare qualities of that Nestor of French literature? It might, perhaps, be sufficient to tell you, as Xenophon said with so much simplicity of one of his most illustrious contemporaries, that Barthelemi was an excellent man in all respects. In fact, those who knew him were at a loss which to admire most—his immortal Anacharsis, or his own life. His policy consisted in goodness; his science was an immense treasure of every thing that could purify the morals, perfect the taste, render man more dear to man, and contribute to the splendour of his

(A) The references here are to the duodecimo edition of the Memoirs of the Academy of Inscriptions.

his country. A ſingle trait will convince you of the mildneſs of his philanthropic mind: 'Why is it not permitted (he often ſaid) to a mortal to bequeath proſperity to his fellow-creatures?' After having been overwhelmed with the favours of fortune, which came unexpectedly and unſought, he became poor; yet his character, far from ſinking under the preſſure, acquired new reſpect; and he proved that poverty, ſupported with dignity, is not leſs honourable than wealth accompanied with benevolence. Perſecuted, as all virtuous and enlightened citizens were, he carried with him to the dungeon of that tyranny which you have ſo gloriouſly deſtroyed, the conſtancy and ſerenity of Socrates. It was there that the venerable old man offered to his companions in misfortune the magnificent ſpectacle of a good man ſtruggling with adverſity. I have ſaid that he was rich; but let us not forget that he was not rich at the expence of the unfortunate, and that he adopted all the branches of his numerous family. The republic has gained by that family good citizens, who ſerve her in the moſt uſeful and brilliant manner. Barthelemi felt that the period of his diſſolution was approaching; yet though exhauſted by long fatigue, and bending beneath the weight of 80 years, his ſenſibility was ſtill vigorous, and your juſt decrees made the cloſing ſcene of his life happy. When he heard that you were endeavouring to repair the ills under which ſo many thouſand innocent men laboured, he lifted up his hands to heaven, and exclaimed, 'Glory to God—honour to the national convention—I have lived long enough!' In the preſent poſture of affairs, the country demands all your attention. I ſhall therefore confine myſelf to requeſt the favour due to the manes of the illuſtrious Barthelemi. One of his nephews, I do not mean your reſpectable ambaſſador at Baſle, but the citizen Courcey, has, for 25 years, diſcharged all the duties of a ſon to his uncle, and for a long time has performed the functions of keeper of the medals and antiquities of the national cabinet. I move, that the citizen Courcey be appointed to that office, which he has already proved himſelf ſo worthy to fill."

Whatever became of this motion, which was referred to the committee of public inſtruction, the cruelty of the government purſued the family; and the late baniſhment of his other nephew by the directory, of which he was a member, ſurpaſſes, if poſſible, the injuſtice of Robeſpierre to the uncle. But their crimes were the ſame: both Barthelemis were men of mild diſpoſitions and friends to peace.

BARTHOLOMEW, St. a pariſh in Charleſton diſtrict, S. Carolina, containing 2.138 white perſons. By the cenſus of 1790, it contained 12,606 inhabitants, of whom 10.338 were ſlaves. It ſends 3 repreſentatives and 1 ſenator to the ſtate legiſlature. Amount of taxes £1,566-10 4 ſterling.—*Morse.*

Bartholomew St. one of the Caribbee iſlands, in the W. Indies, 25 miles N. of St. Chriſtopher's, and 30 N. E. of Saba. It is reckoned 5 leagues in circumference, but has little ground fit for manuring. It produces tobacco, caſſava, and abounds with woods. The trees moſt in eſteem are, 1. The ſoap tree, or aloes tree. 2. The calaback. 3. The canapia, whoſe gum is an excellent catharic. 4. The parotane, whoſe boughs grow downward, take root again, and form a kind of bulwark and ſtrong defence in time of attack. All along the ſhore are thoſe trees called Sea Trees, whoſe boughs are curiouſly plaited together, and look as if they were glazed. Here is an infinite variety of birds, and a peculiar kind of lime ſtone, which the inhabitants export to the adjacent iſlands. They have likewiſe plenty of lignumvitæ and iron wood. Its ſhores are dangerous, and the approaching them requires a good pilot; but it has an excellent harbour, in which ſhips of any ſize are ſheltered from all winds. Half its inhabitants are Iriſh Roman Catholics, whoſe predeceſſors ſettled here in 1666; the others are French, to whom the iſland lately belonged. It was ceded by France to the crown of Sweden in 1785. They depend on the ſkies for water, which they keep in ciſterns. It was a neſt for privateers when in the hands of the French; and at one time had 50 Britiſh prizes in its harbor. N. lat. 17, 56. W. long. 63. 10.—*ib.*

BARTRAM (John) a celebrated ſelf-taught philoſopher and botaniſt, was born near the village of Darby in Cheſter county, Pennſylvania, in the year 1701. His grandfather John Bartram with his family from Derbyſhire in England, came over with the adherents of the famous William Penn, when he eſtabliſhed the colony of Pennſylvania in 1682.

He very early in life manifeſted an ardent thirſt for knowledge; but the great diſtance from Europe, then the ſeat of arts and ſciences, and the infant ſtate of the colony, rendered it difficult to obtain even a moderate education: however the reſources of his own mind, and the moſt intenſe application ſurmounted the difficulties of his ſituation. Aſſociating with the moſt reſpectable characters, he obtained the rudiments of the learned languages, which he ſtudied with extraordinary application and ſucceſs. So earneſt was he in the purſuit of learning that he ſeldom ſat at his meals without his book, often his victuals in one hand and his book in the other. He had an early inclination for the ſtudy of medicine and ſurgery, and acquired ſo much knowledge as to adminiſter great relief to the indigent and diſtreſſed in his neighbourhood; and as moſt of his medicines were drawn from the vegetable kingdom, this furniſhed him with opportunity for proſecuting the ſtudy of botany which was his favourite object, together with natural hiſtory. Bred a huſbandman, he cultivated the ground as the principal means of ſupporting a large family, he proſecuted his avocations as a philoſopher, being attentive to the œconomy of nature, and obſerving her moſt minute operations. When ploughing or ſowing his fields or mowing his meadows, his inquiſitive mind was exerciſed in the contemplation of the vegetable ſyſtem and of animated nature.

He was the firſt American who conceived and carried into effect the deſign of a botanic garden for the reception and cultivation of American vegetables as well as exotics, and of travelling for the acquiſition of them: and for the purpoſe of accompliſhing this ſcheme he purchaſed a plantation in a delightful ſituation on the banks of the Schuylkill, about five miles from Philadelphia, where he laid out with his own hands, a large garden, containing ſix or ſeven acres comprehending a variety of ſoils and ſituations, which he ſoon furniſhed with a great variety of the moſt curious and beautiful vegetables, collected in his various

excurſions

Bartram. excursions in different parts from Canada to Florida. Botany being his favourite pursuit he soon made such proficiency therein that the great Linnæus said in one of his letters, that he was the greatest natural botanist in the world. His progress in botany, natural history and philosophy, attracted the notice and esteem of the principal literary and eminent characters in America, among whom were James Logan, Esq. Dr Franklin and Dr Kennersley of Philadelphia, Dr Colden of New York and Dr Clayton of Virginia, and introduced him to the correspondence and friendship of Peter Collinson, Esq. which continued for nearly fifty years and terminated only with life; Lord Petre, Dr Dillenius, Sir Hans Sloane, Mr Catesby, Dr Fothergill, Dr Hill, Gronovius, Linnæus, Professor Kalm, M. Wrangle, &c. who furnished him with such books, philosophical apparatus, &c. as his genius and situation required, thereby lessening the difficulties with which he had to struggle in a newly settled country, and promoting the object which his benevolent mind had contemplated in communicating his discoveries and collections to Europe. These communications occasioned him to be employed in collecting whatever was new and curious to furnish and ornament the European gardens and plantations with the productions of the New World. His industry and success in the pursuit of science procured him fellowship in many literary and scientific societies in Europe, as those of London, Edinburgh, Stockholm, &c. and at last he was appointed American Botanist to his Britannic Majesty George the Third, in which appointment he continued till his death in September 1777, in the Seventy-sixth year of his age.

He employed much of his time in excursions through the provinces then subject to England; chiefly in autumn, when his agricultural avocations least required his presence at home. The object of these journeys was to collect curious and non-descript vegetables, fossils, &c. His ardour in these pursuits was such that at the age of 70 he made a journey into East Florida to explore the natural productions of that country. His travels among the Native Indians were attended with much danger and difficulty, and the different parts of the country, from the shores of Lakes Ontario and Caiuga to the source of the river St Juan in E. Florida, contributed through his hands to enrich and embellish the gardens and forests of Europe with elegant flowering shrubs, plants, and useful and ornamental trees.

He was an ingenious mechanic, several monuments of which still remain at the house in which he lived which he built himself, after quarrying the stone: and he was often his own mason, carpenter, black-smith, &c. and generally made his own farming utensils.

His stature was rather above the middle size, erect and slender, a sandy complection, cheerful countenance, with an air of solemnity, his manners modest and gentle, an amiable disposition and liberal mind, a lover of charity and social order, he was never known to enter into a litigious contest with any one, active and temperate, but always maintained a plentiful table, and annually on new year's day he made an entertainment at his own house, consecrated to friendship and philosophy. He was an advocate for liberty, and for the abolition of Negro slavery, and gave freedom to an excellent young African whom he had brought up, and who continued gratefully in his service while he lived. Born and educated in the Society of Friends (called Quakers) he was a pious man. The following distich was engraved by himself on a stone in the wall over the front window of his own apartment.

> " 'Tis God alone, the Almighty Lord,
> " The Holy One by me ador'd."

JOHN BARTRAM, 1770.

Barytes || Batavia.

BARYTES, one of the earths. See Chemistry in this Supplement, Part I. Chap. iv.

BASTER, the name given by the Dutch at the Cape of Good Hope to the offspring of a white man and Hottentot woman.

BAT, an animal which has been described under its generic name Vespertillio in the *Encycl.* but since that article was written, we have met with an account of a new species, so very singular, that, if the veracity of our author can be depended on, it is well intitled to a place here. This species was discovered in the country of the Nimiquas, in the interior of Africa, by *M. Vaillant*, during the course of his second travels, and is by him called the *oreillar* bat. To this title it has indeed a very good claim; for it has, he says, four ears, or at least the external part of four ears, each ear being double; the outer fold, which serves as a covering to the inner, is very ample, being two inches eight lines high, and nearly as broad when stretched out. On the nose also a membrane stands erect, one inch four lines in height, which might be taken for another ear, as it has exactly the shape of one. This membrane, as well as the ears and wings of the animal, are of a rusty red, paler below than above. The body is only three inches long, and is covered with very fine greyish hair. Its width, from the tip of one wing to that of the other, is eight inches. The reader will pardon me, says our author, for inserting these trifling details of measurement, of which I am not more fond than himself; but they appeared to me necessary here, to convey an accurate idea of the extraordinary length of the ears of this animal, which are certainly larger in proportion than those of any other we are acquainted with, since they are only four lines, or the third part of an inch, shorter than the body itself.

BATAVIA, the capital of the Dutch settlements in the East Indies, has been already described under the article Java in the Encyclopædia. The following account of it, however, as well as of the country around it, and the manners and customs of its various inhabitants, as they presented themselves to Sir George Staunton in March 1793, will probably prove acceptable to many of our readers.

The city of Batavia, including the suburbs, consists of near eight thousand houses, inhabited by Dutch, Chinese, and natives of Java. The houses of the Chinese are low, and crammed with people. The Dutch houses are well built, clean, and spacious, and their construction for the most part well suited to the climate. The doors and windows are wide and lofty. The ground floors are covered with flags of marble, which being sprinkled frequently with water, give a pleasant coolness to the apartment; but a considerable proportion of those was untenanted, which denoted a declining settlement. Among other circumstances which announced the same, were those of the Company's vessels lying useless ufelefs in the road, for want of cargoes to fill, or men to navigate them ; no fhips of war to protect their commerce, even againft pirates, who attacked their veffels fometimes in the fight of Batavia road ; an invafion threatened from the Ifle of France ; the place in no condition of defence, particularly againft an enemy lefs affected by the climate than Europeans ; fometimes as many of the troops in hofpitals as fit for duty ; commiffioners expected from Holland to reform abufes. Such a commiffion, implying a general fufpicion, could not be welcome ; nor was it quite certain whether, in fome minds, its arrival or that of the enemy was deprecated the moft cordially.

The fortifications of Batavia, though a place of fo much importance, were not, when Sir George faw them, fuch as would be deemed formidable in Europe ; but when the difficulties were confidered of forcing the paffage of the river, or of landing troops on other parts of the ifland, it might perhaps be thought of greater ftrength than it would at the firft view have credit for. The defences of the river were the water fort, fituated at its entrance, having mounted or difmounted fourteen guns and two howitzers. It confifted of a parapet, originally well conftructed, retained by a wall ; but the parapet was much neglected, and the wall nearly deftroyed by the conftant working of the fea. This fort was protected on the land fide by a noxious fwamp, and towards the fea, on the northweft, by extenfive flats, over which even boats could not pafs. The only good approach was that by the channel, which it fees and defends. The next work upon the river was on the weft fhore, about a quarter of a mile from the water fort. It is a battery mounting feven guns, bearing down the river. Oppofite to this was a battery of fix guns, facing the river, and two to the eaftward. This formed one flank of a line that occupied the low land to the north-eaft of the town. The line was a low breaft-work of earth, that was fcarcely difcoverable. The canals which interfect the town joined the great canal or river, at the diftance of half a mile from the entrance. Below the junction a boom was laid of wood, armed with iron fpikes. A little above was the caftle, a regular fquare fort, but without ravelins or other outworks. It had two guns mounted on each flank, and two, or fometimes three, on each face : they were not *en barbette*, nor properly *en embrafure*, but in a fituation between both, having both their difadvantages without the advantage of either. The wall was of mafonry, about 24 feet high. It had no ditch, but a canal furrounded it at fome diftance. It had no cordon. The length of the exterior fide of the work was about 700 feet. The town is rectangular, three quarters of a mile long, and half a mile broad, inclofed by a wall of about 20 feet in height. Small projections were conftructed, of various forms, at intervals of about 350 feet. Thefe generally mounted three guns each. It was alfo furrounded by a canal, having feveral fluices. At fhort diftances from the town, three or four fmall ftar forts of earth were erected in particular paffes, perhaps for defence againft the inhabitants of the ifland.

The eftablifhment of regular troops was 1200 Europeans, of whom 300 were to be artillery, the reft infantry. But as it was found impoffible, on account of the climate, to keep the number complete, recourfe was had to the natives, of whom 500 were employed ; fo that the eftablifhment of European regulars was reduced to 700. There were alfo 300 volunteers of the town, who were formed into two companies, but they were not difciplined. Their regulars were very numerous, confifting of enrolled natives of Java, who were never embodied, and of Chinefe, of whom the Dutch were fo jealous as to arm them with lances only. Much dependence was not to be placed on the exertions of either of thefe bodies in favour of the Dutch ; and as they lofe many of their European troops every year, their eftablifhment appeared too fmall for any effectual refiftance. The chief protection of their ill-manned veffels lying here, muft be from the fortified ifland of Onruft, well fituated to command the channel that affords the principal paffage into the road. The work upon that ifland was of a pentagonal form ; its baftions were fmall and low, not more than 12 feet the higheft, and not always connected by curtains. A few batteries were lately conftructed on the outfide of this work, that bore towards the fea. On thefe and on the baftions about 40 guns were mounted in different directions. South of thefe was another ifland, at the diftance of a few hundred yards, on which two batteries, mounting together 12 guns, had been lately erected.

The caftle is built of coral rock, brought from fome of the adjoining iflands, compofed of that material ; and has the advantage of a fortification of brick, in which cannon ball is apt to bury itfelf without fpreading fplinters or fhattering the wall. A part of the town wall is built of lava, which is of a dark blue colour, of a very hard denfe texture, emits a metallic found, and refembles very much fome of the lava of Vefuvius. It is brought from the mountains in the centre of Java, where a crater is ftill fmoking. No ftone of any kind is to be found for many miles behind the city of Batavia. Marble and granite are brought thither from China, in veffels belonging to that country, commonly called *junks*, which generally fail for Batavia from the ports of the provinces of Canton and Fokien, on the fouthern and fouth-eaft coafts of that empire, laden chiefly with tea, porcelain, and filks.

The chief protection of Batavia againft the attacks of a foreign enemy, arifes from the havoc which it is well known the climate would make amongft European troops. This was acknowledged to Lord Macartney by fome of the Dutch officers themfelves, and even by one of the counfellors of the Indies. Such indeed is the climate, that there have been very few examples of ftrangers remaining long in Batavia without being attacked by fever, which is the general denomination in that place for illnefs of every kind. Europeans foon after their arrival firft become languid and feeble, and in a few weeks, or even in a few days, are taken ferioufly ill. The diforder at firft is commonly a tertian ague, which after two or three paroxyfms becomes a double tertian, and then a continued remittent, that frequently carries off the patient in a fhort time. Many fall victims to the fecond or third fit ; but in thefe cafes a conftant delirium, and a great determination of the blood to the brain, accompany the other fymptoms. In fome it begins in a quotidian form, with regular intermiffions for a day or two ; and then becomes a continued remittent, attended with the fame fatal confequences as the former. Of the Europeans of all claffes who come to to ſettle at Batavia, it is ſuppoſed that not half the number always ſurvives the year. The place reſembles in that reſpect a field of battle or a town beſieged. The frequency of deaths renders familiar the mention of them, and little ſigns are ſhewn of emotion or ſurpriſe on hearing that the companion of yeſterday is to-day no more. It is probable, female Europeans ſuffer leſs at Batavia than the men. The former ſeldom expoſe themſelves to the heat of the ſun, make frequent uſe of the cold bath, and live more temperately than the other ſex.

But it is not to thoſe who have lately arrived from Europe that this havoc is wholly confined. The greateſt number of the Dutch ſettlers, even thoſe who had reſided long in the country, appeared wan, weak, and languid, as if labouring with the "diſeaſe of death." Their place of reſidence, indeed, is ſituated in the midſt of ſwamps and ſtagnated pools, from whence they are every morning ſaluted with "a congregation of foul and peſtilential vapours," whenever the ſea breeze ſets in, and blows over this moraſs. The meridian ſun raiſes from the ſhallow and muddy canals, with which the town is interſected, deleterious miaſmata into the air; and the trees, with which the quays and ſtreets are crowded, emit noxious exhalations in the night.

The general reputation of the unhealthineſs of Batavia is indeed ſuch as to deter even Dutchmen, who can reſide at home with any comfort, from coming to it, notwithſtanding the temptations of fortunes to be quickly amaſſed in it. From this circumſtance it happens, that offices and profeſſions are often neceſſarily entruſted to perſons little qualified to fill them. One of the clergymen, and the principal phyſician of the place, were both ſaid to have originally been barbers. The United Provinces furniſh even few military recruits. The reſt are chiefly Germans, many of whom are ſaid to have been kidnapped into the ſervice. Though nominally permitted, after a certain length of time, to return home, they are in fact compelled to enliſt for a longer time, the pay being too ſcanty to allow them to ſave enough to defray the expence of their paſſage to Europe. The government is accuſed of the barbarous policy of intercepting all correſpondence between theſe people and their mother country; by which means they are deprived of the conſolation of hearing from their friends, as well as of the chance of receiving ſuch aſſiſtance as might enable them to get home.

Difficult, however, as it is, on account of the climate, to recruit the army, ſuch is the deſire of accumulating wealth in a foreign land, that it draws annually great numbers of Chineſe as well as of Dutch to Batavia. Both indeed belong generally to the humbler claſſes of life, and are bred in ſimilar habits of induſtry in their own country; but the different circumſtances that attend them after their arrival in Batavia put an end to any further reſemblance between them. The Chineſe have there no way of getting forward but by the continuance of their former exertions in a place where they are more liberally rewarded, and by a ſtrict economy in the preſervation of their gains. They have no chance of advancing by favour, nor are public offices open to their ambition; but they apply to every induſtrious occupation, and obtain whatever either care or labour can accompliſh. They become in town retailers, clerks, and agents; in the country they are farmers, and are the principal cultivators of the ſugar-cane. They do at length acquire fortunes, which they value by the time and labour required to earn them. So gradual an acquiſition makes no change in their diſpoſition or mode of life. Their induſtry is not diminiſhed, nor their health impaired. The Dutch, on the contrary, who are ſent out by the Company to adminiſter their affairs in Aſia, become ſoon ſenſible that they have the power, wealth, and poſſeſſions of the country at their diſpoſal. They who ſurvive mount quickly into offices that are lucrative, and not to them laborious. They riſe to the dignity of governor-general and counſellors of the Indies, as the members of the Batavian government are called. Their influence likewiſe enables them to ſpeculate in trade with vaſt advantage. The drudgery and detail of buſineſs are readily undertaken by the Chineſe; while their principals find it difficult, under ſuch new circumſtances, to retain their former habits, or to reſiſt a propenſity to indolence and voluptuouſneſs, though often attended with the ſacrifice of health, if not of life. Convivial pleaſures, among others, are frequently carried to exceſs.

In ſeveral houſes of note throughout the ſettlement, the table is ſpread in the morning at an early hour: beſide tea, coffee, and chocolate, fiſh and fleſh are ſerved for breakfaſt; which is no ſooner over than Madeira, claret, gin, Dutch ſmall beer, and Engliſh porter, are laid out in the portico before the door of the great hall, and pipes and tobacco preſented to every gueſt, and a bright braſs jar placed before him to receive the phlegm which the tobacco frequently draws forth. This occupation continues ſometimes with little interruption till near dinner time, which is about one o'clock in the afternoon. It is not very uncommon for one man to drink a bottle of wine in this manner before dinner; and thoſe who have a predilection for the liquor of their own country ſwallow ſeveral bottles of Dutch ſmall beer, which they are told dilutes their blood, and affords plenty of fluids for a free perſpiration. Immediately before dinner, two men ſlaves go round with Madeira wine, of which each of the company takes a bumper as a tonic or whetter of the appetite. Then follow three females, one with a ſilver jar containing water, ſometimes roſe-water, to waſh; a ſecond with a ſilver baſon and low cover of the ſame metal, pierced with holes, to receive the water after being uſed; and the third with towels for wiping the hands. During dinner a band of muſic plays at a little diſtance: the muſicians are all ſlaves, and pains are taken to inſtruct them. A conſiderable number of female ſlaves attend at table, which is covered with a great variety of diſhes; but little is received, except liquors, into ſtomachs already cloyed. Coffee immediately follows dinner. The 24 hours are here divided, as to the manner of living, into two days and two nights; for each perſon retires, ſoon after drinking coffee, to a bed, which conſiſts of a mattraſs, bolſter, pillow, and chintz counterpane, but no ſheets; and puts on his night dreſs, or muſlin cap and looſe long cotton gown. If a bachelor, which is the caſe of much the greateſt number, a female ſlave attends to fan him while he ſleeps. About ſix they riſe, dreſs, drink tea, take an airing in their carriages, and form parties to ſpend the evening together to a late hour. The morning meetings conſiſt generally of men, the ladies ſeldom chooſing to appear till evening.

Few of theſe are natives of Europe, but many are deſcended

Batavia. descended from Dutch settlers here, and are educated with some care. The features and outlines of their faces are European; but the complexion, character, and mode of life, approach more to those of the native inhabitants of Java. A pale languor overspreads the countenance, and not the least tint of rose is seen in any cheek. While in their own houses they dress like their slaves, with a long red checkered cotton gown descending to the ankles, with large wide sleeves. They wear no head dress, but plait their hair, and fasten it with a silver bodkin on the top of the head, like the country girls in several cantons of Switzerland. The colour of their hair is almost universally black; they anoint it with the oil of the cocoa nut, and adorn it with chaplets of flowers. When they go abroad to pay visits, or to take an airing in their carriages, and particularly when they go to their evening parties, they dress magnificently, in gold and silver spangled muslin robes, with a profusion of jewels in their hair, which however, is worn without powder. They never attempt to mould or regulate the shape by any fancied idea of elegance, or any standard of fashion; and consequently formed a striking contrast with such few ladies as were lately arrived from Holland, who had powdered hair and fair complexions, had contracted their waists with stays, wore large head dresses and hoops, and persevered in the early care of forcing back the elbows, chin, and shoulders. Every native lady is constantly attended by a female slave handsomely habited, who, as soon as her mistress is seated, sits at her feet before her, on the floor, holding in her hands her mistress's gold or silver box, divided into compartments, to contain areca nut, cardamom seeds, pepper, tobacco, and slacked lime; all which, mixed together in due proportions, and rolled within a leaf of betel, constitute a masticatory of a very pungent taste, and in general use. When in the public assemblies the ladies find the heat disagreeable, they retire to free themselves from their costly but inconvenient habits, and return without ceremony in a more light and loose attire, when they are scarcely recognizable by strangers. The gentlemen follow the example; and throwing off their heavy and formal dresses, appear in white jackets, sometimes indeed adorned with diamond buttons. The elderly gentlemen quit their periwigs for nightcaps. Except in these moments the members of this government have always combined their personal gratification with the Eastern policy of striking awe into vulgar minds, by the assumption of exterior and exclusive distinctions. They alone, for instance, appear abroad in crimson velvet. Their carriages are distinguished by peculiar ornaments. When met by others, the latter must stop and pay homage to the former. One of the gates of the city is opened only to let them pass. They certainly succeed in supporting absolute sway over a vast superiority in number of the descendents of the original inhabitants of the country, as well as of the slaves imported into it, and of the Chinese attracted to it by the hope of gain; those classes, though healthy, active, and as if quite at home, readily obeying a few emaciated Europeans. Such is the consequence of dominion once acquired; the prevalence of the mind over mere bodily exertions, and the effect of the combination of power against divided strength.

The native Javanese are in general too remote from civilization to have any wants that are not easily satisfied in a warm and fertile climate. No attempt is made to enslave their persons; and they find the government of the Dutch less vexatious than that of others, who divide some share of the sovereignty of the island with them. The sultan of Mataran rules to the east, the emperor of Java in the centre, and the king of Bantam to the west; while the coast and effective power almost entirely belong to Holland. Those other sovereigns are descended from foreigners also; being Arabians, who imported the Mahometan religion into Java, and acquired the dominion of the country; a few inhabitants in the mountains excepted, who have preserved their independence and their faith, and among other articles that of the transmigration of souls. According to the Dutch accounts, nothing can be more tyrannic than those Mahometan rulers. The emperor is said to maintain his authority by an army of many thousand men dispersed throughout his territories, beside a numerous female guard about his person. These military ladies are trained, it seems, to arms, without neglecting those accomplishments which may occasion a change in the occupation of some among them, rendering them the companions, instead of being the attendants, of his Imperial majesty. This singular institution may owe its origin to the facility of obtaining recruits, if it be true, as the same accounts pretend, that the number of female births exceeds very considerably that of males in Java.

Most of the slaves are imported into it from Celebes and other eastern islands. They do not form a corps, or have any bond of union: nor is the general conduct of their owners towards them calculated to aggravate the misfortune of being the property of others. They are not forced to excessive labour. They have sufficient sustenance; but many of the males among them, who had formerly perhaps led an independent life till made captives in their wars, have been found to take offence against their masters upon very slight occasions, and to wreak their vengeance by assassination. The apprehension of such an event is among the motives for preferring at Batavia female slaves for every use to which they can be applied; so that the number purchased of them much exceeds that of the other sex. The slaves when determined on revenge often swallow, for the purpose of acquiring artificial courage, an extraordinary dose of opium, and soon becoming frantic as well as desperate, not only stab the objects of their hate, but sally forth to attack in like manner every person they meet, till self-preservation renders it necessary to destroy them. They are said in that state to be *running a muck*; and instances of it are not more common among slaves than among free natives of the country, who in the anguish for losing their money, effects, and sometimes their families, at gaming, to which they are violently addicted, or under the pressure of some other passion or misfortune, have recourse to the same remedy, with the same fatal effects.

In the country round Batavia the eye looks in vain for the common animals and vegetables which it had been daily accustomed to meet in Europe. The most familiar bird about the house of the embassador's host was the crown bird, as it was called at Batavia, which was not, however, the *ardea pavonina* of Linnæus, but the *columba cristata*, having nothing except its crest in common with the former. The same gentleman had also at his country house some large cassowary birds, which, though long in his possession, and having the appearance of tameness, sometimes betrayed the fierceness of their nature, attacking with their strong bill those who approached too near them. The vegetation of the country is likewise new. Even the parterres in the gardens are bordered, instead of boxwood, by the Arabian jessamine, of which the fragrant flowers adorn the pagodas of Hindostan. The Dutch, who are so fond of gardens in Holland, have transferred that taste, where it can certainly be cultivated with more success, and indulge it to a great extent at their houses a little way from the city of Batavia; but still within that fenny district, concerning which an intelligent gentleman upon the spot used the strong expression, that the air was pestilential, and the water poisonous. Yet the country is every where so verdant, gay, and fertile; it is interspersed with such magnificent houses, gardens, avenues, canals, and draw-bridges; and is so formed in every respect to please, could health be preserved in it—that a youth coming just from sea, and enraptured with the beauty of every object he saw around him, but mindful of the danger there to life, could not help exclaiming, 'what an excellent habitation it would be for immortals!'

The most tolerable season here is from March or April to November; when the rains begin, and last the rest of the year. The sea breeze sets in about ten o'clock in the morning, and continues till four or five in the afternoon. It becomes then calm till seven or eight, when the land breeze commences, and continues at intervals till day-break, followed by a calm for the remaining hours of the 24. Fahrenheit's thermometer was, in Batavia road, during the Lion's remaining there, from 86° to 88°, and in the town from 88° to 92°; but its variations by no means corresponded to the sensations produced by the heat on the human frame; the latter being tempered by any motion of the air, which circumstance has little effect upon the thermometer. Nor are the animal sufferings here from heat to be measured by its intenseness at any given moment of the day, but by its persisting through the night; when, instead of diminishing, as it does in colder countries, sometimes 20 degrees, it keeps generally here within four or five of what it attains in the shade, when the sun is at its highest elevation.

The native Javanese derive, however, one advantage at least from an atmosphere not subject to the vicissitudes of temperature experienced in the northern parts of Europe, where diseases of the teeth are chiefly prevalent; as they are here entirely exempt from such complaints. Their habit of living chiefly on vegetable food, and of abstaining from fermented liquors, no doubt contributes to this exemption; yet such is the caprice of taste, that jet black is the favourite colour and standard of beauty for the teeth amongst them, comparing to monkeys those who keep them of the natural colour. They accordingly take care to paint, of the deepest black, all their teeth, except the two middle ones, which they cover with gold leaf. Whenever the paint or gilding is worn off, they are as attentive to replace it on the proper teeth, as the belles of Europe are to purify and whiten theirs.

We have mentioned the rich vegetation of the country and the gardens which the Dutch have planted. In these gardens or orchards they cultivate the nutmeg, the clove, the camphor, and the cinnamon trees, together with the pepper plant, which creeping like a vine, is supported on a living tree. It is a species of the pepper plant that affords the leaf called *betel*, chewed so universally by the southern Asiatics, and serving for the inclosure of a few slices or bits of the areca, from thence erroneously called the *betel nut*. The areca nut tree is among the smallest of the tribe of palms, but comes next in beauty to the mountain cabbage tree of the West Indies; the latter differing chiefly in its size and amazing height from the areca nut tree, the diameter of whose jointed trunk seldom exceeds four inches, or height 12 feet. But the symmetry of each is perfect; the columns of a temple cannot be more regular than the trunk, which rises without a branch, while the broad and spreading leaves which crown the top form the ornamented capital. The areca nut, when dried, has some similitude in form and taste to the common nutmeg, but is of a less size.

It would have been very extraordinary, and very culpable, in Sir George Staunton, and Dr Gillan physician to the embassy, if they had not, when on the spot, inquired into the truth of Foersch's account of the *upas* or poison-tree of Java (see *Poison Tree of Java*, Encycl.) But the most minute inquiries were made respecting it; and the result of them was, that no such tree is known at Batavia, and certainly does not exist where Foersch has planted it. It is indeed a common opinion at Batavia, that there exists in that country a vegetable poison, which, rubbed on the daggers of the Javanese, renders the slightest wounds incurable; though some European practitioners have of late asserted that they had cured persons stabbed by those weapons, but not without having taken the precaution of keeping the wound long open, and procuring a suppuration. One of the keepers of the medical garden at Batavia assured Dr Gillan, that a tree distilling a poisonous juice was in that collection, but that its qualities were kept secret from most people in the settlement, lest the knowledge of them should find its way to the slaves, who might be tempted to make an ill use of it. In the same medical garden, containing it seems hurtful as well as grateful substances, is found also the plant from whence is made the celebrated gout remedy, or moxa of Japan, mentioned in the works of Sir William Temple, and described in the Encyclopædia under the titles of Artemisia and Moxa.

The whole country abounds with esculent fruits, and, amongst others, with the mangosteen, which is ripe in March, and is considered as the most delicious of all fruits (see Garcinia, *Encycl.*) Pine apples are in Java planted not in gardens, but in large fields; and are carried like turnips in heaps upon carts to market, and sold for considerably less than a penny each, where money is cheaper than in England. It was a common practice to clean swords, or other instruments of steel or iron, by running them through pine apples, as containing the strongest and cheapest acid for dissolving the rust that covered them. Sugar sold for about five-pence a pound. All sorts of provisions were cheap, and the ships crews fed on fresh meat every day.

The serpents and noxious reptiles in Java have been mentioned elsewhere; but Sir George Staunton assures us, that not many accidents happen from them. Among the pagan Javanese, the crocodile, he says, is an object not

not only of fear, but alfo of religious veneration, to which offerings are made as to a deity. When a Javanefe feels himfelf difeafed, he will fometimes build a kind of coop, and fill it with fuch eatables as he thinks moft agreeable to the crocodiles. He places the coop upon the bank of the river or canal, in the perfect confidence that, by the means of fuch offerings, he will get rid of his complaints; and perfuaded, that if any perfon could prove fo wicked as to take away thofe viands, fuch perfon would draw upon himfelf the malady for the cure of which the offering was made. According to Sir George Staunton, Batavia road lies in 6° 10′ fouth lat. and 106° 51′ eaft long. from Greenwich.

BATH, a townfhip in Lincoln co. Diftrict of Maine, containing 949 inhabitants. It lies on the W. fide of Kennebeck River about 13 miles from Wifcaffet, 60 N. E. from Portland, 32 from Hallowell, 13 from Pownalboro', and 165 N. E. from Bofton. N. lat. 43. 49.—*Morse.*

Bath, a county of Virginia, about 60 miles in length, and 50 in breadth; bounded E. by the county of Augufta. It is noted for its medicinal fprings, called the *Hot* and *Warm* fprings, near the foot of Jackfon's Mountain, which fee.—*ib.*

Bath, a thriving town in Berkly co. Virginia, fituated at the foot of the Warm Spring Mountain. The fprings in the neighbourhood of this town, although lefs efficacious than the Warm Springs in Bath co. draw upwards of 1000 people here, during fummer, from various parts of the United States. The water is little more than milk-warm, and weakly impregnated with minerals. The country in the environs is agreeably diverfified with hills and valleys; the foil rich, and in good cultivation; 25 miles from Martinfburg, and 269 miles S. W. from Philadelphia.—*ib.*

Bath, a townfhip in Grafton co. N. Hampfhire, containing 493 inhabitants. It lies on the E. bank of Connecticut River 35 miles N. E. by N. from Dartmouth College, and 97 N. W. from Portfmouth.—*ib.*

Bath, or *Port Bath*, an ancient town in Hyde co. N. Carolina, on the N. fide of Tar River about 24 miles from Pamplico Sound, 61 S. by W. of Edenton, and is the port of entry on Tar River. It contains about 12 houfes, and is rather declining. N. lat. 35. 31. W. long. 77. 15.—*ib.*

Bath, a village in the eaftern parifh of St Thomas, in the Ifland of Jamaica, in the W. Indies. It has its rife and name from a famous hot fpring in its vicinity, faid to be highly efficacious in curing the dry belly-ache. The water is fulphureous, and flows out of a rocky mountain about a mile diftant; and is too hot to admit a hand being held in it.—*ib.*

Bath, a village in the co. of Renffalaer, New-York, pleafantly fituated on the eaft bank of Hudfon river, nearly oppofite the city of Albany, at the head of floop navigation. A mineral fpring has been difcovered here, faid to poffefs valuable qualities; and a commodious bathing-houfe has been erected, at a confiderable expenfe, containing hot, cold, and fhower baths. —*ib.*

BAY OF FUNDY, wafhes the fhores of the Britifh provinces of New-Brunfwick on the N. and Nova-Scotia on the E. and S. This bay is 12 leagues acrofs, from the Gut of Annapolis to St John's, the principal town of New-Brunfwick. The tides are very rapid in this bay, and rife at Annapolis Bafin about 30 feet; at the Bafin of Minas, which may be termed the N. arm of this bay, 40 feet; and at the head of Chignecto channel, an arm of this bay, the fpring tides rife 60 feet.—*ib.*

BAY OF ISLANDS, lies on the W. fide of Newfoundland Ifland in the gulf of St Lawrence. This bay is very extenfive, having 3 arms, by which feveral rivers empty into it. It has feveral iflands; the chief of which are called Harbor, Pearl, and Tweed. The centre of the bay lies in about 49. 5. N. lat. and 58. 15. W. long. from Greenwich.—*ib.*

BEAR *Grafs Creek*, a fmall creek on the eaftern fide of Ohio River, a few hundred yards N. of the town of Louifville, in Kentucky. This is the fpot where the intended canal is propofed to be cut to the upper fide of the *Rapids*. From the mouth of the creek, to the upper fide of the rapids, is not quite 2 miles. This would render the navigation of the Ohio fafe and eafy. The country on the fides of this creek, between Salt River and Kentucky River is beautiful and rich.—*ib.*

BEAUFORT, a feaport town in Carteret co. on the N. E. fide of Core Sound, and diftrict of Newbern, N. Carolina. It contains about 20 houfes, a court-houfe and gaol, and the county courts are held here. It is 55 miles S. by E. of Newbern, and about 27 from Cape Lookout. N. lat. 34. 47.—*ib.*

Beaufort, the chief town of Beaufort diftrict, S. Carolina, is fituated on the ifland of Port Royal, at the mouth of Coofawhatchie River. The courts which were formerly held here, are now removed to the town of Coofawhatchie, on the above fmall river. Beaufort is a little pleafant town, of about 60 houfes, and 200 inhabitants; who are diftinguifhed for their hofpitality and politenefs. It has a fine harbor, and bids fair to become a confiderable town. It ufed to be a ftation for the Britifh fquadron when in their poffeffion. Beaufort is fituated 26 miles from Purifburg, and 73 from Charlefton, to the S. W. noted for its healthy fituation. N. lat. 32. 26. W. long. 80. 55.—*ib.*

Beaufort *Diftrict*, in the lower country of S. Carolina, lies on the fea coaft, between Combahee and Savannah rivers. It is 69 miles in length, and 37 in breadth, and is divided into 4 parifhes, viz. St Helena, St Luke, Prince William, and St Peter, which contain 18,753 inhabitants; of whom only 4346 are whites. The northern part of this diftrict abounds with large forefts of cyprefs; the lands, however, are fit for raifing rice, indigo, &c. It fends 12 reprefentatives and 4 fenators to the ftate legiflature; each parifh fending an equal number. Amount of taxes £3,022-2-11 fter.—*ib.*

BEAVER *Creek*, runs into Lake Erie, at its E. end; about 7 miles S. E. from Fort Erie.—*ib.*

BEAVERS *Town*, at *Tufkarawas*, lies between Margaret's Creek, an upper N. W. branch of Mufkingum River and the N. branch of that river; at the head of which N. branch there is only a mile's portage to Cayahoga River. Beavers Town lies about 85 miles N. W. from Pittfburg. A little below this a fort was erected in 1764.—*ib.*

BECKET, a townfhip in Berkfhire co. Maffachufetts, containing 751 inhabitants. It is 10 miles E. of

Stockbridge,

Stockbridge, 17 from Lenox, and 130 W. from Boston.—*ib.*

BEDFORD, a townſhip in Hillſborough co. New-Hampſhire, which was incorporated in 1750, and contains 898 inhabitants. It lies on the W. bank of Merrimack River 56 miles W. of Portſmouth.—*ib.*

Bedford, a townſhip in Middleſex co. Maſſachuſetts, containing 523 inhabitants; 13 miles northerly from Boſton.—*ib.*

Bedford, New, is a flouriſhing town in Briſtol co. in the ſame ſtate, containing 3313 inhabitants; 58 miles ſouthward of Boſton. It lies at the head of navigation on Acuſhnet River. Lat. 40. 41. N. long. 70. 52. W. from Greenwich.—*ib.*

Bedford, a townſhip in W. Cheſter co. New York, containing 2470 inhabitants, including 38 ſlaves. It lies contiguous to Connecticut, 12 miles N. from Long-Iſland Sound, and 35 from the city of New-York. In the ſtate cenſus of 1796, there appears to be 302 electors.—*ib.*

Bedford, a town on the W. end of Long Iſland New-York, 4 miles N. W. from Jamaica Bay, and 6 E. from the city of New-York.—*ib.*

Bedford, *Co.* in Pennſylvania, lies on Juniatta River; has part of the ſtate of Maryland on the S. and Huntingdon co. N. and N. E. It contains 13,124 inhabitants, including 46 ſlaves; and has ½ of its lands ſettled, and is divided into 9 townſhips.

Its chief town, Bedford, lies on the S. ſide of the Rayſtown branch of the ſame river; 25 miles eaſtward of Berlin, and 210 W. of Philadelphia. It is regularly laid out; and the inhabitants, who live in 41 log houſes and 9 of ſtone, have water conveyed in wooden pipes to a reſervoir in the middle of the town. They have a ſtone gaol; the market-houſe, court-houſe, and record office, are built of brick. Bedford was incorporated in 1795, and their charter is ſimilar to that of Cheſter. N. lat. 40, W. long. 78. 50.—*ib.*

BEDMINSTER, in Somerſet co. New-Jerſey, is a townſhip containing 1197 inhabitants, including 169 ſlaves.—*ib.*

BEEKMAN, a conſiderable townſhip in Ducheſs co. New-York, containing 3597 inhabitants, including 106 ſlaves. In the ſtate cenſus of 1796 there appears to be 502 electors in this townſhip.—*ib.*

BEER is a liquor ſo palatable to the natives of Britain, and, when properly made, ſo wholeſome, eſpecially in long voyages at ſea, that Mr Thornton of Eaſt Smithfield obtained a patent, dated April 15, 1778, for inventing a method of reducing *malt* and *hops* to an eſſence or extract, from which beer may be made anywhere, either at ſea or in diſtant countries. Though we do not perceive any great degree of ingenuity diſplayed in this invention, yet as the account of it is ſhort, we ſhall lay it before our readers.

His method then of preparing an eſſence or extract of malt and hops is, by the tranſmitted heat of compreſſed vapour of boiling water, and a proper apparatus for that purpoſe. This apparatus may be made of iron, tin, or copper: it conſiſts of a boiler of any dimenſions, a double veſſel, and conducting tubes. The double veſſel conſiſts of one veſſel placed within another, and fitted tight at their rims. The upper veſſel forms the upper part of the under veſſel, and contains the liquor to be evaporated. The under veſſel is everywhere incloſed, except at an aperture communicating with the boiler, and at another aperture communicating with the conducting tubes; and is conſtructed ſo as not to allow any part of the vapour condenſed into drops within it to eſcape, except back again into the boiler: it is not ſo extenſive as to act as a common refrigeratory, and yet is capacious enough to prevent the liquor boiling over. The aperture communicating with the boiler is large enough to freely admit the vapour from the boiler into the under veſſel; and the aperture communicating with the conducting tubes is of a proper ſize to allow of the vapour in the under veſſel being compreſſed, to a degree capable of tranſmitting to the liquor to be evaporated a proper heat, and at the ſame time to ſerve as a paſſage for more heat than is neceſſary to keep up that degree of compreſſion. The conducting tubes are to convey this ſuperfluous heat or vapour, to be uſed for farther purpoſes, or immediately out of the building.

BEETLE, an inſect deſcribed in the Encyclopædia under the name given to it by naturaliſts, Scarabæus. Since that article was publiſhed, we have met with an account of a nondeſcript ſpecies, which is furniſhed with very ſingular armour for its own defence. It was brought to M. Vaillant in the interior parts of Africa by a Nimiqua woman, and is by him called a ſuperb beetle not to be found in any cabinet of Europe. "While I was examining this beautiful inſect (ſays he) with attention, I felt my face ſuddenly wetted by a cauſtic liquor, of a very ſtrong alkaline ſmell. The ſprinkling was accompanied by a ſort of exploſion, loud enough to be heard at ſome diſtance. Unfortunately ſome of the liquor entered one of my eyes, and occaſioned ſuch inſupportable pain, that I thought I ſhould have loſt the ſight of it. I was obliged to keep it covered for ſeveral days, and bathe it from time to time with milk. In every part of my face that the alkaline liquor had touched, I felt the pain of a burn; and everywhere the ſkin changed to a deep brown, which wore out only by degrees and a long time after. This will not be ſurpriſing to many, who already are acquainted with the ſame property in ſeveral inſects of the ſame genus; for inſtance, in that beautiful golden-green bupreſtis, which is ſo common in our kitchen-gardens in Europe: but as the inſect of which I am here ſpeaking is much larger, and inhabits a very hot country, it is natural that the effect produced by it ſhould be more ſtriking; tho' the liquor which our golden bupreſtis ejects at its enemy occaſions a very ſenſible ſmart, and its ſmell is conſiderably pungent."

The naturaliſts Dorci and Olivier have given, in their Entomology, the figure of this African inſect, which our author communicated to them, but they have given it erroneouſly. The human face, obſervable on its anterior corcelet in their figure, does not exiſt in nature; but M. Vaillant having given no figure of it himſelf, we cannot gratify our readers with a correct repreſentation.

BEGAH, a land meaſure in Bengal, about one-third of an Engliſh acre.

BEHADER *(Valiant)*, a title of honour conferred by the Mogul emperors upon either Mahomedans or Hindoos, and placed after their name or other title.

BEHEM (Martin), though hitherto little talked of, was one of the moſt enterpriſing men that ever lived, and

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and deserves to have his name transmitted with reverence to the latest posterity. Born at Nuremberg, an Imperial city in the circle of Franconia, of a noble family not yet extinct, he had the best education which the darkness of that age would permit him to have; and the studies to which from his infancy he was most addicted, were those of geography, astronomy, and navigation. As he advanced in life, he often thought of the existence of the antipodes and of a western continent, of which he was ambitious to make the discovery.

Filled with this great idea, in 1459 he paid a visit to Isabella, daughter of John I. king of Portugal, at that time regent of the duchy of Burgundy and Flanders; and having informed her of his designs, he procured a vessel, in which, sailing westward, he was the first European who is known to have landed on the island of Fayal. He there established in 1460 a colony of Flemings, whose descendants yet exist in the Azores, which were for some time called the Flemish Islands. This circumstance is proved, not only by the writings of contemporary authors, but also by the manuscripts preserved in the records of Nuremberg; from the Latin of which the following is translated: "Martin Behem tendered his services to the daughter of John King of Lusitania, who reigned after the death of Philip of Burgundy, surnamed the *Good;* and from her procured a ship, by means of which, having sailed beyond all the then known limits of the Western Ocean, he was the first who in the memory of man discovered the island of Fayal, abounding with beech trees, which the people of Lusitania call *faye;* whence it derived its name. After this he discovered the neighbouring islands, called by one general name the *Azores*, from the multitude of hawks which build their nests there (for the Lusitanians use this term for hawks, and the French too use the word *essos* or *esores* in their pursuit of this game); and left colonies of the Flemish on them, when they began to be called Flemish Islands (A)."

After having obtained from the regent a grant of Fayal, and resided there about twenty years, Behem applied in 1484 (eight years before Columbus's expedition) to John II. king of Portugal, to procure the means of undertaking a great expedition towards the south-west. This prince gave him some ships, with which he discovered that part of America which is now called Brazil; and he even sailed to the Straits of Magellan, or to the country of some savage tribes whom he called Patagonians, from the extremities of their bodies being covered with a skin more like a bear's paws than human hands and feet.

A fact so little known, and apparently so derogatory to the fame of Columbus, ought not to be admitted without sufficient proof; but the proofs which have been urged in support of its authenticity are such as cannot be controverted. They are not only the letters of Behem himself, written in 1486, and preserved in the archives of Nuremberg, but likewise the public records of that city; in which we read that "Martin Behem, traversing the Atlantic Ocean for several years, examined the American islands, and discovered the strait which bears the name of Magellan before either Christopher Columbus or Magellan sailed those seas; whence he mathematically delineated, on a geographical chart, for the king of Lusitania, the situation of the coast around every part of that famous and renowned strait long before Magellan thought of his expedition."

This wonderful discovery has not escaped the notice of contemporary writers. The following passage is translated from the Latin chronicle of Hartman Schedl: "In the year 1485, John II. king of Portugal, a man of a magnanimous spirit, furnished some galleys with provisions, and sent them to the southward, beyond the Straits of Gibraltar. He gave the command of this squadron to James Canus, a Portuguese, and Martin Behem, a German of Nuremberg in Upper Germany, descended of the family of Bonna: a man very well acquainted with the situation of the globe; blessed with a constitution able to bear the fatigues of the sea; and who, by actual experiments and long sailing, had made himself perfectly master with regard to the longitudes and latitudes of Ptolemy in the west. These two, by the bounty of Heaven, coasting along the Southern Ocean, and having crossed the equator, got into the other hemisphere, where, facing to the eastward, their shadows projected towards the south and right hand. Thus, by their industry, they have opened to us another world hitherto unknown, and for many years attempted by none but the Genoese, and by them in vain. Having finished this cruize in the space of 26 months, they returned to Portugal with the loss of many of their seamen by the violence of the climate."

Besides this evidence of the first discovery of America having been made by Behem, we find the following particulars in the remarks made by Petrus Mateus on the canon law, two years before the expedition of Columbus: "*Primæ navigationes*, &c. The first Christian voyages to the newly discovered islands became frequent under the reign of Henry, son of John, king of Lusitania. After his death Alphonsus V. prosecuted the design; and John, who succeeded him, followed the plan of Alphonsus, by the assistance of Martin Bohem, a very skilful navigator; so that in a short time the name of Lusitania became famous over the whole world." Cellarius, one of the most learned men of his age, says expressly, "*Behcimcus non modo*, &c. Bœhm did not think it enough to survey the island of Fayal, which he first discovered, or the other adjacent islands which the Lusitanians call *Azores*, and we, after the example of Bœhm's companions, call *Flemish* islands, but advanced still farther and farther south, until he arrived at the remotest strait, through which Ferdinand Magellan, following

(A) Although this record is contrary to the generally received opinion, that the Azores were discovered by Gonsalva Velho, a Portuguese, yet its authenticity seems unquestionable. It is confirmed not only by several contemporary writers, and by Wagenseil, one of the most learned men of the last century, but likewise by a note written on parchment in the German language, and sent from Nuremberg, a few years ago, to M. Otto, who was then investigating the discovery of America. The note contained, with other things, the following facts: "Martin Beham, Esq; son of Mr Martin Beham of Scoperin, lived in the reign of John II. king of Portugal, in an island which he discovered, and called the island of *Fayal*, one of the Azores, lying in the Western Ocean."

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following his track, afterwards failed, and called it after his own name."

All thefe quotations, which cannot be thought tedious, fince they ferve to prove a fact almoft unknown, feem to demonftrate, that the firft difcovery of America is due to the Portuguefe and not to the Spaniards; and that the chief merit belongs to a German aftronomer. The expedition of Ferdinand Magellan, which did not take place before the year 1519, arofe from the following fortunate circumftance: This perfon, being in the apartment of the king of Portugal, faw there a chart of the coaft of America drawn by Behem, and at once conceived the bold project of following the fteps of this great navigator. Jerome Benzon, who publifhed a defcription of America in 1550, fpeaks of this chart; a copy of which, fent by Behem himfelf, is preferved in the archives of Nuremberg. The celebrated aftronomer Riccioli, though an Italian, yet does not feem willing to give his countryman the honour of this important difcovery. In his *Geographia Reformata*, book. iii. p. 90. he fays, "Chriftopher Columbus never thought of an expedition to the Weft Indies until his arrival in the ifland of Madeira, where, amufing himfelf in forming and delineating geographical charts, he obtained information from Martin Bœhm, or, as the Spaniards fay, from Alphonfus Sanchez de Huelva a pilot, who had chanced to fall in with the ifland afterwards called *Dominica*." And in another place: "Let Bœhm and Columbus have each their praife; they were both excellent navigators; but Columbus would never have thought of his expedition to America, had not Bœhm gone there before him. His name is not fo much celebrated as that of Columbus, Americus, or Magellan, although he is fuperior to them all."

That Behem rendered fome very important fervices to the crown of Portugal, is put beyond all controverfy by the recompence beftowed on him by King John; of which the following account has been given to the public from the archives of Nuremberg. "In the year 1485, on the 18th of Feb. in Portugal, in the city of Allafavas, and in the church of St Salvador, after the mafs, Martin Behem of Nuremberg was made a knight, by the hands of the moft puiffant Lord John II. king of Portugal, Algarve, Africa, and Guinea; and his chief fquire was the king himfelf, who put the fword in his belt; and the Duke of Begia was his fecond fquire, who put on his right fpur; and his third fquire was Count Chriftopher de Mela, the king's coufin, who put on his left fpur; and his fourth fquire was Count Martini Marbarinis, who put on his iron helmet; and the king himfelf gave him the blow on the fhoulder, which was done in the prefence of all the princes, lords, and knights of the kingdom; and he efpoufed the daughter of a great lord, in confideration of the important fervices he had performed; and he was made governor of the ifland of Fayal."

Thefe marks of diftinction, conferred on a ftranger, could not be meant as a recompenfe for the difcovery of the Azores, which was made twenty years before, but as a reward for the difcovery of Congo, from whence the Chevalier Behem had brought gold and different kinds of precious wares. This difcovery made much greater impreffion than that of a weftern world made at the fame time, but which neither increafed the wealth of the royal treafury, nor fatisfied the avarice of the merchants.

In 1492 the Chevalier Behem, crowned with honours and riches, undertook a journey to Nuremberg, to vifit his native country and his family. He there made a terreftrial globe, which is looked on as a mafterpiece for that time, and which is ftill preferved in the library of that city. The outline of his difcoveries may there be feen, under the name of weftern lands; and from their fituation it cannot be doubted that they are the prefent coafts of Brazil, and the environs of the Straits of Magellan. This globe was made in the fame year that Columbus fet out on his expedition; therefore it is impoffible that Behem could have profited by the works of that navigator, who befides went a much more northerly courfe.

After having performed feveral other interefting voyages, the Chevelier Behem died at Lifbon in July 1506, regretted by every one, but leaving behind him no other work than the globe and chart which we have juft been fpeaking of. The globe is made from the writings of Ptolemy, Pliny, Strabo, and efpecially from the account of Mark Paul, the Venetian, a celebrated traveller of the 13th century; and of John Mandeville, an Englifhman, who, about the middle of the 14th century, publifhed an account of a journey of 33 years in Africa and Afia. He has alfo added the important difcoveries made by himfelf on the coafts of Africa and America.

From thefe circumftantial accounts, but very lately brought to light, there can be little doubt, we think, but that America was difcovered by Martin Behem. Dr Robertfon is indeed of a different opinion: but great as we willingly acknowledge his authority to be, we may differ from him without prefumption, fince he had it not in his power to confult the German documents to which we have appealed, and has himfelf advanced facts not eafily to be reconciled to his own opinion. He allows that Behem was very intimate with Chriftopher Columbus; that he was the greateft geographer of his time, and fcholar of the celebrated John Müller, or Regiomontanus; that he had difcovered, in 1483, the kingdom of Congo, upon the coaft of Africa; that he made a globe which Magellan made ufe of; that he drew a map at Nuremberg, containing the particulars of his difcoveries; and that he placed in this chart land which is found to be in the latitude of Guiana. He adds indeed, without proof, that this land was a fabulous ifland; but if authentic records are to give place to bare affertion, there is an end of all hiftorical evidence. If Behem took for an ifland the firft land which he difcovered, it was a miftake furely not fo grofs as to furnifh grounds for queftioning his veracity, or for withholding from him for ever that juftice which has been fo long delayed.

But this very delay will by fome be thought a powerful objection to the truth of Behem's claim to the difcovery of America; for if it was really difcovered by him, why did not he leave behind him fome writing to confirm the difcovery to himfelf? and why did not the court of Portugal, fo jealous of the difcovery of the new world, proteft againft the exclufive claim of the Spaniards?

To thefe objections we may reply, that, however plaufible they may at firft appear, they do not in the

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smallest degree invalidate the positive evidence which we have urged for the Chevalier Behem's being the real discoverer of the new world; for it would surely be very absurd to oppose the *difficulty of assigning motives* for *certain* actions performed at a remote period, to the *reality* of *other* actions for which we have the testimony of a cloud of contemporary witnesses. Supposing it were true, therefore, that Behem had left behind him no writing claiming to himself the discovery of any part of the continent of America, the only inference which could be drawn from his silence would be, either that he was a man of great modesty, or that his mind was intent only on the acquisition of knowledge to himself, without feeling the usual impulse to communicate that knowledge to others. But it is not true that he has left behind him no claim of this discovery to himself. The letters to which we have appealed, and which are preserved in the archives of Nuremberg, together with the globe and map, which he certainly made, furnish as complete a confirmation of his claim as could have been furnished by the most elegant account of his voyages.

For the silence of the Portuguese, many reasons might be assigned. The discoveries of Columbus were made so much farther north than those of Behem, that, in an age when geographical knowledge was so very limited, both Spaniards and Portuguese might very naturally believe that the country discovered by the former of these navigators had no connection with that discovered by the latter. At any rate, the Portuguese, whose discoveries proceeded from avarice, were satisfied with scraping together gold wherever they could find it; and finding it in Africa, they thought not of searching for it in a more distant region, till the success of the Spaniards shewed them their mistake.

One thing more is worthy of attention. The long stay of Columbus at Madeira makes his interview with Behem more than probable. It is impossible that he should have neglected seeing a man so interesting, and who could give him every kind of information for the execution of the plan which he had formed. The mariners who accompanied the Chevalier Behem might also have spread reports at Madeira and the Azores concerning the discovery of which they had been witnesses. What ought to confirm us in this is, that Mariana says himself (book xxvi. chap. iii.), that a certain vessel going to Africa, was thrown by a gale of wind upon certain unknown lands; and that the sailors at their return to Madeira had communicated to Christopher Columbus the circumstances of their voyage. All authors agree that this learned man had some information respecting the western shores; but they speak in a very vague manner. The expedition of the Chevalier Behem explains the mystery (B).

BEHRING's *Bay*, on the N. W. coast of N. America, is separated from Admiralty Bay, on the northward, by a point of land; and lies N. W. from Cross Sound.—*Morse*.

BEHRING's *Straits*, separate Asia from America, are so called from the Russian navigator, Capt. Behring, who with Ishirikow, sailed from Kamptschatka, in Siberia, on the Asiatic coast, in quest of the New World, in a quarter where it had, perhaps, never been approached. They both discovered land within a few degrees of the N. W. coast of America. But the more recent discoveries of Capt. Cook, and his successor, Clarke, have confirmed the near approximation of the two continents. Cape Prince of Wales is the most westerly point of the American continent, hitherto known. It is situated in N. lat. 65. 46. E. long. 191. 45. and is 39 miles distant from the eastern coast of Asia.

The sea, from the S. of Behring's Straits, to the crescent of isles between Asia and America, is very shallow. It deepens from these straits (as the British seas do from Dover) till soundings are lost in the Pacific Ocean; but that does not take place but to the S. of the isles. Between them and the straits is an increase from 12 to 54 fathoms, except only off St Thaddeus Noss, where there is a channel of greater depth. From the volcanic disposition, it has been judged probable, not only that there was a separation of the continents at these straits, but that the whole space from the isles to that small opening had once been dry land; and that the fury of the watery element actuated by that of fire, had, in very remote times, subverted and overwhelmed the tract, and left the islands to serve as monumental fragments.

The famous Japanese map places some islands seemingly within these straits, on which is bestowed the title of *Ya Zue*, or the kingdom of the dwarfs. This gives some reason to suppose that America was not unknown to the Japanese; and that they had, as is mentioned by Kæmpfer, and Charlevoix, made voyages of discovery; and, according to the last, actually wintered upon the continent, where probably meeting with the Esquimaux, they might, in comparison of themselves, and justly, distinguish them by the name of dwarfs.—*ib.*

BEKIA, or *Becouya*, or *Boquio*, a small British island among the Granadillas; 55 miles N. E. of Granada, and 65 leagues from Barbadoes. It was called Little Martinico by the French, and has a safe harbour from all winds; but no fresh water. It is only frequented by those who catch turtle. The soil produces wild cotton, and plenty of water melons. —*ib.*

BELCHER, a township in Hampshire co. Massachusetts, containing 1485 inhabitants, who subsist chiefly by farming. It lies 12 miles E. of Hadley, and 85 W. of Boston.—*ib.*

BELFAST, a township and bay in Hancock co. District of Maine, both situated in what is called the Waldo Patent, at the mouth of Penobscot River and on its western side; 38 miles N. E. by E. from Hallowell, and 246 N. E. from Boston. The town contains 245 inhabitants. The Bay, on the N. western part of which the town stands, runs up into the land by three short arms. Islesborough Island lies in the middle of it, and forms two channels leading to the mouth of Penobscot river.—*ib.*

(B) For the greater part of this memoir we are indebted to M. Otto's paper on the discovery of America, published first in the second volume of the American Transactions, and afterwards by Nicholson in N° II. and III. of his Journal.

Bellaire || Benson.

BELLAIRE, a post-town near the centre of Harford co. Maryland, and the chief of the county. It contains a court-house and gaol, and is thinly inhabited; distant from Harford, 6 miles, N. W; 22 N. E. from Baltimore, and 86 W. S. W. from Philadelphia. —*Morse.*

BELLINGHAM, a small farming township in Norfolk co. Massachusetts, containing 735 inhabitants, 20 miles northerly from Providence, and 34 southerly from Boston.—*ib.*

BELLS *Mill*, a settlement in N. Carolina, near the Moravian settlements, at the source of Deep river the N. western-most branch of the N. W. branch of Cape Fear, and about 50 miles W. of Hillsborough.—*ib.*

BELPRE, a post-town and small settlement in the territory N. W. of the Ohio, on the N. W. bank of Ohio river between the Hockhocking and Muskingum rivers and opposite the mouth of the Little Kanhaway; about 14 miles below Marietta, and 480 S. W. by W. from Philadelphia.—*ib.*

BELVIDERE, a new township in Franklin co. Vermont.——Also a village in New-Jersey, in Sussex co. situated on Delaware river at the mouth of Pequest river and 11 miles above Easton, in Pennsylvania.—*ib.*

BENNINGTON, a county in the S. W. corner of Vermont, having Windham co. on the E. and the state of N. York on the W; into which state it sends Batten Kill and Hoosack rivers, which both rise here, and fall into Hudson river 14 miles apart: Rutland co. lies on the N. and the state of Massachusetts on the S. It contains 19 townships, of which Bennington and Manchester are the chief. It has 12,254 inhabitants, including 16 slaves. The mountains here furnish iron ore in abundance, and employ already, a furnace and two forges.—*ib.*

Bennington, the shire town of the above county, and the largest town in the state of Vermont, having about 160 houses, in the compact part of the town, is situated at the foot of the Great Mountain, near the S. W. corner of the state, 24 miles easterly from the junction of Hudson and Mohawk rivers, and about 52 from the S. end of Lake Champlain, at the confluence of the E. and S. bays; and lies 55 miles from Rutland; 202 miles N. easterly from New-York; and 300 in the same direction from Philadelphia. N. lat. 42. 42. W. long. 74. 10. Bennington has several elegant buildings. Its public edifices are a congregational church, state house and gaol. It is the oldest town in the state, having been first settled in 1764, and is in a flourishing condition, containing 2,400 inhabitants. Within the township is Mount Anthony, which rises very high in a conical form.

Two famous battles were fought in or near this town, in one day, Aug. 16, 1777, in which Col. Stark gained great fame. The British lost 4 brass field pieces, and other military stores; and besides those slain, 700 were taken prisoners. The killed and wounded of the Americans were about 100 men. This defeat contributed, in a great measure, to the subsequent surrender of Gen. Burgoyne's army.—*ib.*

BENSON, the N. westernmost township in Rutland co. Vermont, is situated on the E. side of Lake Champlain; 57 miles N. N. W. of Bennington, and has 658 inhabitants. Hubberton river passes through Benson in its way to East Bay. Cockburne's Creek, which feeds the same bay, rises here.—*ib.*

Bereans.

BEREANS, in ancient church history, the inhabitants of Berea. They are highly commended in Scripture for their ready reception of the gospel, upon a fair and impartial examination of its agreement with the Old Testament prophecies. Sopater, a Berean, attended the apostle Paul to Asia. Acts xvii. 10—13. and xx. 4.

Bereans, in modern church history, a sect of Protestant dissenters from the church of Scotland, who take their title from, and profess to follow, the example of the ancient Bereans, in building their system of faith and practice upon the Scriptures alone, without regard to any human authority whatever.

Doctrines.

The Bereans agree with the great majority of Christians, both Protestants and Catholics, respecting the doctrine of the Trinity, which they hold as a fundamental article of the Christian faith; and they also agree in a great measure with the *professed* principles of both our established churches respecting predestination and election, though they allege that these doctrines are not consistently taught in either church. But they differ from the majority of all sects of Christians in various other important particulars. Such as,

1. Respecting our knowledge of the Deity. Upon this subject, they say, that the majority of professed Christians stumble at the very threshold of revelation; and, by admitting the doctrine of natural religion, natural conscience, natural notices, &c. not founded upon revelation, or derived from it by tradition, they give up the cause of Christianity at once to the infidels; who may justly argue, as Mr Paine in fact does in his Age of Reason, that there is no occasion for any revelation or word of God, if man can discover his nature and perfections from his works alone. But this, the Bereans argue, is beyond the natural powers of human reason; and therefore our knowledge of God is from revelation alone; and that without revelation man would never have entertained an idea of his existence.

2. With regard to faith in Christ, and assurance of salvation through his merits, they differ from almost all other sects whatsoever. These they reckon *inseparable*, or rather the *same*; because, they argue, God hath expressly declared, "He that believeth shall be saved;" and therefore it is not only absurd, but impious, and in a manner calling God a liar, for a man to say, "*I believe* the Gospel, but *have doubts* nevertheless of my own salvation." With regard to the various distinctions and definitions that have been given of different kinds of faith, they argue, that "there is nothing incomprehensible or obscure in the meaning of this word as used in Scripture; but that as faith, when applied to human testimony, signifies neither more nor less than the mere simple belief of that testimony as true, upon the authority of the testifier; so, when applied to the testimony of God, it signifies precisely the belief of his testimony, and resting upon his veracity alone, without any kind of collateral support from concurrence of any other evidence or testimony whatever." And they insist, that as this faith is the gift of God alone, so the person to whom it is given is as conscious of possessing it, as the being to whom God gives life is of being alive; and therefore he entertains no doubts either of this faith or his consequent salvation through the merits of Christ, who

Bereans.

who died and rose again for that purpose. In a word, they argue, that the Gospel would not be what it is held forth to be, "glad tidings of great joy," if it did not bring full personal assurance of eternal salvation to the believer: which assurance, they insist, "is the present infallible privilege and portion of every individual believer of the Gospel." These definitions of faith, and its inseparable concomitant assurance, they prove by a variety of texts, which our room permits us not to quote.

3. Consistently with the above definition of faith, they say, that the sin against the Holy Ghost, which has alarmed and puzzled so many in all ages, is nothing else but *unbelief;* and that the expression, that "it shall not be forgiven, neither in *this world* nor that which is to come," means only, that a person dying in infidelity would not be forgiven, neither under the former dispensation by Moses (the then *present* dispensation, kingdom, or government of God), nor under the Gospel dispensation, which, in respect of the Mosaic, was a kind of future world or kingdom to come.

4. The Bereans interpret a great part of the Old Testament prophecies, and in particular the whole of the Psalms, excepting such as are merely historical or lauditory, to be typical or prophetical of Jesus Christ, his sufferings, atonement, mediation and kingdom: and they esteem it a gross perversion of these Psalms and prophecies to apply them to the experiences of private Christians. In proof of this, they not only urge the words of the apostle, that "no prophecy is of any private interpretation," but they insist that the whole of the quotations from the ancient prophecies in the New Testament, and particularly those from the Psalms, are expressly applied to Christ. In this opinion many other classes of Protestants agree with them.

5. Of the absolute all superintending sovereignty of the Almighty, the Bereans entertain the highest ideas, as well as of the uninterrupted exertion thereof over all works in heaven, earth, and hell, however unsearchable by his creatures. "A God without election (they argue), or choice in all his works, is a god without existence—a mere idol—a non-entity. And to deny God's election, purpose, and express will in all his works, is to make him inferior to ourselves." For farther particulars respecting the Berean doctrines, we must refer the reader to the works of Messrs Barclay, Nicol, Brookshank, &c.

Origin.

The Bereans first assembled as a separate society of Christians in the city of Edinburgh in autumn 1773, and soon after in the parish of Fettercairn. The opponents of the Berean doctrines allege, that this new system of faith would never have been heard of, had not Mr Barclay, the founder of it, been disappointed of a settlement in the church of Scotland. A respectable clergyman of the established church has even hinted something to this purpose in Sir John Sinclair's Statistical Account, Vol. IX. p. 599. But the Bereans, in answer to this charge, appeal not only to Mr Barclay's doctrine, uniformly preached in the church of Fettercairn, and many other places in that neighbourhood, for fourteen years before that benefice became vacant; but likewise to two different treatises, containing the same doctrines, published by him about ten or twelve years before that period. They admit, indeed, that, previous to May 1773, when the general assembly, by sustaining the king's presentation in favour of Mr Foote, excluded Mr Barclay from succeeding to the church of Fettercairn (notwithstanding the almost unanimous desire of the parishioners), the Bereans had not left the established church, or attempted to erect themselves into a distinct society; but they add, that this was by no means necessary on their part, until by the assembly's decision they were in danger of being not only deprived of his instructions, but of being scattered as sheep without a shepherd. And they add, that it was Mr Barclay's open and public avowal, both from the pulpit and the press, of those peculiar sentiments which now distinguish the Bereans, that was the first and principal, if not the only, cause of the opposition set on foot against his settlement in Fettercairn.

Practice.

Having thus given a concise view of the origin and distinguishing doctrines of Bereanism, it only remains to mention a few particulars relative to the practice of the Bereans as a Christian society. Infant baptism they consider as a divine ordinance instituted in the room of circumcision; and they think it absurd to suppose that infants, who all agree are admissible to the kingdom of God in heaven, should nevertheless be incapable of being admitted into His visible church on earth. They commemorate the Lord's supper in general once a month; but as the words of the institution fix no particular period, they sometimes celebrate it oftener, and sometimes at more distant periods, as may suit their general convenience. In observing this ordinance, they follow the primitive apostolic plan, without any previous days of fasting or preparation; as they apprehend that such human institutions only tend to make an idol of the ordinance, and to lead people to entertain erroneous ideas of its superior solemnity and importance. Equal and universal holiness in all manner of conversation, they recommend at all times, as well as at the table of the Lord. They meet every Lord's day for the purpose of preaching, praying, and exhortation to love and good works. With regard to the admission and exclusion of members, their method is very simple. When any person, after hearing the Berean doctrines, professes his belief and assurance of the truths of the Gospel, and desires to be admitted into their communion, he is cheerfully received upon his profession, whatever may have been his former manner of life. But if such an one should afterwards draw back from his good profession or practice, they first admonish him; and if that has no effect, they leave him to himself. They do not think that they have any power to deliver up a backsliding brother to Satan. That text and other similar passages, such as, "Whatsoever ye shall bind on earth shall be bound in heaven," &c. they consider as restricted to the apostles and to the inspired testimony alone, and not to be extended to any church on earth, or any number of churches or of Christians, whether deciding by a majority of votes or by unanimous voices. Neither do they think themselves authorised, as a Christian church, to enquire into each others political opinions, any more than to examine into each others notions of philosophy. They both recommend and practise, as Christian duties, submission to lawful authority; but they do not think that a man, by becoming a Christian, or joining their society, is under any obligation, by the rules of the Gospel, to renounce his rights of private judgment upon matters of public or private importance. Upon all

Bereans ‖ Berkenhout. such subjects they allow each other to think and act as each may see it his duty. And they require nothing more of their members than a uniform and steady profession of the apostolic faith, and a suitable walk and conversation. With regard to feet-washing and the like practices, which some other sects of Christians consider as duties, the Bereans are of opinion that they are by no means obligatory. They argue, that the example given by our Saviour of washing the feet of his disciples was not an institution of an ordinance, but merely a familiar instance, taken from the custom of the country, and adopted by our Lord on that occasion, to teach his followers that they ought at all times to be ready to perform even the meanest offices of kindness to each other.

Present state. It may not be improper to add to the above delineation of the principles and practice of the Bereans, that their doctrine has found converts in various places of Scotland, England, and America, and that they have congregations in Edinburgh, Glasgow, Paisley, Stirling, Crieff, Dundee, Arbroath, Montrose, Fettercairn, Aberdeen, and other towns in Scotland; as well as in London and various places in England; not to add Pennsylvania, the Carolinas, and other States in America.

The above account of the doctrines, origin, practice, and present state of this society, has been given to us by the founder himself.

BERGEN *Co.* in New-Jersey, on Hudson river, lies opposite New-York, on the E. and was first planted by the Dutch, from New-York. It contains 6 townships, of which the chief are Bergen and Hackinsack, and 12,601 inhabitants, including 2301 slaves. Here are 7 Dutch Calvinist churches, and 2 of Dutch Lutherans. There is a copper mine here, which when worked by the Schuylers (to whom it belonged) was considerably productive; but it has been neglected for many years.

It is a mountainous, rough and hilly county, 30 miles long, and 25 broad. It forms part of the E. and northern end of the state; and its N. W. extremity meets the N. E. part of Sussex co.; so that these two counties embosom Morris and Essex counties, except on the S. W. and form the whole breadth of the state in that quarter.—*Morse.*

BERKENHOUT (Dr John), was about the year 1730 born at Leeds in Yorkshire, and educated at the grammar school in that town. His father, who was a merchant, and a native of Holland, intended him for trade; and with that view sent him at an early age to Germany, in order to learn foreign languages. After continuing a few years in that country, he made the tour of Europe in company with one or more English noblemen. On their return to Germany they visited Berlin, where Mr Berkenhout met with a near relation of his father's, the Baron de Bielfeldt, a nobleman then in high estimation with Frederick the Great king of Prussia; distinguished as one of the founders of the Royal Academy of Sciences at Berlin, and universally known as a politician and a man of letters. With this relation our young traveller fixed his abode for some time; and, regardless of his original destination, became a cadet in a Prussian regiment of foot. He soon obtained an ensign's commission, and in the space of a few years was advanced to the rank of captain. He quitted the Prussian service on the declaration of war between England and France in 1756, and was honoured with the command of a company in the service of his native country. When peace was concluded in 1760, not choosing, we suppose, to lead a life of inactivity on half pay, he went down to Edinburgh, and commenced student of physic. During his residence at that university, he published his *Clavis Anglica Linguæ Botanicæ;* a book of great utility to all students of botany.

Berkenhout. Having continued some years at Edinburgh, Mr Berkenhout went to the university of Leyden, where he was admitted to the degree of M. D. in the year 1765. On this occasion he published a thesis, intitled, *Dissertatio medica inauguralis de Podagra,* which he dedicated to his relation Baron de Bielfeldt. Returning to England, Dr Berkenhout settled at Isleworth in Middlesex, and soon after published his *Pharmacopæia Medici,* the third edition of which was printed in 1782. In 1778 he was sent by government with the commissioners to America. Neither the commissioners nor their secretary were suffered by the congress to proceed further than New York. Dr Berkenhout, however, found means to penetrate as far as Philadelphia, where the congress was then assembled. He appears to have remained in that city for some time without molestation: but at last they began to suspect that he was sent by Lord North for the purpose of tampering with some of their leading members. The Doctor was immediately seized and committed to prison.

How long he remained a state prisoner, or by what means he obtained his liberty, we are not informed; but we find from the public prints, that he rejoined the commissioners at New York, and returned with them to England. For this temporary sacrifice of the emoluments of his profession, and in consideration of his having, in the service of his sovereign, committed himself to the mercy of a congress of enraged republicans, he obtained a pension.

Many years previous to this event, Dr Berkenhout had published his *Outlines of the Natural History of Great Britain and Ireland,* in three volumes 12mo; a work which established his reputation as a naturalist. In the year 1773 he wrote a pamphlet, entitled, *An Essay on the Bite of a Mad Dog, in which the Claim to Infallibility of the Principal Preservative Remedies, against the Hydrophobia is examined.* This pamphlet is inscribed to Sir George Baker, and deserves to be universally read.

In the year following Dr Berkenhout published his *Symptomatology;* a book which is too universally known to require any recommendation.

At the beginning of the year 1788 he published a work, entitled, *First Lines of the Theory and Practice of Philosophical Chemistry,* which he dedicated to Mr Eden, now Lord Auckland, who had been one of the commissioners whom he accompanied to America.

These, we believe, are the Doctor's principal publications in the line of his profession; but he wrote on many other subjects with equal ability. His translation of *Count Tessin's Letters,* which was his first publication, and dedicated to the present king when prince of Wales, evinces his knowledge of the Swedish language, and shews him to have been a good poet. His *Essay on Ways and Means,* proves him to have been better acquainted with the system of taxation than most other men

men who have written on the fubject. His biographical powers appear in his *Biographia Literaria*; and in all his works are fufficient proofs of his claffical learning, and that the Italian, French, German, and Dutch languages, were familiar to him. He poffeffed likewife a very confiderable degree of mathematical fcience, which he acquired in the courfe of his military ftudies; and to thofe more folid attainments he is faid to have added no fmall fkill in the fine arts of painting and mufic. This eminent man, who, for the variety and promptitude of his knowledge, has been compared to the Admirable Crichton, died on the 3d of April 1791.

BERKLEY, a townfhip in Briftol co. Maffachufetts, containing 850 inhabitants; 50 miles fouthward of Bofton.—*Morse.*

Berkley, the name both of a county and town, in Charlefton Diftrict, S. Carolina, lying near Cooper and Afhley rivers. In the cenfus of 1791, it was called St John's Parifh, in Berkley co. and contained 752 free perfons, and 5170 flaves.—*ib.*

Berkley *Co.* in Virginia, lies W. of the Blue Ridge, N. of Frederick co. and feparated from the ftate of Maryland, on the N. and E. by Potowmack river. This fertile county, about 40 miles long and 20 broad, has 16,781 free inhabitants and 2932 flaves. Martinfburg is its chief town.—*ib.*

Berkley's *Sound,* on the N. W. coaft of N. America, lies on the eaftern fide of Quadras Ifles. The land on its eaftern fide is oppofite Cape Flattery, and forms the N. fide of the Straits de Fuca.—*ib.*

BERK's *Co.* in Pennfylvania, has Northampton co. on the N. E.; Northumberland on the N. W.; part of Luzern on the N.; Dauphin and Lancafter counties S. W. and Chefter and Montgomery S. E. It is watered by Schuylkill River and is 53 miles long and near 29 broad, containing 1,030,400 acres. Here iron ore and coal are found in plenty, which fupply feveral iron works. The northern parts are rough and hilly. Berks contains 30,179 inhabitants, of whom 65 only are flaves. It has 29 townfhips, of which Reading is the chief.—*ib.*

BERKSHIRE *Co.* in Maffachufetts, is bounded W. by New York ftate; S. by the ftate of Connecticut; E. by Hampfhire co. and N. by the ftate of Vermont. It thus runs the whole extent of the ftate from N. to S. and contains twenty-fix townfhips; the chief of which are Stockbridge, Lenox, Great Barrington, Williamftown, and Pittsfield; and the number of inhabitants 30,291. White and clouded marble is found in feveral towns, in the rough and hilly parts of this county. In February, 1796, the legiflature paffed an act to eftablifh a college in Williamftown, by the name of Williams College.—*ib.*

Berkshire, a newly fettled townfhip, in Franklin co. Vermont.—*ib.*

BERLIN, a neat and flourifhing town of York co. Pennfylvania, containing about 100 houfes. It is regularly laid out, on the S. W. fide of Conewago Creek, 13 miles wefterly of Yorktown, and 101 W. of Philadelphia. N. lat. 39. 56.—*ib.*

Berlin, a townfhip in Orange co. Vermont, on Dog River a branch of Onion River from the S.; which laft feparates Berlin from Montpelier, on the N. N. W. Berlin contains 134 inhabitants, and is about 94 miles N. eafterly from Bennington.—*ib.*

Berlin, a townfhip in Hartford co. Connecticut, 12 miles S. S. W. of Hartford, 42 N. W. of New-London; and 26 N. N. E. of New-Haven.—*ib.*

Berlin, a townfhip in Worcefter co. Maffachufetts, containing 512 inhabitants; 34 miles W. of Bofton, and 15 N. E. of Worcefter. Hops have been cultivated here lately, and promifed to be a valuable article of hufbandry.—*ib.*

Berlin, in Somerfet co. formerly in that of Bedford, Pennfylvania, lies on a branch of Stony Creek, a fouth water of Conemaugh River on the W. fide of the Alleghany Mountain; 25 miles weftward of Bedford; 23 N. W. of Fort Cumberland, in Virginia, and 200 W. of Philadelphia. Stone Creek, the chief fource of Kifkeminitas river rifes N. N. E. of Berlin. N. lat. 39. 54.—*ib.*

BERMUDA HUNDRED, or *City Point,* as it is fometimes called, is a port of entry and poft town, in Chefterfield co. Virginia, fituated on the point of the peninfula, formed by the confluence of the Appamattox with James River, 36 miles wefterly from Williamfburg, 64 from Point Comfort, in Chefapeak Bay, and 315 S. W. by S. from Philadelphia. City Point, from which it is named, lies on the fouthern bank of James River, 4 miles S. S. W. from this town. The exports from this place, chiefly collected at Richmond, 20 miles above it, amounted in 1794, to the value of 773,549, dollars; and from the 1ft of October, to 1ft December 1795, were as follow: 15 kegs of butter, 578 bbls. fuperfine flour, 101 half do. 789 fine do. 393 lbs. indigo, 10 tons pig iron, 100 lbs. faffafras, 80,320 hhd. ftaves, 66,300 bbl. ftaves, 1,819 hhds. tobacco, and 3 kegs manufactured do.—Total exports 90,859 dollars, 45 cents. There are about 40 houfes here, including fome warehoufes. It trades chiefly with the W. Indies, and the different ftates. City Point, in James River, lies in N. lat. 37. 16. W. long. 77. 31½.—*ib.*

BERNARD's *Bay,* lies on the N. W. fide of the gulf of Mexico. The paffage into it, between feveral iflands, is called Pafco de Cavallo.—*ib.*

BERNARDSTOWN, in Somerfet co. New-Jerfey, contains 2377 inhabitants, including 93 flaves.

Alfo the name of a townfhip in Hampfhire co. Maffachufetts, containing 691 inhabitants; diftant 110 miles weftward from Bofton.—*ib.*

BERNE, a townfhip in Albany co. New-York. By the ftate cenfus of 1796, it appears there are 447 of the inhabitants who are electors.—*ib.*

BERNOULLI (John), a celebrated mathematician, was born at Bafil the 7th of Auguft 1667. His father intended him for trade; but his own inclination was at firft for the belles lettres, which, however, like his brother James, whofe life is given in the Encyclopædia, he left for mathematics. He laboured with his brother to difcover the method ufed by Leibnitz, in his effays on the differential calculus, and gave the firft principles of the integral calculus. Our author, with Meffis Huygens and Leibnitz, is faid to have been the firft who gave the folution of the problem propofed by James Bernoulli, concerning the catenary, or curve formed by a chain fufpended by its two extremities. But for more on this fubject, fee Arch in this Supplement.

John Bernoulli had the degree of doctor of phyfic at Bafil, and two years afterward was named profeffor of mathematics.

mathematics in the univerfity of Groningen. It was here that he difcovered the mercurial phofphorus, or luminous barometer; and where he refolved the problem propofed by his brother concerning ifoperimetricals.

On the death of his brother James, the profeffor at Bafil, our author returned to his native country, againft the preffing invitations of the magiftrates of Utrecht to come to that city, and of the univerfity of Groningen, who wifhed to retain him. The Academic Senate of Bafil foon appointed him to fucceed his brother, without affembling competitors, and contrary to the eftablifhed practice; an appointment which he held during his whole life.

In 1714 was publifhed his treatife on the management of fhips; and in 1730 his memoir on the elliptical figure of the planets gained the prize of the Academy of Sciences. The fame Academy alfo divided the prize for their queftion concerning the inclination of the planetary orbits, between our author and his fon Daniel. See Bernoulli (Daniel), *Encycl.*

John Bernoulli was a member of moft of the academies of Europe, and received as a foreign affociate of that of Paris in 1699. After a long life fpent in conftant ftudy and improvement of all the branches of the mathematics, he died full of honours, the 1ft of January 1748, in the 81ft year of his age. Of five fons which he had, three purfued the fame fciences with himfelf. One of thefe died before him; the two others, Nicolas and Daniel, he lived to fee become eminent, and much refpected in the fame fciences.

The writings of this great man were difperfed through the periodical memoirs of feveral academies, as well as in many feparate treatifes. And the whole of them were carefully collected and publifhed at Laufanne and Geneva, 1742, in 4 vols. 4to. He was of undoubted eminence; but even in fcience he was a hafty man, and certainly envious of the fame of Newton.

BERTIE, a maritime co. in N. Carolina, in Edenton diftrict, with the Roanoke its S. boundary, and Albemarle Sound on the E. In it is fituated the ancient Indian tower of Tufcarora. It contains 12,606 fouls, of which number 5141 are flaves.—*Morse.*

BERWICK, or *Abbotftown*, a neat town in York co. Pennfylvania, at the head of Conewago Creek, 13 miles weftward of York, 26 S. S. W. of Harrifburg, and 103 W. by S. of Philadelphia. The town is regularly laid out, and contains about 100 houfes, a German Lutheran, and a Calvinift church. N. lat. 39. 54.—*ib.*

Berwick, or *New-Berwick*, a fmall town of Northumberland co. Pennfylvania, on the N. weftern fide of the E. branch of Sufquehannah River oppofite Nefcopeck Falls, and Nefcopeck Creek, 32½ miles N. E. from Northumberland and Sunbury, at the junction of the E. with the W. branch of Sufquehannah, and 160 N. W. of Philadelphia. N. lat. 41. 3.—*ib.*

Berwick, a townfhip in York co. Diftrict of Maine, containing 3894 inhabitants. It has an incorporated academy, and lies on the E. fide of Salmon Fall River, 7 miles N. W. of York, and 86 E. of N. from Bofton.—*ib.*

BETELGEUSE, a fixed ftar of the firft magnitude, in the right fhoulder of Orion.

BETHABARA, the firft fettlement of the Moravians in the lands of Wachovia, in N. Carolina, begun in 1753; 6 miles N. of Salem, and 183 W. of Halifax, in N. lat. 36. 9. It is fituated on the W. fide of Graffy Creek, which unites with the Gargales, and feveral others; and falls into the Yadkin. It contains a church of the United Brethren, and about 50 dwelling houfes.—*Morse.*

BETHANY, or *Bethania*, a Moravian fettlement and poft town, in the lands of Wachovia, in N. Carolina, begun in 1760; 9 miles N. W. of Salem, 4 N. W. of Bethabara, and 568 S. W. by S. of Philadelphia. It contains about 60 houfes, and a church, built on a regular plan.—*ib.*

BETHEL, a fmall Moravian fettlement on Swetara River in Pennfylvania, 12 miles from Mount Joy.—— A townfhip in Dauphin county.—*ib.*

Bethel, a townfhip in Windfor co. Vermont, containing 473 inhabitants; N. N. W. of, and bounded by Stockbridge, and about 67 miles N. N. eafterly of Bennington. It gives rife to a fmall branch of White River.—*ib.*

Bethel, a townfhip in Delaware co. Pennfylvania. —*ib.*

Bethel (Mount) a townfhip in Northampton county, Pennfylvania.

BETHLEHEM, a town in Albany co. New-York, very fruitful in paftures, and has large quantities of excellent butter. By the ftate cenfus of 1796, 388 of the inhabitants are electors.—*ib.*

Bethlehem, a townfhip in Berkfhire co. Maffachufetts, having 261 inhabitants. It lies about 10 miles S. of E. from Stockbridge, 10 from Lenox, and 130 from Bofton. It borders on Tyringham and Loudon.—*ib.*

Bethlehem, a townfhip in Hunterdon co. New-Jerfey, fituated at the head of the S. branch of Rariton River. It contains 1335 inhabitants, including 31 flaves. Turf for firing is found here.—*ib.*

Bethlehem, a townfhip in Litchfield co. Connecticut, joins Litchfield on the N. and Woodbury on the S.—*ib.*

Bethlehem, a poft town in Northampton co. Pennfylvania, is a celebrated fettlement of the Moravians, or *United Brethren*, of the Proteftant Epifcopal church, as they term themfelves. It is fituated on Lehigh River a weftern branch of the Delaware, 53 miles northerly from Philadelphia, and 18 foutherly from the *Wind Gap*. The town ftands partly on the lower banks of the Manakes, a fine creek, which affords trout and other fifh. The fituation is healthful and pleafant, and in fummer is frequented by gentry from different parts. In 1787, there were 60 dwelling houfes of ftone, well built, and 600 inhabitants. Befides the meeting-houfe, are 3 other public buildings, large and fpacious; one for the fingle brethren, one for the fingle fifters, and the other for the widows. The literary eftablifhments, as well as the religious regulations, here, deferve notice.—In a houfe adjoining to the church, is a fchool for females; and fince 1787, a boarding fchool for young ladies, who are fent here from different parts, and are inftructed in reading and writing (in the Englifh and German tongues) grammar, arithmetic, geography, needle work, mufic, &c. The minifter of the place has the direction of this as well as of the boys fchool, which is kept in a feparate houfe, where they are initiated in the fundamental branches of literature. Thefe fchools, efpecially that for

for the young ladies, are deservedly in very high repute; and scholars, more than can be accommodated, are offered from all parts of the United States.

There is at the lower part of the town a machine, of simple construction, which raises the water, from a spring, into a reservoir, to the height of 100 feet; whence it is conducted by pipes into the several streets of the town.

There is a genteel tavern at the N. end of the town, the profit arising from which, belongs to the society. There is also a store, with a general assortment of goods, an apothecary's shop, a large tan-yard, a currier's, and a dyer's shop, a grist-mill, a fulling-mill, an oil-mill, and a saw-mill, and on the banks of the Lehigh, a brewery. N. lat. 40. 37. W. long. 75. 14. —*Morse.*

BEVERLY, a township and post town in Essex co. Massachusetts, containing 3290 inhabitants, is separated from Salem by a handsome bridge, and is about 20 miles E. of N. of Boston, and 22 S. W. of Newburyport. It has two parishes. In the parish next the harbor, are a number of handsome houses, exhibiting the cheering rewards of enterprise and industry, and the inhabitants are devoted to the fishery and other branches of navigation. In the other part of the town, which is chiefly agricultural, is a cotton manufactory. The bridge, mentioned before, is 1500 feet in length, erected in 1788, and connects this town with Salem. It has a draw for vessels.—*ib.*

BEVERLY'S *Manor*, or *Irish Tract*, in Virginia, is a tract of land, in N. lat. 38. 10. at the head of Massanuten's River, a western branch of the Shenandoah, which rises here by three branches, viz. Middle River, Lewis and Christian Creeks. It lies between the Blue, and the North Ridge. The road from Yadkin River, through Virginia to Philadelphia, passes through here. —*ib.*

BEZOUT (Stephen), a celebrated French mathematician, member of the Academies of Sciences and the Marine, and examiner of the guards of the marine and of the eleves of artillery, was born at Nemours the 31st of March 1730. In the course of his studies he met with some books of geometry, which gave him a taste for that science; and the Eloges of Fontenelle, shewed him the honours attendant on talents and the love of the sciences. His father in vain opposed the strong attachment of young Bezout to the mathematical sciences. April 8, 1758, he was named adjoint-mechanician in the French Academy of Sciences; having before that sent them two ingenious memoirs on the integral calculus, and given other proofs of his proficiency in mathematics. In 1763, he was named to the new office of examiner to the marine, and appointed to compose a system of mathematics for their use; and in 1768, on the death of M. Camus, he succeeded as examiner of the artillery eleves.

Bezout fixed his attention more particularly to the resolution of algebraic equations; and he first found out the solution of a particular class of equations of all degrees. This method, different from all former ones, was general for the cubic and biquadratic equations, and just became particular only at those of the 5th degree. Upon this work our author laboured from 1762 till 1779, when he published it. He composed two courses of mathematics; the one for the marine, the other for the artillery. The foundation of these two works was the same; the applications only being different, according to the two different objects: these courses have every where been held in great estimation. In his office of examiner he discharged the duties with great attention, care, and tenderness. A trait of his justice and zeal is remarkable in the following instance: During an examination which he held at Toulon, he was told that two of the pupils could not be present, being confined by the small-pox: he himself had never had that disease, and he was greatly afraid of it; but as he knew that if he did not see these two young men, it would much impede their improvement, he ventured to their bed sides to examine them, and was happy to find them so deserving of the hazard into which he put himself for their benefit.

Mr Bezout lived in this employment for several years, beloved of his family and friends, and respected by all, enjoying the fruits and the credit of his labours. But the trouble and fatigues of his offices, with some personal chagrines, had reduced his strength and constitution; he was attacked by a malignant fever, of which he died Sept. 27, 1783, in the 54th year of his age, regretted by his family, his friends, the young students, and by all his acquaintance in general.

The books published by him were: 1. Course of Mathematics for the use of the Marine, with a Treatise on Navigation, 6 vols in 8vo, Paris, 1764. 2. Course of Mathematics for the Corps of Artillery, 4 vols in 8vo, 1770. 3. General Theory of Algebraic Equations, 1779.

His papers printed in the volumes of the Memoirs of the Academy of Sciences are: 1. On curves, whose rectification depends on a given quantity, in the volume for 1758. 2. On several classes of equations that admit of an algebraic solution, 1762. 3. First volume of a course of mathematics, 1764. 4. On certain equations, &c. 1764. 5. General resolution of all equations, 1765. 6. Second volume of a course of mathematics, 1765. 7. Third volume of the same, 1766. 8. Fourth volume of the same, 1767. 9. Integration of differentials, &c. vol. 3. Sav. Etr. 10. Experiments on cold, 1777.

BIG BONE *Creek*, in Woodford co. Kentucky, falls into the Ohio from the E. in about N. lat. 39. 17. W. long. 85. 54. It is very small in size, and has three branches; the N. westernmost interlocks with Bank Lick Creek, which falls into Licking River. It is only noticeable for the large bones, and salt licks near it.—*Morse.*

BIG BONE LICKS, THE, lie on each side of the above-mentioned creek, a little below the junction of the two eastern branches, about 8 miles from the mouth of the creek. These, as also the other salt springs, in the western country, are called *Licks*, because the earth about them is furrowed up in a most curious manner, by the buffaloes and deer which lick the earth, on account of the saline particles with which it is impregnated. A stream of brackish water runs through these licks, the soil of which is a soft clay.—The large bones found here, and in several other places near salt licks, and in low soft grounds, thought to belong to the mammoth, still puzzle the most learned naturalists to determine to what animal they have belonged. A thigh bone found here by General Parsons, measured *forty-nine* inches in length. A tooth of this animal is deposited in Yale College. Mr Jefferson, who ſeems to have examined the ſkeleton of one of theſe animals with curious attention, ſays, that "The bones beſpeak an animal of *five or ſix times* the cubic volume of an elephant," as M. Buffon has admitted. Of this animal the natives have no tradition, but what is ſo fabulous, that no conjecture can be aided by it, except that the animal was carnivorous; and this is the general opinion, and was admitted by the late Dr Hunter, of London, from an examination of the tuſks, &c.—*Morſe.*

BIG SANDY *River*, or *Tottervy*, has its ſource near that of Cumberland River; and, ſeparating Virginia from Kentucky, empties into the Ohio, oppoſite the French Purchaſe of Galiopolis, in about N. lat. 38. 30. Vancouver's and Harmar's forts ſtand on this river. On its banks are ſeveral ſalt licks and ſprings. *Little Sandy*, is a ſhort, ſmall river, which falls into the Ohio, about 20 miles W. of Big Sandy River in Maſon co. Kentucky.—*ib.*

BILLERICA, a townſhip in Middleſex co. Maſſachuſetts, incorporated in 1655. It has 1200 inhabitants; nor has there been much variation in the number for half a century. It lies 20 miles northward of Boſton, and is watered by Concord and Shawſheen rivers, which run N. eaſterly into Merrimack River. —*ib.*

BILLINGSPORT, on Delaware River, lies 12 miles below Philadelphia, was fortified in the late war, for the defence of the channel. Oppoſite this fort, ſeveral large frames of timber, headed with iron ſpikes, called *chevaux de friſes*, were ſunk to prevent the Britiſh ſhips from paſſing. Since the peace, a curious machine has been invented in Philadelphia, to raiſe them.—*ib.*

BINOMIAL, a quantity conſiſting of two terms or members, connected by either of the ſigns + and —. See ALGEBRA, def. 9. *Encycl.*

Impoſſible or *Imaginary* BINOMIAL, is a binomial which has one of its terms an impoſſible or an imaginary quantity; as $a + \sqrt{-b}$.

BINOMIAL *Curve*, is a curve whoſe ordinate is expreſſed by a binomial quantity, as the curve whoſe ordinate is $x^a \times \overline{b + d x^c}|^e$. Stirling, Method. Diff. p. 58.

BINOMIAL *Line*, or *Surd*, is that in which at leaſt one of the parts is a ſurd. Euclid, in the tenth book of his Elements, enumerates ſix kinds of binomial lines or ſurds, viz.

Firſt binomial $3 + \sqrt{5}$,
2d binomial $\sqrt{18} + 4$,
3d binomial $\sqrt{24} + \sqrt{18}$,
4th binomial $4 + \sqrt{3}$,
5th binomial $\sqrt{6} + 2$,
6th binomial $\sqrt{6} + \sqrt{2}$.

BINOMIAL *Theorem*. See ALGEBRA, Chap. VII. Sect. iii. (*Encycl.* Vol. I.); and *Infinite* SERIES, (Vol. XVII.) The reader who wiſhes for a fuller account of this famous theorem, may find it in Dr Hutton's Mathematical Tracts, Vol. I.

BIRD-CATCHING, is an art which, as it is practiſed by means of bird-lime, nets, decoys, &c. has been ſufficiently explained in the Encyclopædia. But there is another method of catching birds alive, by means of a *fuſee* or *muſket*, which was invented by M. Vaillant during his travels in Africa, and is ſufficiently ingenious to deſerve a place here. It is as follows:

Put a ſmaller or larger quantity of powder into your fuſee according as circumſtances may require. Immediately above the powder place the end of a candle of ſufficient thickneſs, ramming it well down; and then fill the barrel with water up to the mouth. When at a proper diſtance you fire a muſket thus loaded at a bird, you will only *ſtun* it by watering and moiſtening its feathers; and if you be alert, you may eaſily lay hold of it before it have time to ſpoil its plumage by fluttering. Our author admits, that in his firſt attempts he often put too much powder, or too thick a piece of candle into his fuſee, or fired at too ſhort a diſtance; and when any one of theſe miſtakes was committed, he generally found the candle entire in the animal's belly; but after a ſhort apprenticeſhip he acquired ſufficient ſkill to adjuſt matters ſo as that the water impelled by the powder went directly to the mark, whilſt the tallow being lighter than the water fell ſhort of it. If this method be indeed practicable (for not being ſportſmen we have not made trial of it), it may on many occaſions aid the reſearches of the ornithologiſt.

BIRDS *Neſts*, in cookery. See *Encycl.* and CAP and BUTTON in this *Suppl.*

BLACKLOCK (Dr Thomas) deſerves, on ſo many accounts, to have the principal incidents of his life recorded in this work, that to omit ſuch an article from our liſt of biographical ſketches would be unpardonable negligence. We cannot, however, propoſe to write of him any thing which has not been written before, by an author who has repeatedly appeared before the public, and on each appearance has gained poſſeſſion of the public heart. We ſhall therefore content ourſelves with inſerting in this place a ſhort abridgment of the elegant account of the life and writings of Dr Blacklock, which was prefixed to that edition of his works which was publiſhed in 1793; and if we thus leſſen our own labour, we are conſcious that we ſhall at the ſame time increaſe the pleaſure of our readers.

Thomas Blacklock was in 1721 born at Anan, in the county of Dumfries in Scotland, but his parents were natives of the bordering county of Cumberland; ſo that, though a native of Scotland, his deſcent was Engliſh. His father was a bricklayer, and his mother the daughter of a conſiderable dealer in cattle. Both were reſpectable in their characters, and poſſeſſed, tho' moving in an humble ſphere, a conſiderable degree of knowledge and urbanity. Their ſon was not quite ſix months old when he loſt his eye-ſight in the ſmall-pox, which rendered him as complete a ſtranger to the viſible world as if he had been blind from the hour of his birth. It rendered him likewiſe incapable of learning any of the mechanical arts; and therefore his father kept him at home, and with the aſſiſtance of ſome friends foſtered that inclination which, at a very early period, he ſhewed for books. This was done by reading to him firſt the ſimple ſort of publications which are commonly put into the hands of children, and then ſeveral of our beſt authors, ſuch as Milton, Spencer, Prior, Pope, and Addiſon. His companions, whom his early gentleneſs and kindneſs of diſpoſition, as well as their compaſſion for his misfortune, ſtrongly attached to him, were very aſſiduous in their good offices, in reading to inſtruct and amuſe him. By their aſſiſtance he acquired ſome knowledge of the Latin tongue, but he never was at a grammar ſchool till at a more advanced period of life.

life. Poetry was even then his favourite reading; and he found an enthusiastic delight in the works of the best English poets, and in those of his countryman Allan Ramsay. Even at an age so early as twelve he began to write poems, one of which is preserved in the collection that was published after his death, and is not perhaps inferior to any of the premature compositions of boys assisted by the best education, which are only recalled into notice by the future fame of their authors.

He had attained the age of nineteen when his father was killed by the accidental fall of a malt-kiln belonging to his son-in-law. This loss, heavy to any one at that early age, would have been, however, to a young man possessing the ordinary means of support, and the ordinary advantages of education, comparatively light; but to him—thus suddenly deprived of that support on which his youth had leaned—destitute almost of every resource which industry affords to those who have the blessings of sight—with a body feeble and delicate from nature, and a mind congenially susceptible—it was not surprising that this blow was doubly severe, and threw on his spirits that despondent gloom to which he then gave way in the following pathetic lines, and which sometimes overclouded them in the subsequent period of his life.

> " Dejecting prospect! soon the hapless hour
> " May come; perhaps this moment it impends,
> " Which drives me forth to penury and cold,
> " Naked, and beat by all the storms of heav'n,
> " Friendless and guideless to explore my way;
> " Till, on cold earth this poor unshelter'd head
> " Reclining, vainly from the ruthless blast
> " Respite I beg, and in the shock expire."

He lived with his mother for about a year after his father's death, and began to be distinguished as a young man of uncommon parts and genius. These were at that time unassisted by learning; the circumstances of his family affording him no better education than the smattering of Latin which his companions had taught him, and the perusal and recollection of the few English authors which they, or his father in the intervals of his professional labours, had read to him. Poetry, however, though it attains its highest perfection in a cultivated soil, grows perhaps as luxuriantly in a wild one. To poetry, as we have before mentioned, he was devoted from his earliest days; and about this time several of his poetical productions began to be handed about, which considerably enlarged the circle of his friends and acquaintance. Some of his compositions being shewn to Dr Stevenson, an eminent physician of Edinburgh, who was accidentally at Dumfries on a professional visit, that gentleman formed the benevolent design of carrying him to the Scotch metropolis, and giving to his natural endowments the assistance of a classical education. He came to Edinburgh in the year 1741, and was enrolled a student of divinity in the university there, though at that time without any particular view of entering into the church. In that university he continued his studies under the patronage of Dr Stevenson till the year 1745, when he retired to Dumfries, and resided in the house of Mr M'Murdo, who had married his sister, during the whole time of the civil war which then raged in the country, and particularly disturbed the tranquillity of the metropolis. When peace was restored to the nation, he returned to the university, and pursued his studies for six years longer. During this last residence in Edinburgh, he obtained, among other literary acquaintance, that of the celebrated David Hume, who attached himself warmly to Mr Blacklock's interests, and was afterwards particularly useful to him in the publication of the 4to edition of his Poems, which came out by subscription in London in the year 1756. Previously to this, two editions in 8vo had been published at Edinburgh, the first in 1746, and the second in 1754.

In the course of his education at Edinburgh, he acquired a proficiency in the learned languages, and became more a master of the French tongue than was then common in that city. For this last acquisition he was chiefly indebted to the social intercourse to which he had the good fortune to be admitted in the house of Provost Alexander, who had married a native of France. At the university he attained a knowledge of the various branches of philosophy and theology, to which his course of study naturally led, and acquired at the same time a considerable fund of learning and information in those various departments of science and belles lettres, from which his want of sight did not absolutely preclude him.

In 1757, he began a course of study, with a view to give lectures in oratory to young gentlemen intended for the bar or the pulpit. On this occasion he wrote to Mr Hume, informed him of his plan, and requested his assistance in the prosecution of it. But Mr Hume doubting the probability of its success, he abandoned the project; and then, for the first time, adopted the decided intention of going into the church of Scotland. After applying closely for a considerable time to the study of theology, he passed the usual trials in the presbytery of Dumfries, and was by that presbytery licensed a preacher of the gospel in the year 1759. As a preacher he obtained high reputation, and was fond of composing sermons, of which he has left some volumes in manuscript, as also a Treatise on Morals.

The tenor of his occupations, as well as the bent of his mind and dispositions, during this period of his life, will appear in the following plain and unstudied account, contained in a letter from a gentleman, who was then his most intimate and constant companion, the Rev. Mr Jameson, formerly minister of the Episcopal chapel at Dumfries, afterwards of the English congregation at Dantzic, and who lately resided, and perhaps yet resides, at Newcastle upon Tyne.

" His manner of life (says that gentleman) was so uniform, that the history of it during one day, or one week, is the history of it during the seven years that our personal intercourse lasted. Reading, music, walking, conversing, and disputing on various topics, in theology, ethics, &c. employed almost every hour of our time. It was pleasant to hear him engaged in a dispute, for no man could keep his temper better than he always did on such occasions. I have known him frequently very warmly engaged for hours together, but never could observe one angry word to fall from him. Whatever his antagonist might say, *he* always kept his temper. '*Semper paratus et refellere sine pertinacia, et refelli sine iracundia.*' He was, however, extremely sensible to what he thought ill-usage, and equally so whether it regarded himself or his friends. But his resentment

ment was always confined to a few fatirical verfes, which were generally burnt foon after.

"I have frequently admired with what readinefs and rapidity he could fometimes make verfes. I have known him dictate from thirty to forty verfes, and by no means bad ones, as faft as I could write them; but the moment he was at a lofs for a rhime or a verfe to his liking, he ftopt altogether, and could very feldom be induced to finifh what he had begun with fo much ardour."

This account fufficiently marks that eager fenfibility, chaftened at the fame time with uncommon gentlenefs of temper, which characterifed Dr Blacklock, and which indeed it was impoffible to be at all in his company without perceiving. In the fcience of mind, this is that divifion of it which perhaps one would peculiarly appropriate to poetry, at leaft to all thofe lighter fpecies which rather depend on quicknefs of feeling, and the ready conception of pleafing images, than on the happy arrangement of parts, or the fkilful conftruction of a whole, which are effential to the higher departments of the poetical art. The firft kind of talent is like thofe warm and light foils which produce their annual crops in fuch abundance; the laft, like that deeper and firmer mould on which the roots of eternal forefts are fixed. Of the firft we have feen many happy inftances in that fex which is fuppofed lefs capable of ftudy or thought; from the laft is drawn that mafculine fublimity of genius which could build an Iliad or a Paradife Loft.

Dr Blacklock could never dictate till he ftood up; and as his blindnefs made walking about without affiftance inconvenient or dangerous to him, he fell infenfibly into a vibratory fort of motion of his body, which increafed as he warmed with his fubject, and was pleafed with the conceptions of his mind. This motion at laft became habitual to him; and though he could fometimes reftrain it when on ceremony, or on any public appearance, fuch as preaching, he felt a certain uneafinefs from the effort, and always returned to it when he could without impropriety. This appearance he defcribes in a fhort poem, in which he gives a ludicrous picture of himfelf; a picture indeed, of which, though the outlines are true, the general effect is greatly overcharged. Though his features were hurt by the difeafe which deprived him of fight, there was a certain placid expreffion in his countenance, which marked the benevolence of his heart, and was calculated to procure to him individual attachments and general regard.

In 1762 he married Mifs Sarah Johnfon, daughter of Mr Jofeph Johnfon furgeon in Dumfries; a connection which formed the great folace and bleffing of his future life, and gave him, with all the tendernefs of a wife, all the zealous care of a guardian and a friend. This event took place a few days before his being ordained minifter of the town and parifh of Kircudbright, in confequence of a prefentation from the crown, obtained for him by the earl of Selkirk, a benevolent nobleman, whom Mr Blacklock's fituation and genius had interefted in his behalf. But the inhabitants of the parifh, whether from that violent averfion to patronage, which was then fo univerfal in the fouthern parts of Scotland, from fome political difputes which at that time fubfifted between them and his noble patron, or from thofe prejudices which fome of them might naturally enough entertain againft a paftor deprived of fight, or perhaps from all thefe caufes united, were fo extremely difinclined to receive him as their minifter, that after a legal difpute of nearly two years, it was thought expedient by his friends, as it had always been wifhed by himfelf, to compromife the matter, by refigning his right to the living, and accepting a moderate annuity in its ftead. With this flender provifion he removed in 1764 to Edinburgh; and to make up by his induftry a more comfortable and decent fubfiftence, he adopted the plan of receiving a certain number of young gentlemen as boarders into his houfe, whofe ftudies in languages and philofophy he might, if neceffary, affift. In this fituation he continued till the year 1787, when he found his time of life and ftate of health required a degree of quiet and repofe which induced him to difcontinue the receiving of boarders. In 1767 the degree of doctor in divinity was conferred on him by the univerfity and Marifchal college of Aberdeen.

In the occupation which he thus exercifed for fo many years of his life, no teacher was perhaps ever more agreeable to his pupils, nor mafter of a family to its inmates, than Dr Blacklock. The gentlenefs of his manners, the benignity of his difpofition, and that warm intereft in the happinefs of others which led him fo conftantly to promote it, were qualities that could not fail to procure him the love and regard of the young people committed to his charge; while the fociety, which efteem and refpect for his character and his genius often affembled at his houfe, afforded them an advantage rarely to be found in eftablifhments of a fimilar kind.

In this mixed fociety he appeared to forget the privation of fight, and the melancholy which it might at other times produce in his mind. He entered, with the cheerful playfulnefs of a young man, into all the fprightly narrative, the fportful fancy, and the humorous jeft that rofe around him. Next to converfation, mufic was perhaps the fource of his greateft delight; for he not only relifhed it highly, but was himfelf a tolerable performer on feveral inftruments, particularly the flute. He generally carried in his pocket a fmall *flageolet*, on which he played his favourite tunes; and was not difpleafed when afked in company to play or to fing them; a natural feeling for a blind man, who thus adds a fcene to the drama of his fociety.

Of the happinefs of others, however, we are incompetent judges. Companionfhip and fympathy bring forth thofe gay colours of mirth and cheerfulnefs which they put on for a while, to cover perhaps that fadnefs which we have no opportunity of witneffing. Of a blind man's condition we are particularly liable to form a miftaken eftimate; we give him credit for all thofe gleams of delight which fociety affords him, without placing to their full account thofe dreary moments of darkfome folitude to which the fufpenfion of that fociety condemns him. Dr Blacklock had from nature a conftitution delicate and nervous, and his mind, as is almoft always the cafe, was in a great degree fubject to the indifpofition of his body. He frequently complained of a lownefs and depreffion of fpirits, which neither the attentions of his friends, nor the unceafing care of a moft affectionate wife, were able entirely to remove. The imagination we are fo apt to envy and admire ferves but to irritate this diforder of the mind; and that fancy in whofe creation we fo much delight, can draw, from fources

Blacklock.

sources unknown to common men, subjects of disgust, disquietude, and affliction. Some of his later poems express a chagrin, though not of an ungentle sort, at the supposed failure of his imaginative powers, or at the fastidiousness of modern times, which he despaired to please.

" Such were his efforts, such his cold reward,
" Whom once thy partial tongue pronounc'd a bard;
" Excursive, on the gentle gales of spring,
" He rov'd, whilst favour imp'd his timid wing;
" Exhausted genius now no more inspires,
" But mourns abortive hopes, and faded fires;
" The short-liv'd wreath, which once his temples grac'd,
" Fades at the sickly breath of squeamish taste;
" Whilst darker days his fainting flames immure
" In cheerless gloom and winter premature."

These lines are, however, no proof of " exhausted genius," or " faded fires." " Abortive hopes," indeed, must be the lot of all who, like Dr Blacklock, reach the period of old age. In early youth the heart of every one is a poet; it creates a scene of imagined happiness and delusive hopes; it clothes the world in the bright colours of its own fancy; it refines what is coarse, it exalts what is mean; it sees nothing but disinterestedness in friendship, it promises eternal fidelity in love. Even on the distresses of its situation it can throw a certain romantic shade of melancholy that leaves a man sad, but does not make him unhappy. But at a more advanced age, " the fairy visions fade," and he suffers most deeply who has indulged them the most.

About the time that these verses were written, Dr Blacklock was, for the first time, afflicted with what to him must have been peculiarly distressful. He became occasionally subject to deafness, which, though he seldom felt it in any great degree, was sufficient, in his situation, to whom the sense of hearing was almost the only channel of communication with the external world, to cause very lively uneasiness. Amidst these indispositions of body, however, and disquietudes of mind, the gentleness of his temper never forsook him, and he felt all that resignation and confidence in the Supreme Being which his earliest and his latest life equally acknowledged. In summer 1791 he was seized with a feverish disorder, which at first seemed of a slight, and never rose to a very violent kind; but a frame so little robust as his was not able to resist it, and after about a week's illness it carried him off on the 7th day of July 1791. His wife survives him, to feel, amidst the heavy affliction of his loss, that melancholy consolation which is derived from the remembrance of his virtues.

The writings of Dr Blacklock consisted principally of poems, which were published in 4to in the year 1793; and to that edition was added, *An Essay on the Education of the Blind, translated from the French of M. Hauy*. But besides his avowed works, we have reason to believe that he was the author of many articles in the second edition of the *Encyclopædia*, though we cannot say with certainty what those articles were. If our memory does not deceive us, we have been informed that the preface to that edition was furnished by him; and we have elsewhere attributed to him, on the best authority, the article Blind, and the *Notes* to the article Music: but he undoubtedly contributed much more to the work, and was one of the principal guides of the proprietors.

Black ‖ Blanco.

BLACK *River*. There are two small rivers of this name in Vermont, one falls into Connecticut River at Springfield, the other runs N. into Lake Memphremagog.—*Morse*.

Black *River*, in N. York, interlocks with Canada Creek, and runs N. W. into Iroquois River, boatable 60 miles. Also, a long river which rises in Virginia, and passes south easterly into Nottaway River in N. Carolina.—*ib*.

Black *River*, a British settlement at the mouth of Tinto River, 20 leagues to the E. of Cape Honduras, the only harbor on the coast of Terra Firma, from the island of Rattan to Cape Gracias a Dios, and was for more than 60 years the refuge of the logwood cutters, when the Spaniards drove them from the forests of East Yucatan, which occasioned adventurers of different kinds to settle here, where the coast is sandy, low and swampy; higher up near the rivers and lagoons, which are full of fish, the soil is more fertile, and produces plantanes, cocoa-trees, maize, yams, potatoes, and variety of vegetables; and the passion for drinking spirits, made them plant sugar canes. The forests are full of deer, Mexican, swine and game. The shores abound with turtle, and the woods with mahogany, zebra-wood, sarsaparilla, &c. and indeed the whole settlement flourishes spontaneously without cultivation. —*ib*.

Black *River*, in the island of Jamaica, passes through a level country, is the deepest and largest in the island, and will admit flat bottomed boats and canoes for about 30 miles.—*ib*.

BLADEN, a county of N. Carolina, in Wilmington district. It has 5084 inhabitants, including 1676 slaves.—*ib*.

BLADENSBURG, a post town in Prince George co. Maryland, on the eastern bank of the eastern branch of Potowmack River at the confluence of the N. W. and N. E. branches; 9 miles from its mouth at the Federal City; 38 S. W. from Baltimore, and 12 N. E. from Alexandria, in Virginia. It contains about 150 houses, and a ware-house for the inspection of tobacco.—*ib*.

BLANCO *Capes*. There are many capes of this name, as follow. 1. The N. western point of the bay of Salinas, in the 10th degree of N. latitude; and on the coast of Terra Firma; and, in other maps, is called the N. western point of the gulf of Nicoya.—2. On the coast of California, at the broadest part of the peninsula, in the 32d degree of N. latitude.—3. On the N. W. coast of America, in New-Albion, southward of the mouth of what has been called the *River of the West*, in the 44th degree of N. latitude.—4. A promontory of Peru, in S. America, on the coast of the S. Sea, 120 miles S. W. of Guayaquil, S. lat. 3. 45. W. long. 83.—5. A cape in the southern ocean, on the E. side of Patagonia, S. eastward of Julian Bay, in the 47th degree of S. latitude, 8 leagues W. of Pepys's Island.—*ib*.

Blanco, or *Blanca*, an island 35 leagues from Terra Firma, and N. of Margarita Island in the province of New-Andalusia. It is flat, low, and uninhabited; having savannahs of long grass; is dry and healthy; has plenty of guanas, and some trees of lignumvitæ. N. lat. 11. 50. W. long. 64. 50.—*ib*.

Blanco || Bleaching.

BLANCO, an island on the S. eastern part of the peninsula of Yucatan, in New-Spain. N. lat. 21. W. long. 88. 5.—*Morse.*

BLANDFORD, a township in Hampshire co. Massachusetts, W. of Connecticut River; about 25 miles S. W. of Northampton, and 116 W. of Boston. It has 235 houses, and 1416 inhabitants.—*ib.*

BLANDFORD, a town in Prince George co. Virginia, about 4 miles N. E. from Petersburgh, and is within its jurisdiction. It contains 200 houses and 1200 inhabitants, and is pleasantly situated on a plain, on the eastern branch of Appamattox River. Here are many large stores, and 3 tobacco ware-houses which receive annually 6 or 7000 hhds. It is a thriving place; and the marshes in its vicinity being now drained, the air of this town, and that of Petersburgh, is much meliorated.—*ib.*

BLEACHING. Since the article *Bleaching* in the Encyclopædia was written, very great improvements have been introduced into the art. Of these improvements we shall proceed to give an account.

1 Discovery of the oxy-muriatic acid.

Mr Scheele of Sweden discovered the oxy-muriatic acid, or dephlogisticated muriatic acid, as he called it, about the year 1774, and soon after observed its effects on vegetable colours. His method of procuring it was as follows: In a sand bath is to be placed a glass retort, in which muriatic acid has been poured upon manganese; to this small receivers are to be adapted capable of containing about twelve ounces each, into which is to be poured about two drachms of water, without any other lute than a slip of blotting-paper about the neck of the retort. In about a quarter of an hour a yellow air is perceived in the receiver, which is to be taken off. If the paper has been properly applied, the air rushes out forcibly; the receiver must be quickly stopped, and another applied. Thus many receivers may be filled with the dephlogisticated muriatic acid; but it is necessary to place the retort in such a manner that the drops which rise into its neck may be able to fall back. The water serves to retain the vapours of the acid. "I use (says he) many receivers, that I may not be obliged to repeat a similar distillation for every experiment. It is not proper to employ large ones, because every time they are opened, a great part of the acid is dissipated in the air. What I submitted to examination with this dephlogisticated muriatic acid was placed in the neck of the receiver, which I had stopped. The cork was turned yellow, as by aquafortis. Paper tinged with turnsol became almost white; all red, blue, and yellow flowers, as also green plants, turned yellow in a short time, and the water in the receiver was changed into a pure but weak muriatic acid. Neither alkalis nor acids were able to restore the colours of the flowers, or of the plants."

M. Berthollet, in 1785, proved that this acid was composed of muriatic acid combined with oxygen; and that when it had deprived vegetable matters of their colour, it was reduced to the state of common muriatic acid; that is, it had lost the oxygen with which it was united. This oxygen had combined with the colouring particles of the vegetable matter, and had rendered them colourless. After making these observations, it occurred to him that the oxy-muriatic acid might produce the same effect upon those particles which give colour to thread and cloth, and which it is the object of bleaching to destroy. "At first (says he) I made use of water highly impregnated with this acid; and I renewed it when it was exhausted, until the thread or cloth appeared white; but I soon perceived that they were considerably weakened, and that they were entirely losing their solidity. I then weakened the liquor a little, and I succeeded in bleaching cloth without damaging it. But it speedily became yellow by keeping, especially if it was warmed, or passed through an alkaline ley. I reflected upon the circumstances of common bleaching, and I endeavoured to imitate its process, because I thought the oxygenated muriatic acid might act in the same manner as the exposition of the cloth in the meadows, which alone does not suffice, but which appears only to dispose the colouring parts of the cloth to be dissolved by the alkali of the ley. I examined dew, not only that which falls from the atmosphere, but also that which comes from the nocturnal transpiration of plants; and I observed that both of them were impregnated with oxygen, sufficiently to destroy the colour of paper slightly tinged with turnsol.

2 Its application to bleaching.

Ann. de Chym. II. 158.

"I therefore employed leys, and the action of oxygenated muriatic acid, alternately, and I then obtained a permanent white; and as, at the finishing of the common bleaching, the cloth is passed through sour milk, or through sulphuric acid diluted with a very large quantity of water, I also tried passing the cloth through a very dilute solution of sulphuric acid, and I observed that the white was thereby rendered more clear. As soon as I made use of the leys intermediately, I found that it was not necessary to employ a concentrated liquor, or to let the cloth, at every immersion, remain long therein: by this I avoided two inconveniences, which would have rendered this process impossible to be practised in the large way. The first is the suffocating odour of the liquor, which it would be very inconvenient, and even dangerous, to respire for any length of time, and which has discouraged many persons who tried to use it; the second is, the danger of weakening the cloth. I now also left off mixing any alkali with the oxygenated muriatic acid, as I had practised in the greatest part of my first trials.

"This is nearly the state in which my experiments were, when I made some trials in the presence of the celebrated Mr Watt. A single view sufficed for a philosopher whose genius has been exercised so long upon the arts. In a short time Mr Watt wrote to me from England, that even in the first operation he had bleached five hundred pieces of cloth at Mr Grigor's, who has a large bleaching-ground at Glasgow, and who continues to make use of the new process. In the mean time M. Bonjour, who had hitherto assisted me in my experiments, and who joins great sagacity to a most extended knowledge of chemistry, associated himself with Mr Constant, at Valenciennes, in order to form an establishment in that city."

M. Caillau made a great number of experiments at Paris respecting this new mode of bleaching; but the greatest part of these experiments was made upon cotton, which is more easy to bleach, and does not require leys so often or so strong as flax or hemp. He also went to St Quentin, to perform the operation upon the cloth of that country; but he found that all the cloths, which he had bleached to the satisfaction of the manufacturers, became again of a reddish colour when they were

Bleaching. were expofed to a common ley, or even when they were left for fome time in a warehoufe. Several fimilar complaints were made by other perfons; and M. Berthollet himfelf had obferved the fame thing in his own experiments. M. Bonjour, however, and M. Welter, affirmed that the cloth which they had bleached preferved its colour perfectly. M. Berthollet foon found, that the imperfection in his bleaching was owing to the manner in which he had ufed the leys. "I had contented myfelf (fays he), in thofe trials on fmall pieces which I made in my laboratory, to pour the hot alkaline folution into a veffel where I placed the pieces; it there became cool very rapidly, and therefore did not act with fufficient power; but when I let thefe pieces remain in the liquor, which I kept nearly in a boiling heat during the fpace of two or three hours, they were then no longer fubject to the above mentioned defects: it was therefore merely the weaknefs of the leys which had occafioned the accidents which were experienced by Meffrs Caillau, Décroifille, and myfelf. It is neceffary that the colour of the cloth fhould not be changed by the laft ley, and this is the fureft mark that the bleaching is finifhed; neverthelefs, after this laft action of the ley, it is proper to put the cloth, for a few moments, in the bleaching liquor.

Ann. de Chym. II. 158.

"After this laft immerfion, it is neceffary to plunge the cloth in four milk, or in water acidulated with fulphuric acid. I do not know the moft convenient proportion of fulphuric acid; but it appeared to me that we might fuccefsfully, and without danger, make ufe of one part, in weight, of this acid to fifty of water. We muft keep the cloths during about half an hour in this liquor warmed; after which it is proper to fqueeze them well, and plunge them directly into common water; for if the evaporation fhould take place, the fulphuric acid, becoming thereby concentrated, would corrode them. The cloths being then well wafhed, require only to be dried and dreffed in the ordinary manner, according to their different forts.

"It is of the utmoft importance to take care that the water is not too ftrongly impregnated with the fulphuric acid.

"The bleaching of cotton cloth is much eafier and fhorter; two leys, or at moft three, and as many immerfions in the bleaching liquor, are fufficient for them. As they are bleached fo eafily, it is advantageous, when there are flaxen, hempen, and cotton cloths, to be bleached, to referve for the cotton the liquors which have been previoufly weakened by the cloths of flax or hemp; for it is economical to exhauft the liquors as much as poffible, and thofe which are confiderably weakened ftill fuffice for the cotton, although they have fcarcely any action upon hemp or flax.

"Thread, in the common way of bleaching, is attended with a far greater number of difficulties than cloth; becaufe of the immenfe number of furfaces which it is neceffary to prefent fucceffively to the action of the atmofphere. Some part of thefe difficulties occur in bleaching with the oxygenated muriatic acid; neverthelefs, in the end, it is more advantageous with refpect to thread than with refpect to cloth. Mr Welter has formed at Lifle, with two partners, an eftablifhment for bleaching thread with great fuccefs, and he has already begun fome others. He has found that ten or twelve leys, and as many immerfions, are required for fome forts of thread; and, that the thread may be furrounded with the liquor, it is neceffary to place it, quite loofely, in a bafket, which permits the liquor to penetrate to all its furfaces; when the liquor is much weakened, it is ftill fit to be ufed for the bleaching of cotton.

"I had, in the beginning of my experiments, tried whether the vapour would not be preferable to the oxygenated muriatic acid in a liquid ftate, and I obferved that it bleached with greater quicknefs; but, whatever precautions I employed, it appeared to me that a confiderable lofs of it took place; that thofe parts of the cloths which were the moft expofed to it were fubject to be weakened; and that it was more difficult to obtain an equal whitenefs throughout.

"To prevent all the accidents which may refult from the liquor acting with too great power, it is important to have a means of meafuring its force. M. Decroifille thought of ufing, for that purpofe, a folution of indigo in fulphuric acid. He takes one part of indigo, reduced into fine powder, and eighteen parts of concentrated fulphuric acid; this mixture is put into a matrafs, which is kept, during fome hours, in a water-bath; when the folution is finifhed, it is diluted with a thoufand parts of water. To try the power of the oxygenated muriatic acid, one meafure of this folution is put into a graduated glafs tube, and fome of the liquor is gradually added to it, until the colour of the indigo is deftroyed. We muft firft determine how many meafures of a liquor, the goodnefs of which has been afcertained by experiments made upon cloth, are neceffary to deftroy the colour of one meafure of the folution of indigo, and this number will ferve to eftimate the refpective ftrength of all the liquors which it may be neceffary to compare with it. M. Watt employs, in the fame manner, a folution of cochineal."

5 Method of procuring the acid for bleaching.

M. Berthollet recommended the following method of procuring the oxy-muriatic acid: "If we have good oxyd of manganefe, formed in fmall cryftals, and containing but little extraneous matter, the proportions of the fubftances to be fubmitted to diftillation are the following: Six ounces of calx of manganefe reduced to powder; one pound of common falt, alfo reduced to powder; twelve ounces of concentrated fulphuric acid, or oil of vitriol; from ten to twelve ounces of water.

"When thefe materials are prepared, we muft carefully mix the oxyd of manganefe with the common falt, and introduce the mixture into the diftilling veffel placed upon a fand bath: we muft then pour upon it the fulphuric acid, previoufly diluted (and of which the heat occafioned by its mixture with water is diffipated), and immediately apply to the mouth of the matrafs the tube which is to conduct the gas into the intermediate veffel.—It muft not be forgot, that in this operation the lutes require particular attention.

"The fize of the veffels fhould be fuch, that the diftilling matrafs may be about one-third empty; and, for the quantity above mentioned, the tub fhould hold 100 quarts of water; there fhould alfo be an empty fpace of about 10 quarts, in order that when the gas lodges itfelf in the cavities intended to receive it, the water may have a free fpace to rife in.

"Before the commencement of the operation, the pneumatic tub muft be filled with water. The mixture being made, the gas, which very foon begins to difengage

Bleaching. difengage itfelf, drives out the atmofpherical air which is in the apparatus: when it is judged that the atmofpheric air has paffed into the cavities, it is to be drawn off by means of a bent tube, which is to be introduced fucceffively under each cavity: to drive out the water which has entered into the tube, this laft is to be forcibly blown into. The operation is then fuffered to go on without fire until it is perceived that the bubbles come over but flowly: then a little fire is to be applied, which is not to be haftily increafed at the beginning, but may be gradually augmented, fo that at the end of the operation the matter may be brought to a boiling ftate. It is known to be nearly finifhed when the tube by which the gas is difengaged, and the intermediate veffel, become hot. When the gas is difengaged only in a fmall quantity, the fire may be withdrawn; and when the diftilling veffel retains but a gentle warmth, it is to be unluted, and warm water is to be poured upon the refidue, that it may remain in folution, and thereby be more eafily poured out.

"The operation is longer or fhorter according to the quantity of materials: with that above mentioned, it fhould laft five or fix hours; it is proper not to haften it, that a larger quantity of gas may be drawn off. A fingle perfon is able to manage feveral diftillations at the fame time; to each of which may be given much larger quantities of materials than thofe which have been pointed out.

"The intermediate veffel by degrees becomes filled with a liquor which is pure, though weak, muriatic acid; neverthelefs, we may perform the operation feveral times without extracting it: but when it is fuppofed that there is not fufficient empty fpace, this acid is to be drawn off by means of a fyphon, and, when we have collected a fufficient quantity of it, it may be fubftituted for the mixture of vitriolic acid and common falt in the operation we have defcribed, if we have no other ufe to make of it. That there may pafs but a fmall quantity of muriatic acid, not oxygenated, the firft tube ought to form a right angle, or even an obtufe one, with the body matrafs.

"During the operation, the agitator muft be from time to time put in motion, to favour the abforption of the gas by the water: when it is finifhed, the liquor is of a proper ftrength to ufe in bleaching; or we may put a lefs quantity of water in the tub, and then dilute the liquor according to the proportion already mentioned.

"In this ftate of concentration, although the liquor has a pretty ftrong odour, it neverthelefs is not hurtful, nor even very unpleafant, to thofe who ufe it; it is, however, proper to conduct it into the troughs where the cloths are placed by means of wooden canals, which are to be connected with the faufet or tube which is at the lower part of the tub."—The following is a defcription of the apparatus:

Plate VII. fig. 1. ABCD is a reverberatory furnace, having, on a line with B, many fmall openings in its circumference, to ferve as chimneys; within which, upon a fand-bath *a*, is placed a matrafs *b*, the neck of which ftands out above the furnace, running through the opening D, which is to be clofed with clay. The mouth F, of the neck of the matrafs, is clofed by a cork G, through the middle of which paffes a tube H, which forms a communication between the infide of the matrafs *b*, and the intermediate veffel K, where it alfo paffes through a cork I, which clofes one of the three openings of that veffel. The corks G and I ought to be prepared before-hand, and well fitted to each end of the tube of communication H, which is to be fo difpofed that it may be fitted in immediately after the mixture is made in the matrafs.

The intermediate veffel K is about an eighth part full of water; into it is plunged the tube of fafety L, to prevent danger from regurgitation. This tube ought to be fo high, that the weight of the water which enters into it, by the preffure of the gas, may be great enough to caufe the gas to pafs into the pneumatic tub NOP, by the tube of communication M, which is plunged therein, and reaches to the bottom, where it is bent horizontally, fo that the gas may be emitted under the firft of the three wooden, or (if they can be procured) ftone-ware, cavities, or receivers, which are placed in the infide of the tub, one above the other. O is a handle which ferves to turn the agitator E, the movement of which facilitates the combination of the gas with the water. P is a fpigot and faufet to draw off the liquor.

4 Method of bleaching. It is neceffary to prepare the cloth by leaving it to foak for 24 hours in water, or, which is better, in fome old ley. Afterwards it fhould be fubmitted to the action of one or two good leys; becaufe all the colouring part which may be extracted by the leys would elfe, without any advantage, confume a part of that liquor which it is important to be as fparing of as poffible. After this, the cloth is to be carefully wafhed; then it is to be placed in the troughs, without any part being preffed or confined, in fuch a manner that it may be thoroughly impregnated with the liquor which is to run thereon. The troughs, as well as the tub, ought to be conftructed without iron; for that metal, being rufted by the oxygenated muriatic acid, would produce iron moulds, which could not be taken out but by means of falt of forrel.

The firft immerfion ought to be longer than the others; it may be continued for three hours, after which the cloth is to be taken out; it is to be again fubmitted to the action of ley, and then placed in a trough, that frefh liquor may be poured thereon: it is fufficient that this immerfion, and the following ones, continue half an hour. When the cloth is taken from the trough, the liquor is to be wrung out, it is to be again fubmitted to the ley, and afterwards to frefh immerfions. The fame liquor may ferve until its ftrength is exhaufted: when it is much weakened, there may be fome frefh liquor added to it. When the cloth appears white, except fome black threads and the lifts, it is to be impregnated with black foap, and then ftrongly rubbed: after which it is to be fubmitted to the laft ley and the laft immerfion. We cannot determine what number of leys and immerfions may be neceffary, becaufe it varies according to the nature of the cloth: neverthelefs, the limits of this number are between four and eight for linen or hempen cloths.

The manufacturers at Javelle, to whom M. Berthollet had communicated this procefs, foon after publifhed, in different journals, that they had difcovered a particular liquor which had the property of bleaching cloth by an immerfion of fome hours only. The change they had made in the procefs performed in their prefence, confifted

Bleaching. consisted in putting some alkali into the water which receives the gas; this enables the liquor to become much more concentrated, so that it may be diluted with several times its own quantity of water before it is used.

" These are the proportions which yielded me (says Berthollet) a liquor similar to the pretended Javelle ley; two ounces and a half of common salt, two ounces of sulphuric acid, six drachms of calx of manganese, and, in the vessel where the gas is to be concentrated, one pound of water, and five ounces of potash, which should be dissolved in the water. The Javelle liquor has a somewhat reddish appearance, occasioned by a small quantity of manganese, which either passes in the distillation, because an intermediate vessel is not used, or exists in the potass; most kinds of which contain it, as I have well convinced myself."

" This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more speedily than the liquor itself: but without speaking of the imperfections of the method which is described in the publications from Javelle, and which can only suffice for cotton, we are not able to bleach near the same quantity of cloth with the oxygenated muriatic acid combined in this manner with an alkali, as might be bleached with the same quantity of that acid mixed with water alone; because there is formed a portion of that neutral salt which is known at present by the name of oxygenated muriate of potass, and in which the oxygen becomes concentrated. Now all the oxygen which enters into the composition of this salt is rendered useless for bleaching; because the oxygenated muriate of potash does not destroy colours."

This method of bleaching was very soon adopted in Britain, and is now almost universal among bleachers. A great many changes have been made in the process; one of the most important of which is substituting lead vessels for wooden ones, which, besides weakening its action exceedingly, were very soon destroyed by the acid. We believe, too, that the bleachers very generally add some alkali to the acid, notwithstanding the strong objections which Mr Berthollet has made to that manner of bleaching.

This method of bleaching has been found to answer remarkably well: the only objection that has been made to it is, that the cloth is apt to be weakened. And this, no doubt, must be the case, if care be not taken to prevent the acid from being too much concentrated; but we have little doubt that, with a sufficient degree of caution, it will prove as safe as any other whatever; and, in point of expedition, there cannot surely be any comparison drawn between the old mode of bleaching and the new.

5 Theory of bleaching.

It remains for us now to consider, whether the new discoveries in chemistry do not throw some rays of light upon the theory of bleaching; for it is only by perfecting the theory that we can advance with certainty in our practical improvements.

It has been already observed, in the article BLEACHING (*Encycl.*), that cloth, after being bleached, was a good deal lighter than it had been before the operation: It follows, therefore, that it must have been deprived of something during the bleaching. Cloth bleached by means of the oxy-muriatic acid likewise undergoes a loss of weight; so that, in all probability, both modes act in precisely the same manner.

If raw linen or thread be boiled in a solution of caustic alkali, properly diluted, it gives out something which tinges the ley of a deep brown, and at the same time the alkali loses its causticity. If the linen be boiled in another similar solution, it communicates the same colour, and even a third may be slightly tinged; but after this, alkalis, unless so much concentrated as to injure the texture of the cloth, have no effect on it whatever. If the linen be now plunged into oxy-muriatic acid, properly prepared, and allowed to remain till it begins to become white, and then plunged into an alkaline ley, the alkali loses its causticity, and assumes the same deep colour that the first ley did. Here, then, we have two alkaline solutions; the one saturated with colouring matter before the action of the oxy-muriatic acid on the linen, the other after it. When these solutions are saturated with an acid, a yellow coloured precipitate is obtained, which when dried assumes the appearance of a black powder. Precisely the same substance is obtained from both solutions. This colouring matter is almost insoluble in water. Pure or caustic potass dissolves about double its own weight of it; carbonate of potass not so much.

Hence we see the use of alkalis in bleaching. The colouring matter is not soluble in water, but part of it is soluble in alkali. However, after the alkali has exhausted all its power, the linen is not white: colouring matter, therefore, exists in it, which alkalis cannot act upon. But after being plunged in oxy-muriatic acid, it also becomes soluble in acids. Here, then, is the use of that acid in bleaching—it communicates something to the colouring matter which renders it soluble in alkali. This something, we have already seen, is oxygen. It follows, therefore, that before the greater part of the colouring matter of linen can be extracted by alkalis, it must be combined with oxygen. It is in producing this combination that the use of the exposure to the sun and air consists; and it is because the oxy-muriatic acid produces it almost instantaneously, that the new mode of bleaching is so much more expeditious than the old.

If into the alkaline solution of the colouring matter lime-water be poured, there takes place a copious precipitate, which consists of the lime and colouring matter combined. Lime, therefore, has a stronger affinity for the colouring matter than alkali has: and as the compound of lime and the colouring matter is not very soluble in water, lime-water might be used to deprive the alkaline ley of the colouring matter which it has imbibed; after which it might be used again. Care, however, must be taken that no lime-water remains in the ley; otherwise it might precipitate and fix the colouring matter in the linen, after which it would be very difficult to remove it.

From an alkaline ley, saturated with the colouring matter of linen yarn, Mr Kirwan, by means of muriatic acid, precipitated the colouring matter. He found it to possess the following properties: When suffered to dry for some time on a filter, it assumed a dark green colour, and felt somewhat clammy like moist clay. " I took (says he) a small portion of it, and added it to 60 times its weight of boiling water, but not a particle of it 6 Nature of the colouring matter of linen. *Irish Trans.* 1789.

Bleaching. it was diffolved. The remainder I dried in a fand heat: it then affumed a fhining black colour, became more brittle but internally remained of a greenifh yellow, and weighed one ounce and an half.

"By treating eight quarts more of the faturated ley in the fame manner, I obtained a further quantity of the greenifh depofit; on which I made the following experiments:

"1ft, Having digefted a portion of it in rectified fpirit of wine, it communicated to it a reddifh hue, and was in a great meafure diffolved: but by the affufion of diftilled water the folution became milky, and a white depofit was gradually formed; the black matter diffolved in the fame manner.

"2dly, Neither the green nor the black matter was foluble in oil of turpentine or linfeed oil by a long continued digeftion.

"3dly, The black matter being placed on a red-hot iron, burned with a yellow flame and a black fmoke, leaving a coaly refiduum.

"4thly, The green matter being put into the vitriolic, marine, and nitrous acids, communicated a brownifh tinge to the two former, and a greenifh to the latter, but did not feem in the leaft diminifhed.

"Hence it appears, that the matter extracted by alkalis from linen yarn is a peculiar fort of refin, different from pure refins only by its infolubility in effential oils, and in this refpect refembling lacs. I now proceed to examine the power of the different alkalis on this fubftance. Eight grains of it being digefted in a folution of cryftallized mineral alkali, faturated in the temperature of 60°, inftantly communicated to the folution a dark brown colour; two meafures (each of which would contain 11 pennyweights of water) did not entirely diffolve this fubftance. Two meafures of the mild vegetable alkali diffolved the whole.

"One meafure of cauftic mineral alkali, whofe fpecific gravity was 1,053, diffolved nearly the whole, leaving only a white refiduum.

"One meafure of cauftic vegetable alkali, whofe fpecific gravity was 1,039, diffolved the whole.

"One meafure of liver of fulphur, whofe fpecific gravity was 1,170, diffolved the whole.

"One meafure of cauftic volatile alkali diffolved alfo a portion of this matter."

The colouring matter of cotton is much more foluble in alkali than that of linen; hence the greater facility with which cotton is bleached.

From thefe obfervations, the great importance of alkalis in bleaching, and the neceffity of regulating the ftrength, and afcertaining the purity, of the leys made ufe of, muft be apparent. Manufacturers, therefore, lie under very great obligations to Mr Kirwan, who has lately examined the alkaline matters ufed in bleaching with his ufual accuracy and abilities. The refult of his experiments was as follows:

Irifh Tranf. 1789.

Table of the quantity of mere alkali in 100 Avoirdupois pounds of the following fubftances.

One hundred lbs.	*Mineral Alkali.*
Cryftallized foda	20 lbs.
Sweet barilla	24
Mealy's cunnamara kelp	3,437
Ditto defulphurated by fixed air	4,457
Strangford kelp	1,25

One hundred lbs.	*Vegetable Alkali.*
Dantzic pearl afh	63,33 lbs.
Clarke's refined afh	26,875
Cafhup	19,376
Common raw Irifh weed-afh	1,666
Ditto flightly calcined	4,666

When linen is allowed to remain for fome time in oxy-muriatic acid, it becomes white. It is evident, then, that when the colouring matter of linen is faturated with oxygen, it becomes colourlefs: But linen bleached in this manner very foon becomes yellow, efpecially when expofed to heat. Berthollet, to whofe ingenious experiments and obfervations we are indebted for the greater part of the above remarks, has given the following explanation of the caufe of this change: He diftilled the colouring matter of linen, and obtained a thick oil, a little ammonia, and $\frac{24}{100}$ of carbon remained behind. The oil contained carbon; and he fuppofed that carbonic acid gas, and carbonated hydrogen gas, were difengaged. He concluded in confequence, that one-third of this colouring matter was carbon. The other ingredient in the oil was hydrogen; for Lavoifier has proved that oil is compofed of oxygen and hydrogen. The colouring matter of linen, then, is compofed principally of carbon and hydrogen.

Oxygen combines with hydrogen at a lower temperature than it does with carbon; for if a confiderable quantity of oxy-muriatic acid be mixed with a folution of fugar (a fubftance which confifts chiefly of carbon and hydrogen), and the liquor be evaporated, there remains behind little elfe than carbon, the hydrogen having combined with oxygen and formed water, which had paffed off in the form of vapour. Now, whenever a quantity of hydrogen is feparated from a body principally compofed of hydrogen and carbon, that body affumes a brown or yellow colour, becaufe the carbon becomes predominant; and this colour becomes the deeper the greater the proportion of the carbon is, compared to that of the hydrogen; and at laft, when nothing but carbon remains, it becomes quite black.

It is probable, then, that when the oxy-muriatic acid renders linen white, a quantity of oxygen has combined with the colouring particles, but that this oxygen gradually enters into a combination with the hydrogen, and forms water which paffes off; that then the carbon becomes predominant, and the linen in confequence affumes a yellow colour.*

7 Bleaching of wool and filk.

The fame method does not fucceed in bleaching wool and filk which anfwers for linen and cotton. One would be difpofed to think that thefe fubftances are bleached rather by lofing oxygen than by abforbing it. Wool, for inftance, is rendered white very quickly when expofed to the fumes of fulphurous acid, which we know has a ftrong affinity for oxygen, and foon faturates itfelf with it. But what paffes during the whitening of animal matters has never yet been properly enquired into, though it would not only greatly elucidate *bleaching*, but *dying* likewife, and throw much light upon fome of the obfcureft parts of chemiftry. A great improvement, however, has lately been made by M. Baumé in the manner of bleaching filk. Of this improvement we fhall proceed to give an account.†

Before the filk is wound off the cocons in which the filk worms are inclofed, it is neceffary to kill the infects,

* *Ann. de Chym.* VI. 210.

† See the memoir in the *Ann. de Chym.* xvii. 156, and abridged in *Nicholfon's Journal*, I. 32, from which laft we have taken our account of it.

Bleaching. fects, otherwife they would in all probability eat thro' it and deftroy it. This is commonly done by expofing the cocons, properly wrapped up, for two hours to the heat of about 158 degrees of Fahrenheit in an oven; after which they are kept for a certain time in a mafs to preferve their heat, and effectually deftroy fuch of the infects as might have efcaped the power of the oven. The effect of this procefs is, that the filk is hardened, and is more difficult to wind off than before. Hence the product of filk is lefs by one-ninth part in quantity, and inferior in quality to what might have been obtained by winding off without this previous baking. Mr Baumé, not only from thefe views, but likewife becaufe the filk which has not been baked proves fufceptible of a greater luftre, was induced to deftroy the cryfalis by fpirit of wine. For this purpofe he difpofes them in a wooden box in a ftratum fix inches deep: upon each fquare foot half a pint of fpirit of wine is to be fprinkled with a fmall watering pot made for that purpofe. The liquid is to be equally diftributed, but it is not neceffary that all the cocons fhould be wetted. They are then to be mixed by hand. In the next place another ftratum is to be formed over the firft, nearly of the fame depth, which is to be fprinkled and treated as before. By this method of proceeding, the box becomes filled, and muft then be covered, and left for 24 hours, during which time they become fpontaneoufly heated to about 100 degrees, and the vapour of the fpirit of wine exerts itfelf with wonderful activity. After this treatment they muft be fpread out to dry, which happens in a fhort time, and is abfolutely neceffary previous to winding off.

8

New mode of whitening filk.

The fpirit of wine to be ufed in this operation ought to be of the fpecific gravity .847, at the temperature of 55 degrees. It is of the greateft importance to ufe that fpirit only which has been kept in veffels of glafs, of tinned copper, or of pure tin, Leaden veffels are abfolutely to be rejected; wooden veffels tinge the fpirit, which gives the filk a degree of colour of confiderable permanency, and very inimical to the bleaching procefs.

The filk is wound off upon a reel, while the cocons are kept immerfed in water almoft boiling. Upon this part of the procefs M. Baumé remarks, 1ft, That the dead cocons muft be feparated. Thefe are known by the brown or black fpots on their furface. 2. That well water, which on account of its clearnefs is almoft univerfally ufed in the filk manufactories, moftly contains nitre, and is extremely prejudicial to the bleaching procefs. The prefence of nitrous acid gives a yellow colour, which refifts bleaching and even fcouring; he therefore recommends river-water. 3. In fome countries a fmall quantity of alum is ufed. Neither this nor any other faline fubftance is of the leaft advantage to the colour, beauty, or quality of the filk.

At the four places of contact of the filk upon the reel, all the threads ftick together. It is abfolutely neceffary that this fhould be remedied. The method confifts in foaking the filk in a fufficient quantity of warm water, at about 90 degrees, for about two hours; after which the threads are to be feparated by opening the hanks upon a pin, and lightly rubbing the parts which cohere. When the filk is dry it is to be loofely folded in its original form, and is ready for bleaching.

The filk while wet is foft, and part of its gummy matter is in fuch a ftate, that its threads would readily adhere, if wrung while warm for the purpofe of clearing it of the water. After fuch improper treatment there would be no other remedy than to foak it again in warm water. Bleaching.

The apparatus for bleaching the filk confifts of a ftone-ware veffel, nearly of a conical form, capable of holding about 12 gallons, having a large opening at the one end, and a fmaller of about an inch diameter at the other end. Common pottery cannot be ufed in this operation, becaufe it is foon rendered unferviceable by the action of the muriatic acid, and the ftone-ware itfelf is not very durable. This veffel muft be carefully examined, to afcertain that it does not leak in the flighteft degree; after which the infide is to be rubbed with a pumice-ftone, to clear it of afperities which might break the threads. A cover of the fame material is to be fitted on by grinding; and the fmaller aperture, which in the ufe is the loweft, is to be clofed with a good cork, in the middle of which is thruft a fmall glafs tube about a quarter of an inch in diameter; this is likewife ftopped with a cork, excepting at the time when it is required to draw off the liquid contents of the jar. A fmall perforated falfe bottom is placed within the veffel, to prevent this tube from being obftructed.

Six pounds of yellow raw filk are to be difpofed in the earthen pot; upon this is to be poured a mixture, previoufly made, of 48 pounds of fpirit of wine of the fpecific gravity .867, with 12 ounces of very pure marine acid, abfolutely exempt from all prefence of nitrous acid, and of the fpecific gravity 1.114. The pot is then to be covered, and the whole left in digeftion till the following day, or until the liquor, which at firft affumes a fine green colour, fhall begin to affume that of a dufky brown.

The acidulated fpirit is then to be drawn off, clean fpirit of wine poured upon the filk, and drawn off repeatedly until it paffes colourlefs. The filk is then fuffered to drain without ftirring it. In this ftate it is ready for a fecond infufion.

Forty-eight pounds of fpirit of wine, acidulated with 12 ounces of marine acid, is now to be poured on the filk, and the whole fuffered to remain for 24 hours or longer, until the filk becomes perfectly white. The time required for this fecond infufion is commonly longer than for the firft: it fometimes amounts to two, three, or even fix days, according to circumftances, particularly the temperature and the nature of the filk. Silk which has been in the oven is in general more difficult to bleach.

When the filk has thus obtained its utmoft degree of whitenefs, the acidulated fpirit is to be drawn off into a feparate veffel. This fluid is but flightly coloured, and may be ufed again in the firft infufion of other yellow filk, with the addition of fix ounces more of marine acid. The receiving veffel is to be removed, and another clean veffel fubftituted in its place. The filk is then fprinkled with clean fpirit, and occafionally preffed down with the hand. As foon as the fpirit of wine comes off abfolutely colourlefs, a third infufion is to be made by pouring upon the filk 48 pounds of the pure fpirit without acid, which is to remain till the following day: it is then to be drawn off, and referved for wafhing other filk after the firft infufion.

After the filk has been left to drain, and affords no more fpirit, it ftill retains its own weight of that fluid.

Bleaching.

This is recovered by ſprinkling the ſilk with a ſmall quantity of very clear river-water at a time. While the water applies itſelf and ſubſides along the ſilk, it drives the ſpirit of wine before it, ſo that the firſt portions which flow from the tube are ſcarcely diminiſhed in ſtrength. The addition of water is to be continued until nothing but mere water comes off below.

In this ſituation the ſilk is found to be well bleached, but ſtill retains a portion of marine acid ſufficient to render it harſh to the touch, and after a time brittle. It muſt be waſhed off with water. The beſt method is to put the ſilk looſely into a coarſe woollen bag, which is to be ſecured looſely in another cloth like a ſmall bed or pillow, then placed in a baſket, and left in a running ſtream for five or ſix hours; but where the convenience of a ſtream is wanting, the earthen pot containing the ſilk is to be covered with a cloth, and water pumped through it for five or ſix hours, or until that which iſſues from the lower aperture gives no red colour to the tincture of turnſol. At this period the lower opening is to be cloſed, and the veſſel filled with water, which muſt be changed once or twice in 24 hours.

Though the mineral acids are the moſt powerful and deſtructive of all ſaline ſubſtances, yet they may be applied to ſilk when diluted with ſpirit of wine in very conſiderable doſes. In trials made to aſcertain the maximum, two ounces of marine acid were added to one pound of ſpirit of wine, without altering the ſilk. Two drams of marine acid cauſe a very perceptible alteration in one pound of ſilk.

Spirit of wine which has been mixed with nitrous acid cannot be uſed in bleaching, even though afterwards rectified upon an alkali, becauſe it ſtill retains a portion of nitrous gas. Pure ſpirit of wine without acid extracts a fine yellow colour from ſilk, which does not ſeparate for years, even though expoſed to the ſun's light. Yellow ſilk, expoſed to the ſun, loſes its colour in a ſhort time. The acidulated ſpirit which has been uſed in the infuſion of ſilk, is changed by expoſure to the ſun, but not in ſuch a manner as to be rendered fit for uſe a ſecond time. In order to obtain a beautiful white colour, it is eſſential that the ſilk ſhould be immerſed in a large quantity of the fluid, eſpecially at the firſt infuſion. Without this management it would become neceſſary to make three infuſions in the acidulated ſpirit. When the firſt infuſion is well managed, the ſilk will have loſt all its yellow colour, and become conſiderably white, at the ſame time that the liquor will have begun to change colour a little. As long as it continues of a fine green, it is certain that it has not exhauſted its whole action upon the ſilk. The duration of this firſt infuſion may be longer or ſhorter, without inconvenience, according to the temperature. When the temperature is at 77 of Fahrenheit, the firſt infuſion is often made in 10 or 12 hours. In ſmall experiments the heat of the atmoſphere may be ſupplied by the water bath; in which caſe, all the infuſions are eaſily made in the courſe of a day.

When the firſt infuſion is finiſhed, and the liquor drawn off, the ſilk appears greeniſh: the ſubſequent waſhings in ſpirit of wine clear it of the liquor it retained. This ſprinkling ſhould be made with the watering pot, otherwiſe the quantity poured will be greater, and the management more waſteful.

Pieces of gauze and entire garments of ſilk have been ſucceſsfully bleached in this way.

The fineſt natural white ſilks are rendered infinitely whiter by this proceſs. Spirit of wine alone has the property of depriving yellow ſilk of its colour, which it brings to the ſtate of the naturally white ſilk. In this ſtate the ſilk is diſpoſed to acquire a greater degree of brightneſs by a ſingle infuſion in the acidulated ſpirit. This proceſs has its advantages over the other, to which it is alſo inferior in certain reſpects; concerning neither of which the author has entered into any detail.

The colouring matter was found to be a reſin perfectly animalized, affording by diſtillation the ſame products as other animal matters, and the concrete volatile alkali.

Silk whitened by ſcouring may be dried freely in the air without affecting its luſtre. This is not the caſe with the ſilk bleached in the gum: if it be left at liberty to dry in the air, it reſembles white flax without any luſtre. The beauty of this ſilk conſiſts in its ſhining brilliancy; to ſecure which it muſt be dried in a ſtate of tenſion. Mr Baumé has contrived a ſimple machine for this purpoſe. It conſiſts of a ſtrong ſquare frame of wood ſtanding upright upon feet: the upper horizontal bar is ſix feet long, and has ſix iron pins driven through it at equal diſtances, ſo as to project on each ſide for the purpoſe of receiving twelve bobbins. The lower horizontal bar is moveable up and down in a mortice, by means of a ſcrew at each end: it is furniſhed with ſix holes, adapted to receive as many pins to correſpond with thoſe above. The ſkains of ſilk are to be dreſſed and arranged upon wooden pins, as they are taken out of the ſack from waſhing. As ſoon as there are twelve together, they are to be wrung with a ſtaff; after which the ſkains are to be hung one by one upon as many bobbins put upon the upper pins of the ſquare frame. Another bobbin with tails is to be inſerted in the lower loop of the ſkain, and faſtened to the correſponding pin of the lower bar, by means of a ſtrap and hook, which need not be deſcribed to ſuch as are ſlightly acquainted with mechanical objects. When the machine is thus ſupplied with ſkains on both ſides, the lower bar of the frame is to be preſſed down by the ſcrews until the ſilk is moderately ſtretched. When it is dry, the ſcrews are to be equally ſlackened, the ſkains taken off, and folded with a ſlight twiſt, that they may not be become entangled.

To complete the deſcription of this proceſs, it only remains to ſhow how to recover the alcohol, and enſure the purity of the acids made uſe of.

9

Method of recovering the alcohol uſed,

The alcohol which has been uſed in bleaching ſilk is acid, and loaded with colouring matter. In this ſtate it cannot be again uſed. There are two methods of diſtilling it, which have their reſpective advantages and inconveniences.

By the firſt the acid is loſt; which is ſaturated with potaſs, in order that the diſtillation may be afterwards performed in a copper alembic. A ſolution of potaſs is to be poured into the acid ſpirit, and ſtirred about to promote the ſaturation. Carbonic acid is diſengaged with ſtrong effervescence from the alkali, and the point of ſaturation is known by the uſual teſt, that the fluid does not redden the tincture of turnſol. The diſtillation is then to be made in the copper alembic, and the alcohol reſerved in proper veſſels.

In

Bleaching.

In the second process for distilling without alkali, the acid spirit is distributed into a great number of glass retorts, placed in the sand-bath, on the gallery of a furnace. The first product is scarcely acid; but what follows is more and more so, and must be kept in vessels of glass or stone-ware, which become embarrassing on account of their number. The fluid which remains in the retorts has the colour of beer slightly turbid, and contains the greatest part of the marine acid. It must be poured into one or more retorts, and concentrated by heat gradually applied. The first liquor which comes over is slightly red, turbid, and scarcely acid. This is to be thrown away, and the receivers changed. The succeeding product is the colourless marine acid, of an aromatic smell resembling the buds of poplar. The resin of the silk remains in the retort decomposed by the acid. The marine acid thus obtained is weaker than it originally was; which is in fact of little consequence, as it is pure, and may be safely used, either by increasing the dose proportional to its diminished strength, or by concentrating it if required in the usual way. If this distillation be made in a silver alembic, instead of retorts of glass, and a capital and worm of pure tin be annexed, the alcohol will be obtained so slightly acid as scarcely to redden the tincture of turnsol; but it is sufficiently acid to receive injury if preserved in a copper vessel.

10
And of preparing a pure muriatic acid.

As to the acid, Mr Baumé observes, that the muriatic acid of commerce is unfit for the purpose. It was formerly prepared with the marine salt of the saltpetre manufacturers; and even when it is made with good salt, the decomposition is effected with common vitriolic acid which contains nitrous acid. Marine acid mixed with a small quantity of nitrous acid does not prevent the silk from being beautifully whitened: it even accelerates the process considerably, and in the most satisfactory manner. But the alcohol, every time it is used and rectified, becomes charged with the acid and gas of nitre, which assume the characters of the nitrous anodyne liquor. In this state neither distillations nor repeated rectifications from alkali are sufficient to separate the nitrous matter from the alcohol. Then it is that the success of the operator vanishes, with a degree of rapidity equal to the advances which encouraged his hopes at the commencement.

To purify common sulphuric acid, 100 pounds of it are to be mixed in a large bason of copper with the same quantity of river-water, and stirred with a wooden spatula. The mixture instantly becomes heated to the boiling water point, and a great quantity of red vapour is disengaged, which has the smell of aqua-regia, and arises from the nitric and muriatic acids. When this mixture is made, it is proper to immerse the bason to a suitable depth in a large vessel of water, to hasten the cooling. As soon as it is sufficiently cooled, it is to be drawn off into bottles, and left to become clear during several days. It is in the next place to be decanted, and conveyed into retorts by a syphon funnel, and the rectification proceeded upon until it becomes perfectly white. Towards the end of the operation a small quantity of sulphur sublimes in the neck of the retort. Instead of receivers, a small glass cup is placed beneath the aperture of each retort, in order to facilitate the dissipation of the nitric and muriatic acids. When the acid in the retorts is sufficiently cooled, it is poured a second time into the copper bason, and mixed with 100 pounds of river-water, as at first, and again concentrated in the retorts till it becomes perfectly clear. The muriatic acid is to be disengaged from common salt by the application of this acid in the usual manner.

11
Bleaching paper.

The oxy-muriatic acid is also used very generally for bleaching paper, or rather the stuff out of which paper is made. It has been alleged and we believe with some truth, that since this mode of whitening paper was introduced into this country, the strength of paper is much inferior to what it was formerly. If this be really the case, perhaps it is owing to the use of too concentrated an acid.

We shall finish this article with Mr Chaptal's account of this process, who was the first person that introduced it. "Blotting paper (says he), by being put into oxygenated muriatic acid, is bleached without suffering any injury; and rags of coarse bad cloth, such as are used in the paper manufactories to make this kind of paper, may be bleached by this acid, and will then furnish paper of a very superior quality. I bleached by it an hundred weight of paste, intended to be made into blotting paper, and the increase of value in the product was computed at 25 *per cent.* whereas the expence of the operation, when calculated in the strictest manner, amounted only to 7 *per cent.*

12
Mode of whitening old books.

"The property possessed by this acid, of bleaching paper without injuring its texture, renders it very valuable for restoring old books and smoked prints. The latter, when discoloured to such a degree that the subject of them could hardly be distinguished, were re-established and revived, in so astonishing a manner that they appeared to be new; and old books, soiled by that yellow tinge which time always produces, may be so completely renewed, that one might suppose them to be just come out of the press. The simple immersion of a print in oxgenated muriatic acid (leaving it therein a longer or a shorter time, according to the strength of the liquor (is all that is required for bleaching it; but when a book is to be bleached, some farther precautions are to be used. As it is necessary that the acid should wet every one of the leaves, the book must be completely spread open, and then, by letting the boards of the binding rest upon the sides of the vessel, the paper only will be immersed in the liquor. If any of the leaves stick together, they must be carefully separated, that all of them may be equally impregnated. The liquor takes a yellow tinge, the paper grows white; and after two or three hours the book may be taken out of the liquor, and soaked in clean water, which should be changed from time to time, in order to wash out the acid with which the book is impregnated, and also to deprive it of the disagreeable smell it has contracted.

"The above method, which is the first I made use of, has generally succeeded pretty well; too often, however, the leaves of my books have had a motely appearance, and sometimes several pages were not at all bleached; I was therefore obliged to have recourse to the following more certain process. I began by unsewing the books, and reducing them into sheets; these sheets I placed in divisions made in a leaden vessel; by means of thin slips of wood, so that the leaves when laid flat were separated from each other by very small intervals. I then put the acid into the vessel, pouring it against the side, that the leaves might not be disturbed;

Bleaching ‖ Boar. ed; and when the operation was finished, I drew off the acid, by means of a cock fixed in the bottom of the vessel. I then filled the vessel with clean water, which washed the leaves, and took off the smell of the oxygenated acid. They may then be dried, smoothed, and new bound. In this manner I have restored many valuable books, which had become worthless from the bad state they were in.

13 And prints. "When I had to bleach prints so torn to pieces that they consisted only of fragments fitted together, and pasted upon paper, I was afraid I might lose some of these fragments in the liquor, because they separate from the paper by the softening of the paste; in that case therefore I took the precaution of enclosing the print in a large cylindrical bottle which I turned upside-down, fixing its mouth to that of a vessel in which I had put a mixture proper for disengaging oxygenated muriatic gas. This gas fills the inside of the bottle, and, acting upon the print takes off the stains, ink-spots, &c. while the fragments remain pasted to the paper, and consequently keep their respective places."

BLOCK *Island*, called by the Indians *Manisses*, lies about 21 miles S. S. W. of Newport, and is in Newport co. state of Rhode-Island. It was erected into a township, named *New-Shoreham*, in 1672. This island is 46 miles in length, and its extreme breadth is 38 miles. It has 682 inhabitants, including 47 slaves. It is famous for cattle and sheep, butter and cheese: round the ledges of the island considerable quantities of cod fish are caught. The southern part of it is in N. lat. 41. 8.—*Morse*.

BLOCKLEY, a township in Philadelphia co. Pennsylvania.—*ib*.

BLOCKS (*Encycl.* Plate XCV. fig. 5) *a*, Represents a single block, and *b*, *c*, two double ones of different kinds, without strops; *e*, *f*, two double tackle blocks, iron bound, the lower one, *f*, being fitted with a swivel; *g*, a double iron block with a large hook; *h*, a small block; *i*, a top block: *k*, a voyal block; *l*, a clew garnet block; *m*, the cat block, employed to draw the anchor up to the cat-head. See *Cat-Head*, Encycl.

BLUE HILL, a township in Hancock co. District of Maine, on the W. side of Union River, 344 miles N. E. of Boston, and 13 E. of Penobscot; having 274 inhabitants.—*Morse*.

Blue Hill *Bay*, is formed by Naskeag Point on the W. and Mount Desart Island on the E. It extends northerly up to a mountain on the E. of Penobscot River, which, from its appearance at sea, is called *Blue Hill*. Union River empties into this bay.—*ib*.

Cape or Large Snouted BOAR, a species of the genus Sus, which, according to M. Vaillant, differs from every known species, and has not been accurately described by any writer of natural history. Buffon, indeed, in the Supplement to his History of Quadrupeds, has given a figure of it; but nothing like the head of the animal is discoverable, says our author, in that figure, all its characteristics having been omitted by the draughtsman. M. Vaillant, during his last travels in

Plate VII. Africa, shot a monstrous boar of this species on the banks of Fish-river, and in the country of the *Greater Nimiquas*. He describes it in the following terms: Its snout, instead of being taper and in the form of a proboscis, is, on the contrary, very broad and square at the end. It has small eyes, at a very little distance from each other, level with the surface, and near the top of the forehead. On each cheek a very thick cartilaginous skin projects horizontally, being about three inches long and as many broad. At first sight you would be tempted to take these excrescences for the ears; particularly as the real ears of the animal, sticking as it were to the neck, which is very short, are partly concealed by an enormous mane, the bristles of which, in colour red, brown, and greyish, are 16 inches in length on the shoulders. Directly below these false ears is a bony protuberance on each side, projecting more than an inch, serving the animal to strike with to the right and left. The boar has, besides, four tusks, of the nature of ivory, two in each jaw: the upper ones are seven or eight inches long; very thick at the base, and terminating in an obtuse point, grooved, and rising perpendicularly as they issue from the lips: the lower ones are much smaller, and so close to the upper ones when the mouth is shut, that they appear as one. The head is a truly hideous object. It is scarcely less so than that of the hippopotamus, to which at first view it appears to have a striking resemblance. Systematists, accustomed to view nature only according to rules established by themselves, will be far from acknowledging this animal to be a boar; for, not to mention its large snout, it wants incisive teeth in both jaws. Notwithstanding its wide muzzle, it ploughs up the earth to seek for roots, on which it feeds. It is very active, though large and bulky; running with such speed, that the Hottentots give it the name of the *runner*.

Boar ‖ Bombay.

BOEUF, LE, a place in the N. western corner of Pennsylvania, at the head of the N. branch of French Creek, and 50 miles from Fort Franklin, where this Creek joins the Alleghany; measuring the distance by water. The French fort of Le Boeuf, from which the place has its name, lay about 2 miles E. from Small Lake, which is on the N. branch of French Creek; and from Le Boeuf, there is a portage of 14 miles northerly, to Presque Isle, in Lake Erie; where the French had another fort.

From Le Boeuf, to Presque Isle, is a continued chesnut-bottom swamp (except for about one mile from the former, and two from the latter) and the road between these two places, for 9 miles, 15 years ago, was made with logs, laid upon the swamp. N. lat. 42. 1. W. long. 79. 53. 20.—*ib*.

BOLTON, a township in Chittenden co. Vermont, on Onion River, about 104 miles N. N. E. from Bennington, having 88 inhabitants.—*ib*.

Bolton, a township in Tolland co. Connecticut, incorporated in 1720; and was settled from Weathersfield, Hartford, and Windsor, 14 miles E. from Hartford.—*ib*.

Bolton, a township in Worcester co. Massachusetts; 18 miles N. E. from Worcester, and 34 W. from Boston. It contains 861 inhabitants.—There is a fine bed of limestone in this town, from which considerable quantities of good lime are made yearly.—*ib*.

BOMBAY *Hook*, an island at the mouth of Delaware River about 8 miles long and 2 broad, formed by the Delaware on the eastern side, and Duck Creek and Little Duck Creek on the Maryland side; these are united together by a natural canal. It is proposed to connect Delaware River with Chesapeak Bay,

by

PLATE VII.

LARGE SNOUTED BOAR

BLEACHING

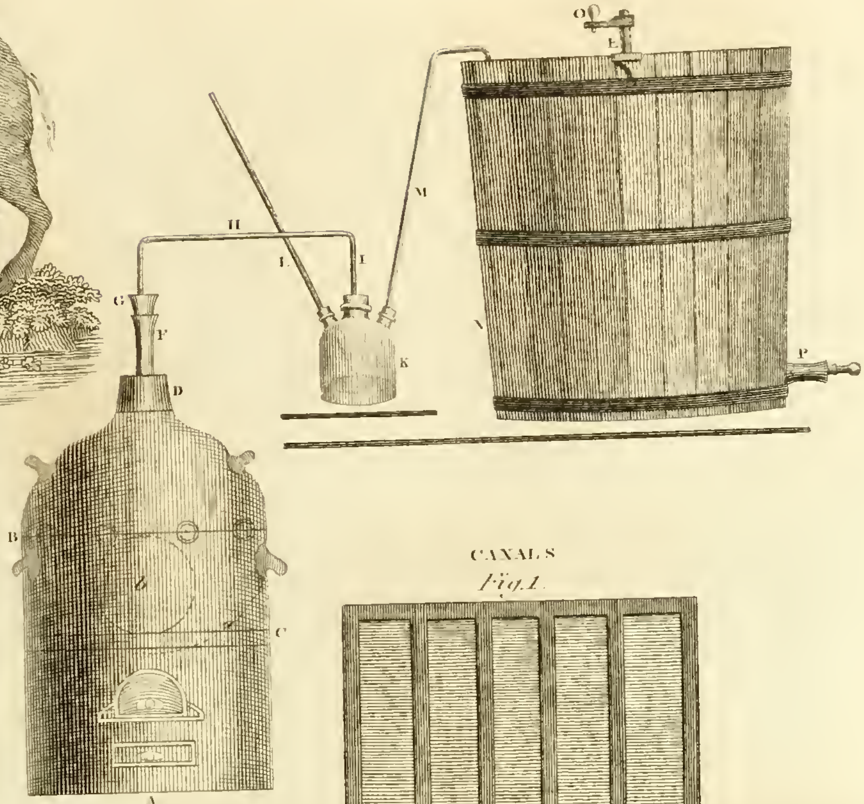
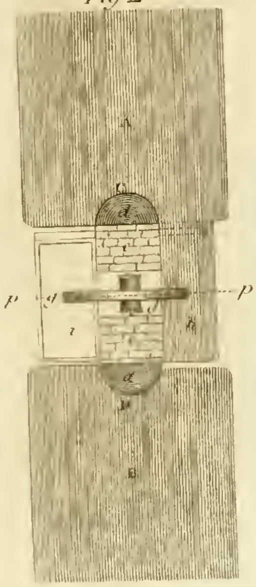


Fig.2.



CANALS

Fig.1.

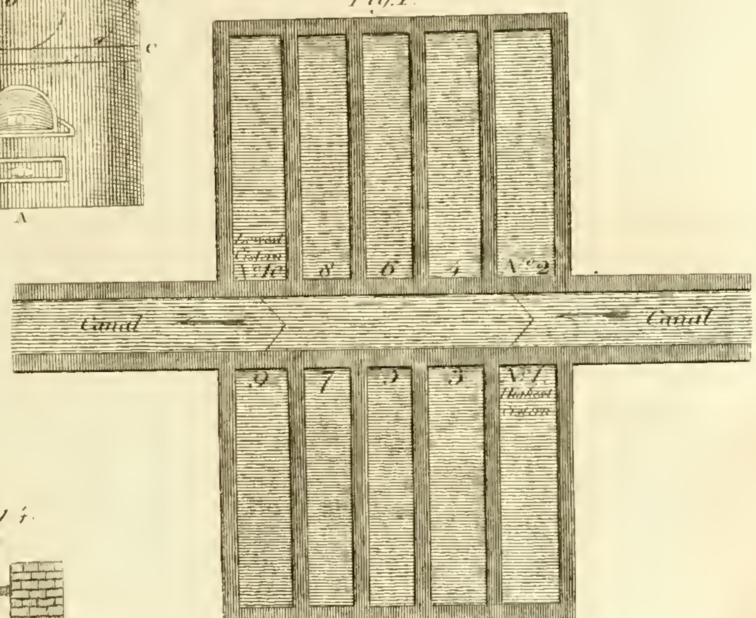


Fig.3.

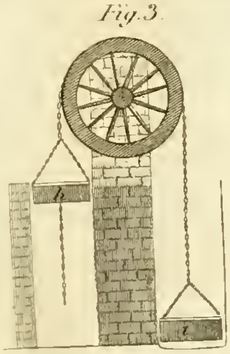


Fig.4.

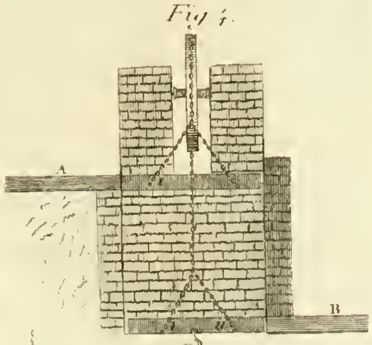


Fig.5.

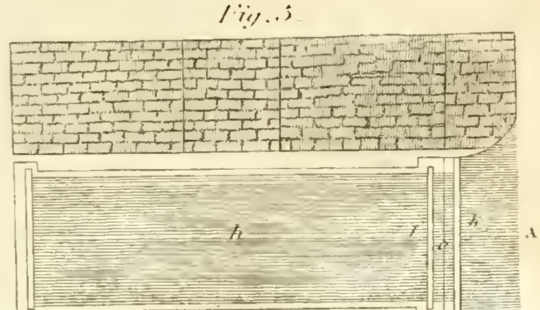
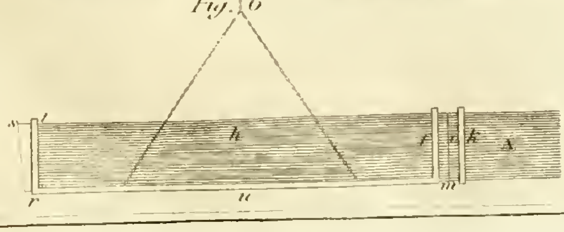


Fig.6.



Lowson sc.

Bonet || Bonnet.

by a canal from Duck Creek to that bay, through Chester River. The N. W. end of Bombay Hook is about 47 miles from Capes Henlopen and May, from the Hook to Reedy Island is 9 miles.

BONET (Theophilus), was born at Geneva in the year 1620. His parents were able to give him the most liberal education, and his genius directed him to the study of physic; and that he might have every advantage, he attended on the lectures of the most eminent professors in many of the celebrated universities in Europe. In 1643 he was admitted to the degree of M. D. and was for some time physician to the Duke of Longueville. His superior skill in his profession soon brought him into considerable repute; but being seized with an excessive deafness, he was obliged to retire from business when about 60 years of age.

During this retirement he employed himself in collecting all the observations which he had made in a practice of forty years duration, and in arranging them under proper heads. His first publication, which was intitled *Pharos Medicorum*, &c. consists of practical cautions, extracted mostly from the works of Bellonius; and in it he points out many errors which then prevailed in the general practice of physic. Of this work he gave to the world a second edition, considerably improved and greatly enlarged; and in 1687 it was a third time printed at Geneva, under the title of *Labyrinthi medici extricati*, &c.

In 1675 he published *Prodromus anatomiæ practicæ, sive de abditis morborum causis*, &c. This was intended merely as an introduction to a work that soon followed, under the title of *Sepulchretum, sive anatomia practica ex cadaveribus morbo denatis*. In these two publications he has collected a great number of curious observations upon the diseases of the head, breast, belly, and other parts of the body.

In 1682 appeared at Geneva *Mercurius Compitalius, sive index medico-practicus per decisiones, cautiones*, &c. in folio; and in 1684 and 1686 two volumes in folio likewise, intitled *Medicini Septentrionalis collatitia*. This last work is a collection of the best and most remarkable observations in physic which had been then made in England, Germany, and Denmark, which Dr Bonet arranged under proper heads, according to the several parts of the human body. At Geneva, in 1692, was published, in three volumes folio, *Polyalthes, sive Thesaurus medica practicus ex quibuslibet rei medicæ scriptoribus congestus*, &c. and some years before, he gave to the world correct editions of *Theodori Turqueti de Maerne tractatus de arthritide, una cum ejusdam aliquot consiliis*; and of *Jacobi Rohaulti tractatus physicus e Gallico in Latinum versus*. This laborious and useful author died of a dropsy on the 29th of March 1698.

BONNET (Charles), was descended from a French family, who being compelled, on account of their religious principles, to emigrate from their native country, established themselves at Geneva in the year 1572. His grandfather was advanced to the magistracy in that city, and adorned by his integrity an eminent station. His father, who preferred the station of a private citizen, paid unremitted attention to the education of his son, who was born on the 13th of March 1720; and Charles, at a very early period, recompensed his father's assiduity, by the amiableness of his disposition, and the rapid progress he made in general literature. When he was about 16 years of age, he applied himself, with great eagerness, to the perusal of *Le Spectacle de la Nature*; and this work made such a deep impression on his mind, that it may be said to have directed the taste and the studies of his future life. What that publication had commenced, was confirmed by the work of *La Pluche*; but having accidentally seen the treatise of *Reaumur* upon insects, he was in a transport of joy. He was very impatient to procure the book; but as the only copy in Geneva belonged to a public library, and as the librarian was reluctant to entrust it in the hands of a youth, it was with the utmost difficulty that he could obtain his end.

Bonnet.

By the possession of this treasure, our assiduous youth was enabled to make several new and curious experiments, which he communicated to Reaumur himself; and the high applause he gained from so great a naturalist added fresh vigour to his assiduity.

In compliance with his father's desires, he applied himself, though with much reluctance, to the study of the law. The works of *Burlamaqui* pleased him the most, on account of the perspicuous and philosophic manner in which the subject was treated: the institutes of *Heineccius* gave him some courage also, as he perceived order and connection; but the Roman law terrified him as the *hydra of Lerna*. Notwithstanding his application to these authors, he still continued attached to natural history, and was very active in making experiments. The experiments which demonstrate that tree-lice propagate without copulation, was communicated by Reaumur to the Academy of Sciences; and this circumstance occasioned an epistolary correspondence between M. Bonnet and that great naturalist. This was doubtless very flattering to a youth of twenty years. The letter of Reaumur was accompanied with a present of that very book which he had borrowed with so much difficulty two years before.

Animated by such distinguished marks of approbation, he diligently employed every moment he could steal from the study of jurisprudence to the completion of his natural history of the tree louse; to experiments on the respiration of catterpillars and butterflies, which he discovered to be effected by stigmata, or lateral pores; to an examination of the construction of the tænia or tap-worm; in frequent correspondence with Reaumur; and in assisting Trembley in his discoveries and publication concerning millepedes, &c. Having in the year 1743 obtained the degree of doctor of laws, he relinquished a pursuit which he had commenced with so much reluctance. In the same year he was admitted a fellow of the Royal Society, to which he had communicated a treatise on insects.

Bonnet being now liberated from his other pursuits, applied himself, without intermission, to collecting together his experiments and observations concerning the tree-louse and the worm, which he published in 1744 under the title of *Insectology*. This work acquired deserved approbation from the public, and was honoured by the commendation of the celebrated B. de Jussieu. He was reproached, however, in a periodical publication, with having paid too little attention to the delicacy of his reader; though his patience and accuracy were acknowledged to be deserving of praise. Such unremitted application and labour could not fail of becoming injurious to his health. Inflammations, nervous

fever,

Bonnet. fever, fore eyes, &c. compelled him to relinquifh the ufe of the microfcope and the ftudy of infects. This prevention was fo extremely mortifying to a man of his tafte and activity of mind, that he was thrown into a deep melancholy, which could only be fubdued by the refolution infpired by philofophy, and the confolations of religion: thefe gradually roufed him from a dejected ftate of mind. About the end of the year 1746 our philofopher was chofen member of the Literary Inftitution at Bologna, which introduced him to a correfpondence with the famed Zanotti, who may be deemed the Fontenelle of Italy.

In the year 1747 he undertook a very difficult work on the leaves of plants; which, of all his publications in natural hiftory, bore the ftrongeft marks of originality, both with refpect to the manner in which his experiments were made, and the difcoveries refulting from them. His extreme attachment to natural hiftory gradually led him to a ftudy of a very different nature; fpeculative philofophy now engaged his whole attention. The firft fruits of his meditations in this department was his *Effay on Pfychology*. In this work the principal facts obfervable in human nature, and the confequences refulting from them, are ftated in a concife and confpicuous manner. He contemplated man from the firft moment of his exiftence, and purfued the developement of his fenfes and faculties from fimple growth up to intelligence. The work, which was publifhed without his name, met with great oppofition, and was criticifed with feverity; but the cenfures were directed more againft his expreffions than his principles; nor were they of fufficient importance to impede the general acceptance of the publication.

His analyfis of the mental faculties was fimply a developement of the ideas contained in the preceding work. It engaged his inceffant attention for the fpace of five years; nor was it completed before 1759. It is fomewhat fingular that both he and the Abbé de Condillac fhould have illuftrated their principles by the fuppofition of a ftatue, organized like the human body, which they conceived to be gradually infpired with a foul, and the progreffive developement of whofe powers they carefully traced. In the year 1760 this work was publifhed at Copenhagen, by order and at the expence of Frederick V. and it was followed in 1762 by contemplations on organized bodies. In this the author had three principal objects before him; the firft was to give a concife view of every thing which appears interefting in natural hiftory, refpecting the origin, developement, and reproduction of organized bodies; the fecond was to confute the two different fyftems founded upon the Epigenefis; and the third was to explain the fyftem of Germs, indicate the ground upon which it was founded, its correfpondence with facts, and the confequences refulting from it. This work was received with much fatisfaction by natural philofophers. The Academy of Berlin, which had propofed the fame fubject as a prize queftion for 1761, declared that they confidered the treatife as the offspring of clofe obfervation and profound reafoning; and that the author would have had an indubitable right to the prize, if he had confined his labours to the precife ftatement of the queftion. It muft alfo be recorded, to the honour of the great *Malefherbes*, that he reverfed the interdict which the public cenfor had laid upon this book, under the pretext that it contained dangerous principles. Bonnet.

The Contemplation of Nature appeared in 1764. In this work the author firft enlarged upon the common conceptions entertained concerning the exiftence and perfections of God; and of the order and uniformity obfervable in the univerfe. He next defcends to man, examines the parts of his compofition, and the various capacities with which he is endowed. He next proceeds to the plants; affembles and defcribes the laws of their economy; and, finally, he examines the infects, indicates the principal circumftances in which they differ from larger animals, and points out the philofophical inferences that may legitimately be deduced from thefe differences; and he concludes with obfervations refpecting the induftry of infects. This work being of a popular nature, the author fpared no pains in beftowing upon it thofe ornaments of which it was fufceptible. The principles which he thus difcovered and explained, induced him to plan *a fyftem of moral philofophy;* which, according to his ideas, confifted folely in the obfervance of that relation in which man is placed, refpecting all the beings that furround him. The firft branch would have comprehended, various means which philofophy and the medical fcience have difcovered for the prevention of difeafe, the prefervation and augmentation of the corporeal powers, and the better exertion of their force: in the fecond, he propofed to fhew, that natural philofophy has a powerful tendency to embellifh and improve our mind, and augment the number of our rational amufements, while it is replete with beneficial effects refpecting the fociety at large. To manifeft the invalidity of opinions, merely hypothetical, he undertook, in the third place, to examine, whether there were not truths within the compafs of human knowledge, to which the moft fceptical philofopher muft be compelled to yield his confent, and which might ferve as the bafis of all our reafonings concerning man and his various relations. He then would have directed his attention to a firft caufe, and have manifefted how greatly the idea of a Deity and Supreme Lawgiver favoured the conclufions which reafon had drawn from the nature and properties of things: but it is deeply to be regretted that his health, impaired by inceffant labour, would not permit him to complete the defign.

His laft publication was the *Palingenefis*, which treats of the prior exiftence and future ftate of living beings.

Of his publications in natural hiftory, thofe deemed the moft excellent are, his Treatife on the beft Means of preferving Infects and Fifh in Cabinets of Natural Hiftory; a differtation on the Loves of the Plants; fundry pieces on the Experiments of *Spallanzani*, concerning the Reproduction of the Head of the Snail; a Differtation on the *Pipa*, or Surinam Toad; and different Treatifes on Bees.

In the year 1783 he was elected honorary member of the Academy of Sciences at Paris; and of the Academy of Sciences and the Belles Lettres at Berlin.

Much of his time was employed in a very extenfive correfpondence with fome of the moft celebrated natural philofophers and others. Of this number were *Reaumur*, *De Geer* the Reaumur of Sweden, *Du Hamel*, the learned *Haller*, the experimental philofopher *Spallanzani*,

lanzani, *Van Swieten*, *Merian*, and that ornament of Switzerland the great *Lambert*. He entertained, however, the utmoſt averſion to controverſy. He thought that no advantage to be obtained by it could compenſate for the loſs of that repoſe which he valued, with Newton, as the *rem prorſus ſubſtantialem*. He never anſwered remarks that were made to the prejudice of his writings, but left the deciſion with the public; yet, ever ready to acknowledge his errors, he was ſincerely thankful to every one who contributed to the perfection of his works. He was uſed to ſay, that one confeſſion, *I was in the wrong*, is of more value than a thouſand ingenious confutations.

His literary occupations, and the care he was obliged to take of his health, prevented him from travelling. He delighted in retirement, and every hour was occupied in the improvement of his mind. The laſt 25 years of his life were ſpent in the ſame rural ſituation where he had paſſed the greater part of his early days; yet notwithſtanding the purſuit of literature was his ſupreme delight, he never refuſed to ſuſpend his ſtudies, when the good of his country ſeemed to demand his ſervices.

He was choſen in 1752 member of the Grand Council in the republic of Geneva; and he aſſiſted regularly at their deliberations till the year 1768, where he diſtinguiſhed himſelf by his eloquence; his moderation, united with firmneſs; by his good ſenſe and penetration in caſes of difficulty; and by the zeal with which he endeavoured to reclaim his fellow-citizens to that ancient ſimplicity of manners which had been ſo conducive to the welfare of the ſtate, and to the love of virtue, ſo eſſential to the exiſtence of genuine liberty. His conduct, in every caſe, was conſiſtent with his principles. He took no pains to accumulate wealth, but remained ſatisfied with a fortune equal to his moderate wants, and to the exerciſe of his benevolence. The perfect correſpondence between his extenſive knowledge and virtuous deeds procured him univerſal eſteem.

In the year 1788 evident ſymptoms of an *hydrops pectoris* manifeſted themſelves; and from this time he gradually declined. He ſuſtained his indiſpoſition with unremitted cheerfulneſs and compoſure. After various fluctuations, uſual in that complaint, he died on the 20th of May 1793, in the 73d year of his age; retaining his preſence of mind to the laſt moment, adminiſtering comfort to ſurrounding friends and relatives, and attempting to alleviate the diſtreſs of his diſconſolate wife, in whoſe arms he expired.

As a demonſtration of the high value placed upon his labours and talents by the literati, we have only to remark, that he was member of moſt of the learned ſocieties of Europe.

BOOK KEEPING, is an art of which the importance is univerſally known; and as commonly practiſed, it has been ſufficiently explained in the Encyclopædia. But ſince that article was written, a great improvement has been introduced into the art, or rather a new method of book-keeping has been invented, by Mr EDWARD THOMAS JONES, of the city of Briſtol, accountant, who calls it the *Engliſh ſyſtem of book-keeping*; and thinks that by it accounts may be more regularly kept, and errors in accounts more eaſily detected, than by any other method hitherto known. We are much inclined to be of his opinion; and ſhall therefore lay before our readers his deſcription of this method, as we find it in the ſpecification of the patent which was granted to him January 26, 1796.

The Engliſh Syſtem of Book Keeping requires three books, called a *day-book* or *journal*, an *alphabet*, and a *ledger*, which muſt be ruled after the following method, *viz.* the day-book to have three columns on each page, for receiving the amount of the tranſactions; one column of which to receive the amount of debits and credits, one column to receive the debits only, and one column to receive the credits only; or it may be ruled with only two columns on each page, one column to receive the amount of the debits, and one column to receive the amount of the credits. There muſt alſo be on each page of the day-book four other columns ruled, two on the left ſide next the amount of the debits, and two on the right ſide next the amount of the credits, for receiving the letter or mark of poſting, and the page of the ledger to which each amount is to be poſted.

The alphabet need not be ruled at all, but muſt contain the name of every account in the ledger, the letter that is annexed to it as a mark of poſting, and the page of the ledger.

The ledger muſt be ruled with three, four, five, or ſeven columns on each page, as may be moſt agreeable, for receiving the amounts of the different tranſactions entered in the day-book. And the proceſs for uſing theſe books, or making up books of accounts on this plan, is as follows.

When a perſon enters into trade, whether by himſelf or with copartners, he muſt have an account opened with himſelf in the ledger; entering firſt in the day-book, and then to the credit of his account in the ledger, the amount of the property he advances into trade: The account may be headed either with his name only, or elſe called his ſtock-account.

If you buy goods, give the perſon credit of whom you purchaſe; when you ſell goods, debit the perſon to whom ſaid goods are ſold. If you pay money, debit the perſon to whom paid, not only for what you pay, but alſo for any diſcount or abatement he may allow, and give the caſhier credit for the neat amount paid. If you receive money, credit the perſon of whom you receive it, not only for what he pays, but alſo for any diſcount or abatement you may allow, and debit the caſhier for the neat amount received; taking care in theſe entries to have nothing myſterious or obſcure, but merely a plain narrative of the fact, introducing not one uſeleſs word, and avoiding every technical term or phraſe except the words debit and credit, which are full and comprehenſive, and the only terms that are applicable to every tranſaction, and may be affixed to every entry.

But as a hurry of buſineſs will ſometimes take place in almoſt every counting-houſe, which may cauſe the entries to be made to the debit inſtead of the credit of an account in the day-book, and to the credit inſtead of the debit, Mr Jones has endeavoured as much as poſſible to counteract the evil, by having only one column for receiving the amount of every tranſaction, whether debits or credits, at the inſtant of making the entry; and, for the convenience of ſeparating the debits from the credits, previous to poſting, which is neceſſary to prevent confuſion and perplexity, he has two other columns on the fame page; that on the left fide into which the amount of every debit muft be carefully entered, and that on the right for the amount of the credits, which columns muft be caft up once a month. The column of debits and credits of itfelf forming one amount; the column for the debits producing a fecond amount; and the column of credits a third amount; which fecond and third amounts, added together, muft exactly agree with the firft amount, or the work is not done right.

By this means the man of bufinefs may obtain monthly fuch a ftatement of his affairs as will fhow how much he owes for that month, and how much is owing to him; and the debits being added together for any given time, with the value of the ftock of goods on hand, will, when the amount of the credit is fubtracted therefrom, fhew the profits of the trade.

Our author now proceeds to the procefs of pofting; which begins with opening an account in the ledger with every perfon to whofe debit or credit there has been an entry made in the day-book; affixing to each account a letter, which is to be ufed as a mark of pofting. The perfon's name, place of abode, and the folio of the ledger, muft then be entered in the alphabet, with the fame letter prefixed to each name as is affixed to the account in the ledger. Next the page of the ledger on which each account is opened (and which will be feen in the alphabet) muft be affixed to each amount in the day-book, in the column for that purpofe. The date and amount of each debit muft then be pofted in the columns for receiving it in the ledger, on the left or debit fide of that account to which it relates; entering, as a mark of pofting in the day-book, againft each amount, the fame letter that is affixed to the account in the ledger, to which faid amount may be pofted. Obferving that the debits of January, February, March, &c. muft be pofted into the column for thefe months in the ledger, and the credits muft alfo be pofted in like manner, filling up each account in the centre, at the expiration of every month, with the whole amount of the month's tranfactions; thus having in a fmall fpace, the whole ftatement of each perfon's account for the year; in the columns to the right and left the amount feparately of each tranfaction; and in the centre a monthly ftatement.

Having defcribed the procefs of this method of book-keeping, he thus fhews how to examine books kept by this method, fo as to afcertain, to an abfolute certainty, if the ledger be a true reprefentation of the day-book; *i. e.* not only if each tranfaction be correctly pofted, as to the amount thereof, but alfo if it be rightly entered to the debit or credit of its proper account. This examination differs from the modes that have heretofore been practifed, as well in expedition as in the certain accuracy which attends the procefs; it being only neceffary to caft up the columns through the ledger debits and credits, according to the examples given; and the amount of thofe columns, if right, muft agree with the columns in the day-book for the fame correfponding fpace of time. Thefe caftings fhould take place once a month; and if the amounts do not agree, the pofting muft then, but not elfe, be called over; and when the time, whether it be one, two, three, or four months, that is allotted to each column of the ledger is expired, the amount of each column fhould be put at the bottom of the firft page, and carried forward to the bottom of the next, and fo on to the end of the accounts; taking care that the amount in the day-book, of each month's tranfactions, be brought into one grofs amount for the fame time.

But although this procefs muft prove that the ledger contains the whole contents of the day-book, and neither more nor lefs, yet it is not complete without the mode of afcertaining if each entry be pofted to its right account; which may be afcertained by the following method. He has laid down a rule that a letter, which may be ufed alphabetically in any form or fhape that is agreeable, fhall be affixed to each account in the ledger, and the fame letter prefixed to the names in the alphabet, thefe letters being ufed as marks of pofting, and affixed to each account in the day-book as it is pofted; it is only neceffary therefore to compare and fee that the letter affixed to each entry in the day-book is the fame as is prefixed to the fame name in the alphabet; a difference here fhews of courfe an error, or elfe it muft be right.

At the end of the year, or at any other time, when perfons balance their accounts, if there be no objections to the profits of the trade appearing in the books, the ftock of goods on hand at prime coft may be entered in the day-book, either the value in one amount, or the particulars fpecified, as may be moft expedient, and an account opened for it in the ledger, to the debit of which it muft be pofted. The cafting up of the ledger muft then be completed; and when found to agree with the day-book, and the amount placed at the bottom of each column, fubtract the credits from the debits, and it will fhew the profit of the trade; unlefs the credits be the greater amount, which will fhew a lofs. In taking off the balances of the ledger, one rule muft be obferved, and it cannot be done wrong: As you proceed, firft fee the difference between the whole amounts of the credits and debits on each page for the year, with which the difference of the outftanding balances of the feveral accounts on each page muft exactly agree, or the balances will not be taken right. By this means every page will be proved as you proceed, and the balances of ten thoufand ledgers, on this plan, could not unobfervedly be taken off wrong.

BORDENTOWN, a pleafant town in Burlington co. New-Jerfey, is fituated at the mouth of Crofswicks Creek, on the E. bank of a great bend of Delaware River; 6 miles below Trenton, 9 N. E. from Burlington, by water, and 15 by land, and 24 miles N. E. from Philadelphia; and through this town, which contains about 100 houfes, a line of ftages paffes from New-York to Philadelphia. The fecond divifion of Heffians was placed in this town, in December, 1776; and by the road leading to it, 600 men of that nation efcaped, when Gen. Wafhington furprifed, and made prifoners of 886 privates, and 23 Heffian officers, at Trenton.—*Morse.*

BOSCAWEN, a townfhip in Hillfborough co. New-Hampfhire, on the weftern bank of Merrimack River above Concord; 43 miles N. W. of Exeter, and 38 S. E. of Dartmouth College; having 1108 inhabitants. Bofcawen Hills are in this neighborhood.—*ib.*

BOSCOVICH (Roger Jofeph), one of the moft eminent mathematicians and philofophers of the prefent age, was born, of virtuous and pious parents, on the 11th of May 1711, in the city of Ragufa, the capital

pital of a ſmall republic of the ſame name, lying on the eaſtern coaſt of the Adriatic Sea. At baptiſm, the name of Roger was given him, to which he added that of Joſeph when he received the ſacrament (A) of confirmation.

He ſtudied Latin grammar in the ſchools which were taught by the Jeſuits in his native city. Here it ſoon appeared that he was endued with ſuperior talents for the acquiſition of learning. He received knowledge with great facility, and retained it with equal firmneſs. None of his companions more readily perceived the meaning of any precept than he; none more juſtly applied general rules to the particular caſes contained under them. He announced his thoughts with great perſpicuity, and came ſoon to compoſe with propriety and elegance. His application was equal to his capacity, and his progreſs was rapid. At the beginning of the 15th year of his age, he had already gone through the grammar claſſes with applauſe, and had ſtudied rhetoric for ſome months. His moral behaviour had likewiſe been very good: he was reſpectful and obedient to his parents and maſters, affable and obliging to his equals, and exemplary in all the duties of religion. It was now time for him to determine what courſe he would ſteer through life; nor did he heſitate long in coming to a reſolution.

The Jeſuit fathers, by teaching the ſciences to youth, were very uſeful, and at the ſame time had a fine opportunity of obſerving their ſcholars and of drawing into their ſociety thoſe boys who ſeemed fit for their purpoſe. Such a ſubject as the young Boſcovich could not eſcape their attention. They ſhewed him particular kindneſs, to which he was not inſenſible. He had an ardent thirſt for learning; to advance in which he felt himſelf capable; and he thought he could nowhere have a better opportunity of gratifying this laudable inclination than in their order, in which ſo many perſons had ſhone in the republic of letters. Accordingly, with the conſent of his parents, he petitioned to be received among them; and his petition was immediately granted, becauſe it was deſired by thoſe to whom it was made.

It was a maxim with the Jeſuits to place their moſt eminent ſubjects at Rome, as it was of importance for them to make a good figure on that great theatre. Wherefore, as Roger's maſters had formed great expectations of him, they procured his being called to that city; whither he was ſent in the year 1725, and entered the noviceſhip with great alacrity. This noviceſhip was a ſpace of two years, in which the candidate made a trial of his new ſtate of life; and in the mean time his new ſuperiors obſerved him, and deliberated whether or not they would admit him into their body. During theſe two years, the novice was principally employed in exerciſes of piety, in ſtudying books of Chriſtian morality, and in becoming perfectly acquainted with the rules and conſtitutions of the order. After theſe two years were paſt, the Jeſuits were willing to retain Boſcovich, and he was no leſs deſirous of remaining with them. He therefore paſſed to the ſchool of rhetoric; in which, for two other years under the moſt expert maſters of the ſociety, young men perfected themſelves in the arts of writing and ſpeaking, which was of ſo great conſequence to perſons who were deſtined to treat ſo much with their neighbours. Here Boſcovich became perfectly well acquainted with all the claſſical authors, and applied with ſome predilection to Latin poetry.

After this he removed from the noviciate to the Roman College, in order to ſtudy philoſophy, which he did for three years. In order to underſtand the doctrine of phyſics, it was neceſſary to premiſe the knowledge of the elements of geometry, which is alſo otherwiſe proper for forming the mind, and for giving to it a true taſte for truth. Here it was that our young philoſopher came to be in his true element; and it now appeared how extremely fit his genius was for this kind of ſtudy. His maſter, though he was able and expert, inſtead of leading him on, was ſcarcely able to keep pace with him, and his condiſciples were left far behind. He likewiſe found the application of the mathematics to natural philoſophy pleaſant and eaſy. From all this, before the end of the three years, he had made a great advancement in phyſical and mathematical knowledge, and his great merit was generally acknowledged by his companions, and well known to his ſuperiors. He had already begun to give private leſſons on mathematics.

According to the ordinary courſe followed by the Jeſuits, their young men, after ſtudying philoſophy, were wont to be employed in teaching Latin and the belles lettres for the ſpace of five years, that ſo they might become ſtill better acquainted with polite learning, and arrive at the ſtudy of theology and the prieſthood at a riper age. But as Roger had diſcovered extraordinary talents for geometrical ſtudies, it was thought by his ſuperiors that it would be a pity to detain him from his favourite purſuits in a drudgery for which ſo many others were fit enough. He was therefore diſpenſed with from teaching thoſe ſchools, and was commanded to commence the ſtudy of divinity.

During the four years that he applied to that ſublime ſcience, he ſtill found ſome leiſure for geometry and phyſics; and even before that ſpace was ended, he was named profeſſor of his beloved mathematics.

He was now placed in an office for which he was ſuperlatively fit, and for which he had a particular predilection. Beſides having ſeen all the beſt modern productions on mathematical ſubjects, he ſtudied diligently the ancient geometricians, and from them learned that exact manner of reaſoning which is to be obſerved in all his works. Although he himſelf perceived eaſily the concatenation of mathematical truths, and could follow them into their moſt abſtruſe receſſes, yet he accommodated himſelf with a fatherly condeſcenſion to the weaker capacities of his ſcholars, and made every demonſtration clearly intelligible to them. When he perceived that any of his diſciples were capable of advancing faſter than the reſt, he himſelf would propoſe his

(A) For this article we are indebted to a dignified clergyman of the church of Rome, who was one of Boſcovich's favourite pupils.

his giving them private leffons, that fo they might not lofe their time; or he would propofe to them proper books with directions how to ftudy them by themfelves, being always ready to folve difficulties that might occur to them.

To the end that he might be the more ufeful to his fcholars, he took time from higher purfuits to compofe new elements of arithmetic, algebra, plain and folid geometry, and of plain and fpheric trigonometry; and although thefe fubjects had been well treated by a great many authors, yet Bofcovich's work will always be efteemed by good judges as a mafterly performance, well adapted to the purpofe for which it was intended. To this he afterwards added a new expofition of conic fections; in which, from one general definition, he draws, with admirable perfpicuity, all the properties of thofe three moft ufeful curves. He had meditated a complete body of pure and mixed mathematics, in which were to be comprehended treatifes on mufic, and on civil and military architecture; but from accomplifhing this he was prevented by other neceffary occupations.

According to the cuftom of fchools, every clafs in the Roman College, towards the end of the fcholaftic year, gave to the public fpecimens of their proficiency. With this view Bofcovich publifhed yearly a differtation on fome interefting phyfico-mathematical fubject. The doctrine of this differtation was defended publickly by fome of his fcholars, affifted by their mafter. At thefe literary differtations there was always a numerous concourfe of the moft learned men in Rome. His new opinions in philofophy were here rigoroufly examined and warmly controverted by perfons well verfed in phyfical ftudies: but he propofed nothing without folid grounds; he had forefeen all their objections, anfwered them victorioufly, and always came off with great applaufe and increafe of reputation. He publifhed likewife differtations on other occafions; and thefe works, though fmall in fize, are very valuable both for the matter they contain, and alfo for the manner in which it is treated. The principal fubjects of thefe differtations are the following: The fpots in the fun; the tranfit of mercury under the fun; the geometrical conftruction of fpheric trigonometry; the aurora borealis; a new ufe of the telefcope for the determination of celeftial objects; the figure of the earth; the arguments made ufe of by the ancients to prove the rotundity of the fame; the circles which are called ofculators; the motion of bodies projected in a fpace void of refiftance; the nature of infinites and of infinitely little quantities; the inequality of gravity in different parts of the earth; the annual aberration of the fixed ftars; the limits of the certainty to which aftronomical obfervations can arrive; a difcuffion on the whole of aftronomy; the motion of a body attracted by certain forces towards an immoveable centre in fpaces void of refiftance; a mechanical problem on the folid of greateft attraction; a new method of ufing the obfervation of the phafes in the lunar eclipfes; the cycloid; the logiftic and certain other curve lines; the forces that are called *living*; the comets; the flux and reflux of the fea; light; whirlwinds; a demonftration and illuftration of a paffage in Newton concerning the rainbow; the demonftration and illuftration of a method given by Euler regarding the calculation of fractions; the determination of the orbits of a planet by means of catoptrics, certain conditions of its motion being given; the centre of gravity and that of magnitude; the atmofphere of the moon; the law of continuity, and the confequences of it in the elements of matter and their forces; the law of the forces that exift in nature; lenfes and dioptrical telefcopes; the perturbation which appears to be caufed mutually by Jupiter and Saturn, and that chiefly about the time of their conjunction; the divifibility of matter and the elements of bodies; the objective micrometer;—befides other fubjects of the like nature, of which he has treated in feparate pieces, or in communications inferted in the tranfactions of literary focieties or academies, he being a member of thofe that are moft famous in Europe. It was in fome of the abovementioned differtations that Bofcovich made known firft to the world his fentiments concerning the nature of body, which he afterwards digefted into a regular theory, which is juftly become fo famous among the learned.

Father Noceti, another Jefuit, had compofed two excellent poems on the rainbow and the aurora borealis. Thefe poems were publifhed with learned annotations by Bofcovich; in which, among other things, he with great fagacity difcovers errors in optics into which De Dominis, Kepler, and others, had fallen.

His countryman, Benedict Stay, after having publifhed the philofophy of Defcartes in Latin verfe, attempted the fame with regard to the more modern and more true philofophy, and has executed it with wonderful fuccefs, to the admiration of all good judges. The two firft volumes of this elegant and accurate work were publifhed with annotations and fupplements by Bofcovich. Thefe fupplements are fo many fhort differtations on the moft important parts of phyfics and mathematics. Here is to be found a folution of the problem of the centre of ofcillation, to which Huygens had come by a wrong method; here he confutes Euler, who had imagined that the *vis inertiæ* was neceffary in matter; here he refutes the ingenious efforts of Riccati on the Leibnitzian opinion of the forces called *living*. He likewife fhews the falfehood of the mathematical prejudice, according to which the right line is confidered as effentially more fimple than curves, and makes it appear, that the notion of the faid right line is commonly accompanied with many paradoxes. He demonftrates, by the doctrine of combinations, fome beautiful theorems concerning the fpace occupied by the fmall maffes of body, with many ufeful obfervations on fpace and time.

Benedict XIV. who was a great encourager of learning, and a beneficent patron of learned men, was not ignorant how valuable a fubject Rome poffeffed in Bofcovich; and this pope gave him many proofs of the efteem he had for him. Two fiffures which had been perceived in the cupola of the church of St. Peter's on the Vatican had occafioned fome alarm. The pope defired Bofcovich and fome other mathematicians to make their obfervations and give their opinion on the fame. They obeyed, and their opinion was printed. They fhewed that there was no caufe to apprehend danger; but, for greater fecurity, they propofed certain precautions, which were adopted and put in execution.

The high opinion which the pope had formed of his talents, and the favour in which he was with Cardinal Valenti, Boſcovich. Valenti, miniſter of ſtate, proved hindrances to his going to America, for which a propoſal was made to him by the court of Liſbon. Some differences had long ſubſiſted between Spain and Portugal concerning the boundaries of their reſpective dominions in that great continent; and John V. of Portugal wiſhed that Boſcovich would go over and make a topographical ſurvey of the country in diſpute. He was not unwilling to undertake ſuch a taſk, which was entirely to his taſte; and he was reſolved at the ſame time to meaſure a degree of the meridian in Brazil, which might be compared with that meaſured at Quito by the French academicians Bouguer and Condamine, with the Spaniards Ulloa and Doy. But the pope hearing of this propoſal, ſignified to the Portugueſe miniſter at Rome, that his maſter muſt needs excuſe him for detaining Boſcovich in Italy, where he had occaſion for him, and could by no means conſent to part with him.

Accordingly a commiſſion was given to Boſcovich by Benedict to correct the maps of the papal eſtate, and to meaſure a degree of the meridian paſſing thro' the ſame. This he performed with great accuracy, aſſiſted by F. Chriſtopher Maire an Engliſh Jeſuit, and likewiſe a great mathematician. Their map was engraved at Rome, and is perhaps the moſt exact piece of the kind that ever was printed, as all the places are laid down from triangular obſervations made by the ableſt hands. Boſcovich alſo publiſhed, in a quarto volume in Latin, an account of the whole expedition, which appeared at Rome in the year 1755, and was afterwards printed at Paris in French in the year 1770. Here he gives a detail of their obſervations and of the methods they followed, and likewiſe of the difficulties they encountered, and how they were ſurmounted. One of theſe embarraſſed them a good deal at the time, but was afterwards matter of diverſion to them and others. Some of the inhabitants of the Apeninnes, ſeeing them paſs from hill to hill with poles and ſtrange machines, imagined that they were magicians come among their mountains in ſearch of hidden treaſures, of which they had ſome traditions: and as tempeſts of thunder and hail happened about the ſame time, they ſuppoſed that theſe calamities were cauſed by the forceries of their new viſitants. They therefore inſiſted that Boſcovich and Maire ſhould depart; and it was not eaſy to convince them that their operations were harmleſs. In this work there is inſerted a deſcription of the inſtruments made uſe of in determining the extent of the degree of the meridian; and the whole work may be extremely uſeful to practical geometricians and aſtronomers.

In the year 1757 the republic of Lucca entruſted Boſcovich with the management of an affair which was to them of conſiderable importance. Between that republic and the regency of Tuſcany there had ariſen a diſagreeable diſpute concerning the draining of a lake, and the direction to be given to ſome waters near the boundaries of the two eſtates. The Luccheſe ſenate choſe our philoſopher to treat of this buſineſs on their part. He repaired to the ſpot, conſidered it attentively, and drew up a writing, accompanied with a map, to ſhew more clearly what appeared to him moſt equitable and moſt advantageous for both parties. In order to enforce his reaſons the more effectually, it was thought proper that he ſhould go to Vienna, where the emperor Francis I. who was likewiſe grand duke of Tuſcany, reſided. He was ſo ſucceſsful in this negociation, that he obtained every thing that Lucca deſired, and at the ſame time acquired great eſteem at the imperial court. In proof of this, the empreſs queen made his opinion be aſked concerning the ſtability of the Ceſarean library, and the repairs to be made in it; which he gave in writing, and it was received with thanks, as being very well grounded. Boſcovich.

When he had concluded the affair which had brought him to Vienna, he foreſaw that, for a month or two, the ſnows in the Alps would not allow him to return to Italy. He therefore reſolved to employ that time in completing his ſyſtem of natural philoſophy, on which he had been meditating for the ſpace of thirteen years. He publiſhed his work on that great ſubject in the beginning of the year 1758, in the abovementioned city. We ſhall in the end give an account of that celebrated ſyſtem, and here go on with our narration.

On his return to Lucca, he not only met with the approbation of all he had done for the intereſt of the republic, but alſo the ſenate, in teſtimony of their gratitude, made him preſents, and inrolled him in the number of their nobility, which was the greateſt honour they had in their power to confer on him.

He, who was thus uſeful to foreigners, could not refuſe to be ſerviceable to his own country when an occaſion of being ſo offered itſelf. The Britiſh miniſtry had been informed, that ſhips of war, for the French, had been built and fitted out in the ſea-ports of Raguſa, and had ſignified their diſpleaſure on that account. This occaſioned uneaſineſs to the ſenate of Raguſa, as their ſubjects are very ſea-faring, and much employed in the carrying trade; and therefore it would have been inconvenient for them to have cauſed any diſguſt againſt them in the principal maritime power. Their countryman Boſcovich was deſired to go to London, in order to ſatisfy that court on the abovementioned head; and with this deſire he complied cheerfully on many accounts. His ſucceſs at London was equal to that at Vienna. He pleaded the cauſe of his countrymen effectually there, and that without giving any offence to the French, with whom Raguſa ſoon after entered into a treaty of commerce.

Boſcovich came to London the more willingly, as he was deſirous of converſing with the learned men of Britain. He was received by the preſident and principal members of the Royal Society with great reſpect; and to that great body he dedicated his poem on the eclipſes of the ſun and moon, which was printed on this occaſion at London, in the year 1760. This is one of his works on which he himſelf put the greateſt value, and it has been much eſteemed by the learned. An edition of it was publiſhed at Venice the year following, and a third at Paris, which is the moſt correct; a tranſlation of it into French has likewiſe been publiſhed at Paris. In this very elegant Latin poem he gives an exact compend of aſtronomy, which ſerves as an introduction to the ſubject; he then explains all that belongs to the doctrine of eclipſes, and their uſe in geography; he conſiders the phenomena that are obſerved in the eclipſes of the ſun, and likewiſe of the moon; he propoſes a theorem, which is his own, concerning the diſtribution of light refracted from the atmoſphere of the earth by the ſhadow of the moon, which happens in the lunar eclipfes; he explains the phenomenon of the reddifh colour which often appears in the moon when fhe is eclipfed, of which a fufficient explication had not before been given; this the author draws from the fundamental doctrine of Newton's theory concerning light and colours; and hence takes occafion to give a clear idea of the principal confequences of the faid theory. All this is clothed with a beautiful poetical drefs, and is adorned with pleafant epifodes, not to mention the learned annotations which are fubjoined. This poem was compofed, for the moft part, whilft the author was in journeys, or by way of amufement, when he was obliged to wait for the opportunities of making aftronomical obfervations.

The fellows of the Royal Society invited Bofcovich to accompany fome of their number to America, to obferve the tranfit of Venus, which was to happen in the year 1762; but being otherwife engaged, he could not accept of that invitation. He intended, however, by all means to obferve that remarkable phenomenon, and had fixed on Conftantinople as a proper place for doing fo. He was conducted thither in a Venetian man of war, and much honoured by one of the baylos of that republic, who commanded the veffel; but, to his great regret, they arrived too late. He returned, by land, in the company of the Englifh ambaffador; and a relation of that journey was publifhed in French and afterwards in Italian.

During thefe journeys, Bofcovich's place in the Roman College was well filled by fome of thofe whom he himfelf had trained up in mathematical learning. He was now called by the fenate of Milan to teach mathematics in the univerfity of Pavia, with the offer of a very confiderable falary. He and his fuperiors thought proper to accede to this propofal, and he was received without being fubjected to any previous examination; which was always obferved, excepting in fuch an extraordinary cafe, by the decrees of the univerfity. Here he taught, with great applaufe, for the fpace of fix years, having at the fame time the care of the obfervatory of the Royal College of Brera. About the year 1770, the emprefs queen made him profeffor of aftronomy and optics in the Palatine fchools of Milan; requiring of him, however, that he fhould continue to improve the obfervatory of Brera; which, under his direction, became one of the moft perfect in Europe.

Here he was extremely happy, teaching the fciences, applying to his favourite ftudies, and converfing and correfponding with men of learning and of polifhed manners; when an event happened which caufed to him the moft fenfible affliction. In the year 1773, the fociety to which he belonged, and to which he had been from his youth warmly attached, was, to his great regret and difappointment, abolifhed. They who had been Jefuits were allowed no longer to teach publicly; nor was there any exception made in favour of Bofcovich, neither (fuch was his humour then) would he have accepted of it, though it had been offered him. Propofals were made to him by feveral perfons of diftinction; and, after fome deliberation, he chofe Paris for his place of abode; to which he was induced by the circumftance of his being intimately acquainted with the prime minifter at that court. He had not been many months at Paris when the univerfity of Pifa fent him an invitation to go thither, in order to profefs aftronomy. But the French minifter, underftanding this, declared to the minifter of Tufcany, that it was the intention of his moft Chriftian majefty to make his dominions agreeable to Bofcovich, by giving him liberal appointments. In fact he was foon naturalized, and two large penfions were beftowed on him; the one as an honourable fupport, to the end that he might profecute his fublime ftudies at his eafe and in affluence; the other as a falary annexed to a new office, created in his favour, under the name of *Director of Optics for the Sea Service*, and with the fole obligation of perfecting the lenfes which are ufed in achromatical telefcopes.

At Paris he remained ten years, applying principally to optics, and much regarded, not only by the moft reafonable men of letters, but likewife by the princes and minifters, both of France and of other nations. But the greateft men are not exempt from being envied. Some of the French were difpleafed that a foreigner fhould appear fuperior to themfelves; others of them could not forget that Bofcovich had difcovered and expofed their miftakes. The irreligion which prevailed too much among thofe who bore the name of philofophers, was difagreeable to him. Thefe, and other fuch circumftances, made him wearied of Paris, and he defired to revifit his friends in Italy; for which purpofe he obtained leave of abfence for two years.

The firft place in Italy in which he made any ftay was at Baffano, a town in the territories of Venice. Here, mindful of his obligations, he printed what he had been preparing for the prefs during his ftay in France; and this compofes five volumes in large octavo, and is a treafure of optical and aftronomical knowledge. The fubjects treated of in thefe volumes are as follow: A new inftrument for determining the refracting and diverging forces of diaphonous bodies; a demonftration of the falfehood of the Newtonian analogy between light and found; the algebraic formulæ regarding the focufes of lenfes, and their applications for calculating the fphericity of thofe which are to be ufed in achromatical telefcopes; the corrections to be made in occular lenfes, and the error of the fphericity of certain glaffes; the caufes which hinder the exact union of the folar rays by means of the great burning glaffes, and the determination of the lofs arifing from it; the method of determining the different velocities of light paffing through different mediums by means of two dioptrical telefcopes, one common, the other of a new kind, containing water between the objective glafs and the place of the image; a new kind of objective micrometers; the defects and inutility of a dioptrical telefcope propofed and made at Paris, which gives two images of the fame object, the one direct, the other inverfe, with two contrary motions of moveable objects; maffes floating in the atmofphere, as hail of an extraordinary fize, feen on the fun with the telefcope, and refembling fpots; the aftronomical refractions, and various methods for determining them; various methods for determining the orbits of comets and of the new planet, with copious applications of thefe doctrines to other aftronomical fubjects, and ftill more generally to geometry and to the fcience of calculation; the errors, the rectifications, and the ufe of quadrants, of fextants, of aftronomical fectors, of the meridian line, of telefcopes called the inftruments of tranfits, of the meridian,

meridian, and of the parallactic machine; the trigonometrical differential formulæ, which are of ſo much uſe in aſtronomy; the uſe of the micrometrical rhombus, extended to whatever oblique poſition; the error ariſing from refractions in uſing the aſtronomical ring for a ſundial, and the correction to be made; the appearing and the diſappearing of Saturn's ring; the methods of determining the rotation of the ſun by means of the ſpots, propoſed formerly by the author, and now perfected; the greateſt exactneſs poſſible in determining the length of a pendulum oſcillating every ſecond of middle time by the compariſon of terreſtrial and celeſtial gravity; a compend of aſtronomy for the uſe of the marine, containing the elements of the heavenly motions, and of the aſtronomical inſtruments to be explained to a prince in the courſe of one month; a method for determining the altitude of the poles with the greateſt exactneſs, by means of a gnomon alone, where other inſtruments are not to be had; the determination of the illuminated edge of the moon to be obſerved on the meridian; a method of uſing the retrograde return of Venus to the ſame longitude, for determining the leſs certain elements of her orbit; a method for correcting the elements of a comet, of which the longitude of the node is given, and the inclination of the orbit has been found nearly; another method for the ſame purpoſe, and for finding the elliptical orbit, when the parabolic one does not agree with the obſervations; a method for correcting the elements of a planet by three obſervations; the projection of an orbit inclined in the plane of the ecliptic; the projection of an orbit inclined in any other plane; the calculation of the aberration of the ſtars, ariſing from the ſucceſſive propagation of light; ſome beautiful theorems belonging to triangles, which are of great uſe in aſtronomy, reduced to moſt ſimple demonſtrations.

After having ſeen the impreſſion of theſe five volumes finiſhed, Boſcovich left Baſſano, made an excurſion to Rome, and viſited his old friends there and in other places of Italy. He then took up his abode at Milan, and applied to the reviſing of ſome of his old works, and to the compoſing of new ones. He ſet himſelf particularly to prepare annotations and ſupplements to the remaining two volumes of Stay's Modern Philoſophy, which he had not had time to publiſh ſooner, and which he lived not to publiſh.

He was happy at Milan in the neighbourhood of Brera, where was his favourite obſervatory; and in the company of many friends, who were become the more dear to him by his long abſence from them. But he began to conſider, with grief, that his two years of abſence were drawing to an end. He was very unwilling to leave Italy and return to France. He thought of applying for a prolongation of his abſence; he thought of making intereſt at the Imperial court for ſome honourable commiſſion, which might be a pretext to him for remaining at Milan; but he was afraid that the propoſal of never returning to France might appear indelicate and ungrateful to a nation from which he was receiving conſiderable penſions. He apprehended that thoſe perſons at Paris who had before oppoſed him, would take occaſion to tax him with ingratitude, and that hence his reputation would be tarniſhed. Theſe, and other ſuch thoughts, occaſioned a great perplexity of mind, which was followed by a deep melancholy; and this could not be alleviated by the advice and comfort of his friends, becauſe by degrees he became incapable of hearing reaſon, his ideas being quite confuſed, and his imagination diſordered. To this diſagreeable change the ſtate of his health perhaps contributed. A gout had been wandering for ſome time through his body, and he had caught a ſevere cold; nor would he admit of medical aſſiſtance, of which he had always been very diffident. It may alſo be that his long and intenſe application had hurt the organs of the brain, which in ſome manner are ſubſervient to the uſe of reaſon as long as the ſoul is united to the body. Be that as it will, during the laſt five months of his life this great man, who had been ſo far ſuperior in reaſoning to his ordinary fellow creatures, was much inferior to every one of them who is endued with the right uſe of the underſtanding. He had indeed ſome lucid intervals, and once there were hopes of a recovery; but he ſoon relapſed, and an impoſthume breaking in his breaſt, put an end to his mortal exiſtence. He died at Milan on the 13th of February 1787, in the 76th year of his age.

He was tall in ſtature, of a robuſt conſtitution, of a pale complexion. His countenance was rather long, and was expreſſive of cheerfulneſs and good humour. He was open, ſincere, communicative, and benevolent. His friends ſometimes regretted that he appeared to be too irritable, and too ſenſible of what might ſeem an affront or neglect, which gave himſelf unneceſſary uneaſineſs. He was always unſtained in his morals, obedient to his ſuperiors, and exact in the performance of all Chriſtian duties, as became a Catholic prieſt, and in the obſervance of the particular rules of his order. His great knowledge of the works of nature made him entertain the higheſt admiration of the power and wiſdom of their Creator. He ſaw the neceſſity and advantages of a divine revelation, and was ſincerely attached to the Chriſtian religion, having a ſovereign contempt of the preſumption and fooliſh pride of unbelievers; and being fully perſuaded that we cannot make a more noble uſe of our underſtanding than by ſubjecting it humbly to the authority of the Supreme Being, who knows numberleſs truths far beyond the utmoſt limits of our narrow comprehenſion, and who may juſtly require our belief of any of them that he ſees fit to propoſe to us.

The death of our philoſopher, who truly deſerved that name, was heard with regret by the learned through Europe, and more than ordinary reſpect has been paid to his memory. At Raguſa funeral exequies were performed for him with great ſolemnity by order of the ſenate, who aſſiſted at them in a body; on which occaſion an eloquent oration in praiſe of him was pronounced. By a decree of the ſame ſenate, a Latin inſcription to his honour, engraved on marble, was placed in the principal church of their city. Of this inſcription the following is a copy:

Boscovichii

Boscovichii Elogium Ragusæ,
Marmore Infculptum.
Rogerio. Nicolai. F. Boscovichio,
Summi. Ingenii. Viro. Philofopho. Et. Mathematico. Præftantiffimo
Scriptori. Operum. Egregiorum
Res. Phyficas. Geometricas. Aftronomicas
Plurimis. Inventis. Suis. Auctas. Continentium
Celebriorum. Europæ. Academiarum, Socio
Qui. In. Soc. Jefu. Cum. Effet. Ac. Romæ. Mathefim. Profiteretur
Benedicto. XIV. Mandante
Multo. Labore. Singulari. Induftria
Dimenfus. Eft. Gradum. Terreftris. Circuli
Boream. Verfus. Per. Pontificiam. Ditionem. Tranfeuntis
Ejufdemque. Ditionis. In. Nova. Tabula. Situs. Omnes. Defcripfit.
Stabilitati. Vaticano. Tholo. Reddundæ
Portubus. Superi. Et. Inferi. Maris. Ad. Juftam. Altitudinem. Redigendis
Reftagnantibus. Per. Campos. Aquis. Emittendis. Commonftravit. Viam
Legatus. A. Lucenfibus. Ad. Francifcum. I. Cæfarem. M. Etruriæ. Ducem
Ut. Amnes. Ab. Eorum. Agro. Averterentur. Obtinuit
Merito. Ab. Iis. Inter. Patricios. Cooptatus
Mediolanum. Ad. Docendum. Mathematicas. Difciplinas, Evocatus
Braidenfem. Extruxit. Inftruxitque. Servandis. Aftris. Speculam
Deletæ. Tum. Societati. Suæ. Superftes
Lutetiæ. Parifiorum. Inter. Galliæ. Indigenas. Relatus
Commiffum. Sibi. Perficiundæ. In. Ufus. Maritimos.
Opticæ. Munus. Adcuravit
Ampla. A. Ludovico XV. Rege. Xmo. Attributa. Penfione
Inter. Hæc. Et. Poefim. Mira. Ubertate. Et. Facilitate. Excoluit
Doctos. Non. Semel. Sufcepit. Per. Europam. Peregrinationes
Multorum. Amicitias. Gratia. Virorum. Principum. Ubique. Floruit
Ubique. Animum. Chriftianarum. Virtutum
Veræque. Religionis. Studiofum. Præ-fe-tulit
Ex. Gallia. Italiam. Revifens. Jam. Senex
Cum. Ibi. In. Elaborandis. Edendisque. Poftremis. Operibus
Plurimum. Contendiffet. Et. Novis. Inchoandis. Ac. Veteribus. Abfolvendis
Sefe. Adcingeret
In. Diuturnum. Incidit. Morbum. Eoque. Obiit. Mediolani
Id. Feb. An. MDCCLXXXVII. Natus. Annos LXXV. Menfes. IX. Dies II.
Huic. Optime. Merito. De. Republica. Civi
Quod. Fidem. Atque. Operam. Suam. Eidem. Sæpe. Probaverit
In. Arduis. Apud. Exteras. Nationes
Bene. Utiliterque. Expediundis. Negotiis
Quodque. Sui. Nominis. Celebritate. Novum. Patriæ. Decus. Adtulerit
Poft. Funebrem. Honorem. In. Hoc. Templo. Cum. Sacro. Et. Laudatione
Publice. Delatum
Ejufdem Templi Curatores
Ex. Senatus. Confulto
M. P. P.

This infcription was compofed by his friend and countryman the celebrated poet Benedict Stay. Zamagna, another of his countrymen, who had likewife been his fellow jefuit, publifhed a panegyric on him in elegant Latin. A fhort encomium of him is to be found in the *Eftratto della Literatura Europea;* and another, in form of a Letter, was directed by M. de la Lande to the Parifian journalifts, and by them given to the public. A more full eulogium has been written by M. Fabroni; and another is to be met with in the journal of Modena; a third was publifhed at Milan by the Abbate Ricca; and a fourth at Naples by the Dr Julius Bajamonti, of which a fecond edition was made in the year 1790. Of this laft chiefly ufe has been made here.

But what muft fecure to Bofcovich the efteem of pofterity are his works, of the greater part of which we have already taken notice. We have mentioned, 1. His Elements of Mathematics, with his Treatife on Conic Sections; 2. His many Differtations publifhed during his profefforfhip in the Roman college; 3. His account of his Survey of the Pope's Eftate; 4. His Theory of Natural Philofophy; 5. His Poem on the Eclipfes; 6. His five volumes printed at Baffano.

To thefe we may add his hydrodynamical pieces. He had made a particular ftudy of the force of running water, and of its effects in rivers; and he was often confulted concerning the beft means to prevent rivers from corroding their banks, and from overflowing the neighbouring plains, which often happens in Italy, where the Alps and Apennines pour down fo many impetuous ftreams. He gave a writing on the damages done by the Tiber at Porto Felice; another on the project of turning

turning the navigation to Rome from Fiumicino to Maccareſe; a third on two torrents in the territory of Perugia; a fourth on the bulwarks on the river Panaro; a fifth on the river Sidone, in the territory of Placentia; a ſixth on the entrance into the ſea of the Adige. He wrote other ſuch works on the bulwarks of the Po; on the harbours of Ancona, of Rimini, of Magna Vacca, and Savona, beſides others, almoſt all which were printed. He had likewiſe received a commiſſion from Clement XIII. to viſit the Pomptin lakes, on the draining of which he drew up his opinion in writing, to which he added further elucidations at the deſire of Pius VI. On theſe occaſions he ſhowed how uſeful philoſophy may be to the public; and of this he gave another proof when it was referred entirely to his judgment to determine whether or not the cupola of the cathedral of Milan could bear the weight of a very high ſpire, which it was propoſed to raiſe on it, and which was actually erected according to his directions.

His application to obſtruſe ſtudies did not hinder him from paying ſome attention to what is more pleaſant. We have ſeen that he was a poet: he was alſo well acquainted with hiſtory, and particularly with that of the Greeks and Romans, and with their antiquities. He wrote a diſſertation on an ancient villa diſcovered in his time upon the Tuſculan Hill, and on an ancient dial found there, which diſſertation was publiſhed at Rome in a literary journal. He wrote likewiſe three letters on the obeliſk of Cæſar Auguſtus, two of which were printed with his own name, and the third under the name of another.

Beſides all theſe works that were given to the public in his lifetime, many writings of his remained in manuſcript in the hands of different perſons, and particularly with his friend M. Gaetani, and many more with Count Michael de Sorgo, a Raguſan ſenator, who inherited all his papers that were in his own hands at his death. Theſe, it is hoped, have either been already ſent to the preſs or will be ſo; as nothing came from the pen of Boſcovich which was not uſeful and deſerving to ſee the light.

It now remains that we give an account of his Theory of Natural Philosophy; and in doing this we ſhall, in the *firſt* place, lay before our readers a view of this ſyſtem. We ſhall, in the *ſecond* place, relate, from what principles and by what ſteps it was deduced. We ſhall, *thirdly*, take notice of the principal objections made to it, and ſubjoin the author's anſwers to the ſame. We ſhall, *finally*, ſhew how happily it may be applied to explain the general properties of matter, as well as the particular qualities of all the claſſes of bodies, which have been examined according to what it teaches.

I View of Boſcovich's ſyſtem of natural philoſophy.

1. In this ſyſtem, therefore, the whole maſs of matter, of which all the bodies of the univerſe are compoſed, conſiſts of an exceeding great, yet ſtill finite, number of ſimple, indiviſible, inextended, atoms. Theſe atoms are endued with *repulſive* and *attractive* forces, which vary and change from the one to the other, according to the diſtance between them, in the following manner: In the leaſt and innermoſt diſtances they repel one another; and this repulſive force increaſes beyond all limits as the diſtances are diminiſhed, and is conſequently ſufficient for extinguiſhing the greateſt velocity, and for preventing the contact of the atoms. In the ſenſible diſtances, this force is *attractive*, and decreaſes, at leaſt ſenſibly, as the ſquares of the diſtances increaſe, conſtituting univerſal gravity, and extending beyond the ſphere of the moſt diſtant comets. Between this innermoſt repulſive force and the outermoſt attractive one, in the inſenſible diſtances, many varieties and changes of the force, or determination to motion, take place: for the repulſive force decreaſes as the diſtance increaſes. At a certain diſtance it comes to vaniſh entirely; and, when that diſtance is increaſed, attraction begins, increaſes, becomes leſs, vaniſhes; and the diſtance becoming greater, the force becomes repulſive, increaſes, leſſens, and vaniſhes as before. Many varieties and changes of this kind happen in the inſenſible diſtances, ſometimes more rapidly, ſometimes more ſlowly, and ſometimes one of the forces may come to nothing, and then return back to the ſame without paſſing to the other. For all this there is full room in the diſtances that are inſenſible to us, ſeeing the leaſt part of ſpace is diviſible *in infinitum*. Beſides theſe repulſive and attractive forces, our atoms have that *vis inertiæ* which is admitted by almoſt all modern philoſophers. Theſe atoms, endued with theſe forces, conſtitute the whole ſubſtance of Boſcovich's ſyſtem; which, however ſimple and ſhort it may appear to be, has numberleſs and very wonderful conſequences, as we ſhall ſee afterwards. But, that a more clear idea of the whole theory may be eaſily formed, we ſhall make uſe of a geometrical figure well accommodated to that purpoſe. The right line C′AC is an axis, from which, in the point A, is drawn the right line AB at right angles. AB is conſidered as an *aſymptote*; on each ſide of which the two curves, quite ſimilar and equal, DEFGHIKLMNOPQRSTVU on the one ſide, and D′E′F′G′ on the other, are placed. Now, if ED be ſuppoſed to be *aſymptotical*, and be extended, it will ſtill approach to BA, but will never come to touch it. This curve ED approaches to the axis C′C, comes to it in E, cuts it and departs to a certain diſtance in F, after which it again approaches the ſame axis and cuts it in G. In like manner it forms the arches GHI, IKL, LMN, NOP, PQL. At laſt it goes on in T*psV*, which is aſymptotical, and approaches to the axis; ſo that the diſtances from it are in a duplicate reciprocal proportion of the diſtances from the right line BA. If from any points of the axis, as from *a*, *b*, *d*, we raiſe the perpendiculars *a g*, *b r*, *d h*, the ſegments of the axis A *a*, A *b*, A *d*, are called *abſciſſes*, and repreſent the diſtances of any two points of matter from one another; and the perpendiculars *a g*, *b r*, *d h*, are called *ordinates*, and exhibit the repulſive or attractive force, according as it lies on the ſame ſide with D, or on the other ſide of the axis.

5 The whole theory expreſſed by a geometrical curve. Plate VI. fig. 6.

Now it is evident that, in this form of the curve line, the *ordinate a g* will be increaſed beyond whatever limits, if the abſciſs A *a* be leſſened likewiſe beyond whatever limits; that if this abſciſs be increaſed to A *b*, the *ordinate* will be leſſened, and will paſs into *b r*, which will ſtill be leſſened as it approaches from *b* to E, where it will come to nothing; that then, the axis being increaſed to A *d*, the *ordinate* will change its direction into *b h*, and, on the oppoſite ſide, will increaſe at firſt to to F, then it will decreaſe through *i l* as far as G, where it will again vaniſh, and again change its direction in *m n* to the former, and that, in the ſame manner, it will vaniſh and change its directions in all the ſections I, L, N, P, R, until the *ordinates o p, v s*, become of a conſtant direction, and decreaſe, at leaſt ſenſibly, in a reciprocal duplicate propoition of the abſciſſes A *o*, A *v*. Wherefore, it is manifeſt, that by ſuch a curve are expreſſed our forces; at firſt *repulſive*, and increaſing beyond all limits, the diſtances being leſſened in like manner, and which decreaſe, the ſame diſtances being augmented; then vaniſh, change their direction, and become *attractive;* vaniſh again, and become *repulſive;* till at laſt, at ſenſible diſtances, they remain on the ſide oppoſite to D, and are *attractive* in a duplicate reciprocal proportion of the diſtances.

We may alſo obſerve, that the *ordinates* may increaſe or decreaſe rapidly, as in *y v, z t*, or ſlowly, as in *v x, z c;* and, conſequently, that the forces may increaſe or decreaſe in like manner. We may add, that the curve may return back without interſecting, or even touching, the axis, as in *f*, and may return after having touched the ſame axis.

Although this curve expreſſes very clearly the *repulſive* and *attractive* forces of our ſyſtem, yet, at firſt ſight, it may appear to be a complicated irregular line. But the author ſhews that his curve is uniform and regular, and may be expreſſed by one uniform algebraical equation; which it will be neceſſary for us to conſider, in order to give ſatisfaction to our readers, and to do juſtice to the theory.

3 The ſimplicity of this curve proved.

Wherefore, from what we have ſeen, the curve muſt have the following ſix conditions: *1ſt*, It muſt be regular and ſimple, and not compoſed of an aggregate of arches of different curves. *2dly*, It is neceſſary that it cut the axis C′AC in certain given points only, at two equal diſtances on each ſide AE′, AE, AG′, AG, and ſo on. *3dly*, That to every *abſciſs* an *ordinate* correſpond. *4thly*, That if we take equal *abſciſſes* on each ſide of A, they have equal *ordinates*. *5thly*, That the right line AB be an *aſymptote*, the area BAED being aſymptotical, and conſequently infinite. *6thly*, That the arches terminated by any two interſections may be varied at pleaſure, and recede to any diſtance from the axis C′AC, and approach at pleaſure to whatever arches of whatever curves, cutting them, touching them, or oſculating them, in any place and manner.

In order to find an algebraical formula expreſſing the nature of a curve line that would anſwer all theſe ſix conditions, let us call the ordinate *y*, the abſciſs *x*, and let it be made $xx=z$. Then let us take the values of all the abſciſſes AE, AG, AI, &c. with the negative ſign, and let the ſum of the ſquares of all theſe values be called *a*, the ſum of the products of every two ſquares *b*, the ſum of the products of every three, *c*, and ſo on; and let the product of all of them be called *f*, and the number of the ſame values *m*. All this being ſuppoſed, let it be made $z^m + a z^{m-1} + b z^{m-2} + c z^{m-3}$ &c. $+ f = \text{P}$. If we ſuppoſe P equal to nothing, it is clear that all the roots of that equation will be real and poſitive; that is, the ſquares only of the quantities AE, AG, AI, &c. which will be the values of *z;* and therefore, as it is $x = \pm\sqrt{z}$, becauſe it is $xx = z$, it is likewiſe clear that the values of *x* will be both AE, AG, AI, poſitive, and A′E′, A′G′, &c. negative.

This being done, let any quantity be multiplied by *z*, providing it hath no common diviſor with P, leſt *z* vaniſhing, it likewiſe might vaniſh; and having made *x* an infiniteſim of the firſt order, it may become an infiniteſim of the ſame, or of a lower order, as will be whatever formula $z^r + g z^{r-1} + h z^{r-2}$ &c. $+ l;$ which, being ſuppoſed equal to *o*, may have as many imaginary, and as many and whatever real roots, providing none of them be thoſe of AG, AE, AI, &c. either poſitive or negative. If then the whole formula be multiplied by *z*, let this product be called Q.

If we make $\text{P}-\text{Q}\,f = o$, this equation will ſatisfy the five firſt conditions above mentioned; and the value of Q being properly determined, the ſixth condition alſo may be complied with.

For, in the firſt place, ſeeing the value P and Q are made equal to *o*, they have no common root, and therefore no common diviſor. Hence this equation cannot be reduced to two by diviſion; and therefore it is not compoſed of two equations, but is ſimple, and therefore exhibits one ſimple continued curve, which is not compoſed of any others; which is the firſt condition.

Secondly, The curve thus expreſſed will cut the axis C′AC in all the points E′, G, I, &c. G′, &c. and in them only: for it will cut that axis only in thoſe points in which $y = o$, and in all of them. Moreover, where it will be $y = o$, it will alſo be $\text{Q}\,y = o;$ and therefore, becauſe of $\text{P}-\text{Q}\,y = o$, it will be $\text{P} = o$. But this will happen only in thoſe points in which *z* will be one of the roots of the equation $\text{P} = o;$ that is, as we have ſeen above, in the points E, G, I, or E′, G, &c.: wherefore, only in thoſe points will *y* vaniſh, and the curve cut the axis. Again, that the ſame curve will cut it in all theſe points, is clear from this, that in them all it will be $\text{P} = o$. Wherefore it will likewiſe be $\text{Q}\,y = o;$ but it will not be $\text{Q} = o$, ſeeing there is no common root of the equations $\text{P} = o$ and $\text{Q} = o:$ it muſt therefore be $y = o$, and the curve will cut the axis: and thus the ſecond condition is ſatisfied.

Beſides, whereas it is $\text{P}-\text{Q}\,x = o$, it will be $y = \frac{\text{P}}{\text{Q}}$: the abſciſs *x* being, however, determined, we will have a certain determinate quantity for *z;* and thus P, Q, will be determined, and the only two of the kind. Wherefore *y* alſo will be ſole and determined; and therefore to every abſciſs *z*, one only ordinate *y* will correſpond. This is the third condition.

Again, whether *x* be aſſumed poſitive or negative, providing it be of the ſame length, ſtill the value $z = xx$ will be the ſame, and therefore the values of both P and Q will be the ſame: wherefore *y* will ſtill be the ſame. Taking, therefore, equal abſciſſes *z* on both ſides of A, the one poſitive, the other negative, they will have equal correſponding ordinates. This is the fourth condition.

If *x* be leſſened beyond all limits, whether it be poſitive or negative, *z* likewiſe will be leſſened beyond all limits, and will become an infiniteſim of the ſecond order: wherefore, in the value P, all the terms will decreaſe *in infinitum*, except in *y*, becauſe all the reſt beſides it are multiplied by *z;* and thus the value P will be as yet finite. But the value Q, which has the formula

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mula multiplied by z, will be lessened *in infinitum*, and will be an infinitesim of the second order: therefore $\frac{P}{Q} = y$ will be augmented *in infinitum*, so as to become an infinite of the second order. Wherefore the curve will have the right line AB for an *asymptote*, and the area BAED will increase *in infinitum*: and if the ordinate y be assumed positive on the side AB, and express repulsive forces, the asymptotic arch ED will lie on the same side AB. This is the fifth condition.

Now the value Q can be varied in infinite manners; so that still the conditions for which it was assumed may be fulfilled; and therefore the arches of the curve intercepted by the intersections may be varied in infinite manners; so that the first five conditions of the curve may be implemented: whence it follows, that they may be so varied that the sixth condition may also be answered.

For if there be given, however many, and whatever arches of whatever curve, providing they be such that they recede always from the asymptote AB, and thus no right line parallel to that asymptote cut these arches in more than one point, and in them let there be taken as many points as you please, and as near one another; it will be easy to assume such a value of P, that the curve shall pass through all these points, and the same may be varied infinitely; so that still the curve will pass through all the same points.

Let the number of points assumed be what you please $= r$, and, from every one of such points, let right lines be drawn parallel to AB, as far as the axis C'AC, which must be the ordinates of the curve that is sought; and let the abscisses from A to the said ordinates be called M^1, M^2, M^3, &c. and the ordinates $'N^1$, $'N^2$, $'N^3$, &c. Let there now be taken a certain quantity $Az^r + Bz^{r-1} + Cz^{r-2} + Gz$, and let this quantity be supposed equal to R. Then let another such quantity T be assumed, so that z vanishing, whatsoever term of it may vanish, and so that there be no common divisor of the value of P, and of the value of R+T; which may be easily done, seeing all the divisors of the quantity P are known. Let it now be made $Q = R + T$, and then the equation of the curve will be $P - Ry - Ty = o$. After this, let there be put in the equation M1, M2, M3, successively for x, and N1, N2, N3, &c. for y; we will have a number of equations equal to r, which will contain the values of A, B, C. . . . . G, each of them of one dimension, in number likewise equal to r; and, besides, we will have the given values of M1, M2, &c. N1, N2, N3, &c. and the arbitrary values which in T are the coefficients of z.

By these equations, which are in number r, it will be easy to determine the values A, B, C, ... G, which are likewise in number r, assuming the first equation, according to the usual method, the value A, and substituting it in all the following equations; by which means the equations will become $r-1$. These, again, by throwing out the value B, will be reduced to $r-2$, and so on until we come to one only; in which the value Q being determined by means of it, going back, all the preceding values will be determined, one by each equation.

The values A, B, C, ... G, being in this manner determined, in the equation $P - Ry - Ty = o$, or $P - Qy = o$, it is clear that, the values M1, M2, M3, &c. being successively put for x, the values of the ordinate y must successively be N1, N2, N3, &c. and, therefore, that the curve must pass through these given points in those given curves; and still the value Q will have all the preceding conditions. For z being lessened beyond whatever limits, every one of its terms will be lessened beyond whatever limits, seeing all the terms of the value of T are lessened which were thus assumed, and likewise the terms of the value R are lessened, which are all multiplied by z; and, besides this, there will be no common divisor of the quantities P and Q, seeing there is none of the quantity P and R+T.

But if two of the nearest of the points assumed in the arches of the curves, on the same side of the axis, be supposed to accede to one another beyond whatever limits, and at last to coincide, which will be done by making two M equal, and likewise two N equal; then the curve sought will touch the arch of the given curve; and if three such points coincide, they will *osculate* it: nay, as many points as we please may be made to meet together where we please; and thus we may have *osculations* of what order we please, and as near one another as we please, the arch of the given curve approaching as we please, and at whatever distances we please, to whatever arches of whatever curves, and yet still preserving all the six conditions required for expressing the law of the repulsive and attractive forces. And whereas the value of T can be varied in infinite manners, the same may be done in an infinite number of ways; and therefore a simple curve, answering the given conditions, may be found out in an infinite number of ways. *Q. E. F.*

What we have said will, we hope, satisfy our readers, and especially those of them who are in the least acquainted with high geometry, that Boscovich's curve is simple, regular, and uniform; and that therefore the law of repulsive and attractive forces, expressed by it, is simple and regular.

II. If this system were a mere hypothesis, it would still be very ingenious, and, from what we shall say afterwards, would still be well adapted for explaining the phenomena of nature. But its author is far from looking upon it as an arbitrary supposition; he assures us that he was led to it by a chain of strict reasoning, from evident principles. We shall now give an abridgement of that reasoning from his Dissertations on the Law of *Continuity*, and from his Theory of Natural Philosophy.

4 Proofs of the theory.

He tells us, then, that in the examination of Leibnitz's opinion of the *vires vivæ*, he came to consider the collision of bodies, and took for example two equal bodies, A proceeding with six degrees of velocity, and B following with the velocity of 12: after the collision, they proceed jointly with the common velocity 9. Now, in the moment of collision, it either happens that A passes abruptly from the velocity 6 to the velocity 9, without passing through the velocity 7 and 8, and B passes from 12 of velocity to 9, without passing through 11 and 10; or else there must be some cause which accelerates the one and retards the other before they come to contact. In the first case, the law of continuity is broken; in the second, immediate contact of bodies would be rejected. Maclaurin saw this difficulty, and mentioned it in his work on *Newton's Discoveries*, l. 1. c. 4. He, not having courage to recede from the common opinion, allowed a breach, in such cases, of the law of continuity; but Boscovich maintains

Boscovich's System of Natural Philosophy. maintains the universality of the law of continuity; and holds, that no bodies touch one another really and mathematically, but only physically and sensibly to us.

5
The law of continuity proved. *The law of continuity is that by which variable quantities, passing from one magnitude to another, pass through all the intermediate magnitudes, without ever abruptly passing over any of them.* This law Boscovich proves to be universal, in the first place, from induction. Thus we see that the distances of two bodies can never be changed without their passing through all the intermediate distances. We see the planets move with different velocities and directions; but in this they still observe the law of continuity. In heavy bodies projected, the velocity decreases and increases through all the intermediate velocities; the same happens with regard to elasticity and magnetism. No body becomes more or less dense without passing through the intermediate densities. The light of the day increases in the morning and decreases at night through all the intermediate possible degrees. In a word, if we go through all nature, we shall see the law of continuity strictly take place, if all things be rightly considered. It is true, we sometimes make abrupt passages in our minds; as when we compare the length of one day with that of another immediately following, and say that the second is two or three minutes longer or shorter than the former, passing all at once, in our way of speaking, round the globe; but if we take all the longitudes, we shall find days of all the intermediate lengths. We likewise sometimes confound a quick motion with an instantaneous one: thus, we are apt to imagine that the ball is thrown abruptly out of the gun; but, in truth, some space of time is required for the gradual inflammation of the powder, for the rarefaction of the air, and for the communication of motion to the ball. In like manner, all the objections made against the law of continuity may be solved to satisfaction.

6
A breach of this law impossible. But however strong this argument from judgment may appear to be, yet Boscovich goes farther, and maintains, that a breach of this law, in the proper cases, is metaphysically impossible. This argument he draws from the very nature of continuity. It is essential to continuity that, where one part of the thing *continued* ends and another part begins, the limit be common to both. Thus, when a geometrical line is divided into two, an indivisible point is the common limit of both: thus time is *continued*; and therefore where one hour ends, another immediately begins, and the common limit is an indivisible instant. Now, as all variations in variable quantities are made in time, they all partake of its continuity; and hence none of them can hasten by an abrupt passage from one magnitude to another, without passing through the intermediate magnitudes. As we cannot pass from the sixth hour to the ninth without passing through the seventh, and eighth; because, if we did, there would be a common limit between the sixth hour and the ninth, which is impossible; so likewise you cannot go from the distance 6 to the distance 9 without passing through the distances 7 and 8; because, if you did, in the instant of passage you would be both at the distance 6 and at the distance 9, which is impossible. In like manner, a body that is condensed or rarefied cannot pass from the density 6 to the density 9, or *vice versa*, without passing through the densities 7 and 8; because, in the abrupt passage, there would be two densities, 6 and 9, in the same instant. The body must pass through all the intermediate densities. This it may do quickly or slowly, but still it must evidently pass through them all. The like may be said of all variable quantities; and thence we may conclude, that the law of continuity is universal.

7
Objections to this law answered. But, in creation, is there not an instance of an abrupt passage from *non-existence* to *existence*? No, there is not; because before existence a *being* is nothing, and therefore incapable of any state. In creation, a *being* does not pass from one state to another abruptly; it passes over no intermediate state: it begins to exist and to have a state, and existence is not divisible. Do we not, at least, allow of an abrupt passage from repulsive to attractive forces in our very theory itself? We do not. Our repulsive forces diminish, through all the intermediate magnitudes, down to nothing; through which, as a limit, they pass to attraction. In the building of a house or ship, neither of them is augmented abruptly; because the additions made to them are effected solely by a change of distances between the parts of which they are composed; and all the intermediate distances are gone through. The like may be said of many other such cases; and still the law of continuity remains firm and constant.

8
Impossibility of contact between bodies. Let us now apply this doctrine to the case above mentioned of the collision of two bodies. We say that the body B cannot pass from the velocity 6 to the velocity 9 without passing through the velocities 7 and 8; because if it did, in the moment of contact of the two superficies it would have the velocities 6 and 9. Now a body cannot have two velocities at the same instant. For if it had two *actual* velocities at the same time, it would be in two different places at the same time: if it had two different *potential* velocities or determinations to a certain velocity, it would be capable of being, after a given time, in two places at once—both which are impossible. It is therefore necessary that it go through the velocities 7 and 8, and through all the parts of them. What we have said of the bodies A and B may be said universally of all bodies. Therefore no two bodies in motion can come to immediate contact; but their velocities must undergo the successive necessary change before contact. And as the velocity to be extinguished may be increased beyond all limits, an adequate cause to effect this extinction must be admitted.

9
Repulsive forces. This naturally leads us to the interior repulsive forces of our system. For the cause retarding the one body and accelerating the other must be a *force*, because by this we mean a determination to motion; and it must be repulsive, because it acts *from* the body; and it must increase beyond all limits, seeing the velocity of the incurring bodies may be increased beyond all limits. It must likewise be mutual, because action and reaction are always equal, as may be proved by induction.

10
Inextended atoms. From these repulsive forces Boscovich deduces the inextension of his atoms: for this repulsion being common to all matter, must cause a perfect simplicity in the first elements of body. If these elements were extended, and consequently compounded of particles of an inferior order, these particles might possibly be separated, and then they might meet, and an abrupt passage from one velocity to another might take place, which we have excluded from nature by induction, and by a positive argument.

Besides

Beſides this, by rejecting the extenſion of the firſt elements of matter, we get rid at once of all the difficulties ariſing from continued extenſion in body, which have always perplexed the philoſophers, and have never been ſatisfactorily explained. If theſe elements of matter are extended, each of them may be divided *in infinitum*, and each part may ſtill be divided *in infinitum*. Can this diviſion be actually made by the power of God or not? Can there be one *infinite* in number greater than another? Can there be a *compound* without a *ſimple* of the ſame kind? Theſe difficulties regard not ſpace, which is no real being; but they would regard matter if it had continued extenſion. All theſe perplexities are removed by maintaining, as Boſcovich does, that the firſt elements of bodies are perfectly ſimple, and therefore inextended (A).

11 Attractive forces.

With regard to the exterior attractive forces of our ſyſtem, there can be no queſtion; ſeeing they conſtitute univerſal gravity, the effects of which we ſee and feel every day. But between the interior repulſive and exterior attractive forces we muſt admit many tranſitions from repulſion to attraction, and from attraction back to repulſion, in inſenſible diſtances, which are indicated to us by coheſion, fermentation, evaporation, and other phenomena of nature. And thus we have given, in ſhort, Boſcovich's proofs of his whole ſyſtem.

12 Objections to the ſyſtem anſwered.

III. This ſyſtem has been well received by the learned in Europe, and has contributed much to render its author famous; yet many objections againſt it have been propoſed. Some are ſtartled at the rejection of all immediate contact between bodies; and indeed Boſcovich is perhaps the firſt of mankind who advanced that opinion; but he allows that bodies approach ſo near to one another, as to leave no ſenſible diſtance between them: and his repulſive forces make the ſame impreſſion on the nerves of our ſenſes as the ſolid bodies could do. And therefore this opinion of his, however new, is nowiſe contrary to the teſtimony of our ſenſes. He only removes a prejudice which was before univerſal.

Some ſay, that they cannot even form an idea of an inextended atom, and that Boſcovich reduces all matter to nothing: but certainly extenſion is not neceſſary for the eſſence of a *being*, as muſt be allowed by all thoſe who hold that ſpirits are inextended. Becauſe all the bodies that fall under our ſenſes are extended, we are apt to look upon extenſion as eſſential to matter: but this error may be corrected by reflection, and an idea of an inextended atom may be formed, by conſidering the nature of a mathematical point, which is the limit of any two contiguous parts of a line.

Others again have ſaid, that if the elements of matter were void of extenſion, there would be no difference between body and ſpirit. But the difference between body and ſpirit does not conſiſt in the having or not having extenſion; but in this, that the atoms of matter are endued with repulſive and attractive forces, which ſpirit has not; and ſpirit has a capacity of thought and volition which bodies have not.

We may here obſerve, that among the ancients Zeno, and among the moderns Leibnitz, held, that the firſt principles of matter are inextended points. But both held this opinion with the inconſiſtency, that they maintained the continued extenſion of bodies, without ever being able to ſhew how continued extenſion could ariſe from inextended elements.

It has been objected likewiſe, that our repulſive and attractive forces are no better than the occult qualities of the Peripatetics. The like objection has been made to Newton's attraction: but the anſwer is eaſy. We obſerve the effects, and take notice of them; for them we muſt admit an adequate cauſe, without being able to determine, whether that cauſe is an immediate law of the Creator, or ſome mediate inſtrument that he makes uſe of for that purpoſe.

Some are unwilling to give up the idea of motion occaſioned by immediate impulſe: but can they ſhow a good reaſon why *ſome diſtance* may not occaſion motion as well as *no diſtance?* Theſe are the principal objections that have been made againſt the Boſcovichian ſyſtem.

IV. Before we proceed to the explication of phenomena by means of our theory, we muſt advert, that in the curve expreſſing this theory, the abſciſſes denote the diſtances between the atoms that are under conſideration; the ordinates give the preſent *force*, and the area between any two of theſe ordinates gives the ſquare of the velocity generated between them: the arches are either repulſive or attractive, according as they fall upon the ſame ſide with the aſymptotic curve EG, or on the oppoſite ſide. 13 Obſervations with regard to the curve.

We muſt, in the next place, conſider the paſſages from one ſide of the axis to the other. Sometimes the paſſage is from repulſion to attraction, at other times from attraction to repulſion. The firſt are called *limits of coheſion*, becauſe a particle removed from that limit returns back to it; becauſe if it is removed to a greater diſtance it is attracted back, and if it is removed nearer it is repelled back. The ſecond are called *limits of noncoheſion;* becauſe a particle removed thence to a greater diſtance is repelled ſtill further, and if removed nearer it is attracted ſtill nearer. Of the firſt kind are E, I, N; of the ſecond are G, L. Likewiſe, when the curve touches the axis, it may either be an attractive part of the curve, or a repulſive part. Theſe limits may be nearer one another, or farther away; and the limits of coheſion may be ſtronger or weaker, according as the forces near them are greater or leſs. 14 Limits of coheſion, &c.

Boſcovich conſiders minutely the effects of theſe varieties of limits and forces; firſt with regard to two points, then with regard to three and four, demonſtrating

(A) If a particle of matter is not extended, in what reſpect does it differ from a point of ſpace? Says Boſcovich, it is endowed with attractive and repulſive forces. What is this *it* before it is thus endowed? Does it *then* differ from a point of ſpace? We can form no notion of any ſuch difference. But a point of ſpace, conſidered as an individual, is diſtinguiſhed from another individual only by its ſituation; it is therefore immoveable, but matter is moveable. Have theſe forces, then, which make matter an object of ſenſe, any ſubſtratum, any thing in which they are inherent as qualities? What are the things which theſe qualities diſtinguiſh from each other as individuals?

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ing the great variety of forces that may ariſe from theſe various combinations, and ſhewing how from ſimple atoms a great variety of bodies may be formed. He particularly proves, that, from the various poſition of the atoms, they may either always repel or always attract other atoms, or do neither. Four atoms may form a pyramid, eight may form a cube, and ſo on, in regular or irregular figures. Particles of the loweſt order may compoſe particles of a ſecond order, theſe of a third, and ſo on. This he exemplifies by a library, in which the letters of the books ſhould be compoſed of ſmall points, placed ſo near one another as that their diſtance could not be perceived without the help of a microſcope. Here the letters will be compoſed of points, the words of letters, and all the variety of books on different ſubjects, and in different languages, would be compoſed of words. In like manner, he ſays, his atoms may compoſe particles, theſe may compoſe others of different orders, of which may be formed various bodies, animal, vegetable, air, fire, water, earth, whole planets, central bodies, the whole univerſe.

15 Compoſition of bodies.

16 The ſyſtem applied, to account for

But to be more particular, our author proceeds to apply his ſyſtem to mechanics, and demonſtrates, with his uſual accuracy and originality, what regards the centre of gravity, action and reaction, the colliſion of bodies, the centre of equilibrium, and of oſcillation.

Of theſe ſubjects he treats in the ſecond part of his *Theoria;* to which we muſt refer our learned readers, as it cannot be eaſily abridged.

In the third part of the ſame work he proceeds to account for the general properties of matter, beginning with *impenetrability*. This naturally flows from the interior repulſive forces, which prevent the compenetration of any two points. Beſides, as the leaſt part of ſpace is diviſible *in infinitum*, it is infinitely improbable that any two points ſhould ever meet, ſeeing they have an infinite number of other lines in which they can move, beſides the one that would join them. But an apparent compenetration might take place, if one body ſhould meet another with ſo great a velocity as not to give time to the repulſive forces to exert their action. Thus an iron ball may paſs ſwiftly near a ſtrong magnet, without being ſenſibly attracted by it, which it would be if it moved more ſlowly. Thus a ball from a gun paſſes through a piece of wood ſo quickly as to make only a paſſage for itſelf, without breaking the neighbouring parts, which it would do were its motion more ſlow. Of this kind of compenetration we have a reſemblance in *light* paſſing through pellucid bodies.

17 Impenetrability,

18 Coheſion,

Coheſion has never been well accounted for by any philoſopher before Boſcovich. From his ſyſtem it follows naturally, as we have ſeen in ſpeaking of the limits of coheſion; for when two atoms are placed in a limit of that kind, they neceſſarily cohere more or leſs ſtrongly, according as that limit is ſtronger or weaker. From the coheſion of the atoms ariſes the coheſion of compounded particles, and conſequently of ſenſible bodies.

19 Extenſion,

From the coheſion of particles ariſes the extenſion of bodies; becauſe there muſt always be ſpace between the particles. However, it is evident that this extenſion is not formed of a continuity of matter; though it may appear to be ſo to our ſenſes, which cannot perceive the ſmall intermediate diſtance between the parts of ſome bodies, and much leſs the diſtances between the ſimple elements of which they are compoſed.

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20 Figure,

Extenſion of bodies involves *figurability;* becauſe every extended body muſt be ſurrounded by ſome ſuperficies of a certain figure; but the ſuperficies of bodies can never be accurately determined, upon account of the inequalities in all ſurfaces. We take however, that figure for the true one which the body appears to come neareſt. Thus we call the earth a globe, notwithſtanding the hills and valleys that are on it.

Under the ſame figure, and of the ſame magnitude, there may be contained very different quantities of matter. Hence we come to the conſideration of *denſity*. That body is moſt denſe which contains in the ſame ſpace the greateſt number of atoms, and *vice verſa*.

21 Denſity,

This denſity may be increaſed beyond any given limits by the nearer approach of the atoms to one another. Hence a body of any given magnitude, however ſmall, may come to be diviſible beyond any given limits.

22 Mobility,

Mobility, which is likewiſe reckoned among the general properties of body, is eſſential to our ſyſtem, ſeeing an eſſential part of it conſiſts in *forces*, which are determinations to motion, at leaſt in certain diſtances.

23 Gravity,

Univerſal gravity in ſenſible diſtances is likewiſe a branch of our theory. On which ſubject it may be obſerved, that perhaps our curve, after it has extended beyond the ſphere of the comets moſt diſtant from the ſun, may depart from its aſymptotical nature, and approach to the axis, interſect it, and paſs to repulſion. This would effectually anſwer the objection made by ſome againſt Newton's attraction, when they allege, that, from his opinion, it would follow, that the fixed ſtars, and all matter, would be drawn together into one maſs. If ſuch a repulſion takes place, it may ſoon paſs again into attraction, and form limits of coheſion; ſo that our ſun may be in ſuch a limit with regard to the fixed ſtars, and our planetary ſyſtem make only a ſmall part of the whole univerſe. And this may ſuffice concerning the general properties of matter.

24 Fluidity,

Let us now deſcend to ſome particular claſſes of bodies, of which ſome are fluid, others ſolid. The parts of fluid bodies are eaſily ſeparated, and eaſily moved round one another, becauſe they are ſpherical and very homogeneous; and hence their forces are directed more to their centres than to one another, and their motions through one another are leſs obſtructed. Between the particles of ſome of them there is very little attraction, as in fine ſand or ſmall grains of ſeed, which approach much to fluidity. The particles of ſome others of them attract one another ſenſibly, as do thoſe of water, and ſtill more thoſe of mercury. This variety ariſes from the various combinations of the particles themſelves, of which we have already taken notice. But in air the particles repel one another very ſtrongly; and hence comes that great rarefaction, when it is not compreſſed by an external force. Its particles muſt be placed in ample limits of repulſion.

25 Solidity,

Solid bodies are formed of parallelopipeds, fibres, and of irregular figures. This occaſions a greater coheſion than in fluids, and prevents the motion of the parts round one another; ſo that when one part is moved all the reſt follow. Of theſe bodies ſome are harder, whoſe particles are placed in limits which have ſtrong repul-

ſive

Bofcovich's Syftem of Natural Philofophy.

five arches within them; others are fofter, whofe particles have thofe arches of repulfion weaker. Some are flexible, the particles of which are placed in limits that have weak arches of repulfion and attraction on each fide; and if thofe arches are fhort, the particles may come to new limits of cohefion, and remain bent: but if the arches are longer, the former repulfion and attraction will continue to act, and bring back the body to its former pofition; nay, in doing this with an accelerated velocity, the parts will pafs their former limits, and vibrate backwards and forwards, as may be feen in a bended fpring. Thus elafticity is accounted for.

26 Softnefs, flexibility, and elafticity.

27 Vifcofity.

Vifcous bodies ftand in the middle between folid and fluid. Their particles have lefs cohefion than the firft, and more than the fecond: they ftick to other bodies by an attraction which their particles have from their compofition. In like manner water itfelf fticks to fome bodies, and is repelled by others. All which arifes from the different compofition of the particles, which gives a variety of refpective forces.

28 Organization.

What appears very wonderful in nature, is the compofition of organic bodies. But if we confider that particles may be fo formed, that they may repel fome and attract others, the whole of vegetation, nutrition, and fecretion, may be underftood, and follows from our fyftem. And as one particle may attract another in one part only, and repel it in every other fituation, hence may be gathered the orderly fituation of the particles in many cryftallizations. The great variety of repulfive and attractive forces, or limits of cohefion, of the pofition of atoms, and of combinations of particles, will account for all thefe phenomena.

29 Chemical operations.

The chemical operations, which are fo curious in themfelves, and fo ufeful to fociety, are well explained by Bofcovich's fyftem, and ferve as a confirmation of its truth. Of this we fhall give fome inftances. When fome folids are thrown into fome liquids, there happens to be a greater attraction between the particles of the folid and of the liquid than there is between the particles of the folid itfelf. Hence the particles of the folid are detached and furrounded by the fluid; this mixture retaining the form of globules, and therefore continuing to be fluid. This is called *folution*. But when the folid particles are covered to a certain depth, the attractive forces ceafe on account of the different diftances, and no more of the folid is detached. Then the fluid is faid to be *faturated*. If into this mixture another folid be put, the particles of which attract the fluid more ftrongly, and perhaps at greater diftances than the particles of the former; then the fluid will abandon the former and cleave to the latter, diffolving them, and the particles of the former will fall to the bottom in the form of powder, into which they had been reduced by the folution. This feparation is called *precipitation*. Perhaps rain arifes from a precipitation of this kind, when the aqueous particles are left by the air, which is more ftrongly attracted by fome other particles floating in the atmofphere.

Fluids of the fame fpecific gravity are eafily mixed; and even though the fpecific gravity be different, the particles of the one attract thofe of the other, in fuch a manner that they feem to form one fluid by a kind of folution. Nay, it happens, that two fluids mixed together form a folid, becaufe their particles come to be in the limits of cohefion. They may even occupy lefs fpace than they did before, by being attracted into lefs diftances between their parts.

Fermentation is a neceffary confequence of our fyftem. For when bodies, whofe particles, by the variety of their compofition, are endued with different forces, come to be mixed, there muft arife an agitation of the parts, and an ofcillation among them; fometimes greater, fometimes lefs, according to the nature of the particles. This agitation is ftopped by the expulfion of fome particles, by the intrufion of others into vacant fpaces and by the impreffion of external bodies; but always there is a change in what remains, becaufe there is a new difpofition of particles.

30 Fire and fufion, &c.

Fire confifts in a violent fermentation of fulphureous matter, efpecially when it meets with the matter of light in any quantity. This fermentation agitates ftrongly the parts of other bodies, feparates them from one another, and often throws them into a ftate of fufion; the cohefion between their parts being broken, and they being thrown into a circular motion. In this ftate they may be often mixed together, fo as to form one body; they may be again feparated by the action of the fame fire, which evaporates fome of them fooner, fome later. Hence the art of fmelting metals.

When, in the agitation occafioned by fire, fome of the particles are thrown out into an arch of repulfion, they may fly off and evaporate. Sometimes the whole body may be thrown into a ftrong repulfion and volatilization, or a fudden explofion take place; when, before the particles are near an equilibrium, a fmall force may occafion a great change; as the foot of a bird may occafion the fall of a great rock, which was before almoft detached from a mountain. In evaporation, the bodies that remain affume a particular figure, as all falts do; and this upon account of their particles having certain parts only that attract one another, and confequently occafion a particular difpofition. All thefe chemical operations evidently prove that there are in nature repulfive and attractive forces between the particles of bodies at fmall diftances; which greatly confirms our whole fyftem.

31 Light.

Bofcovich holds, that light is an *effluvium*, emitted with great velocity from the luminous bodies by a ftrong repulfion. He explains all the moft remarkable properties of this extraordinary matter according to his own principles, and that with great acutenefs. On this fubject it is obfervable, that Newton faw the neceffity of admitting repulfive forces for the reflexion of light, which extend at fome diftance from the reflecting furface, and therefore refemble the repulfive forces of our theory.

32 Electricity and magnetifm.

Our author gives likewife a probable explication of electricity, according to Franklin's ingenious hypothefis, and likewife of magnetifm, deducing the whole of the appearances from various attractions and repulfions. He fuppofes that fire and the electrical fluid differ only in this, that fire is in actual fermentation, and not fo the electrical fluid.

33 Senfation.

Finally, he explains our bodily fenfations, in which he agrees pretty much with other philofophers; excepting in this, that what they attribute to the immediate contact of bodies, or of certain particles emitted from them, he afcribes to attractions and repulfions; which indeed

Boſcovich's Syſtem of Natural Philoſophy.

indeed are particularly fit for cauſing that motion in our nerves, which is ſuppoſed to take place in the organs of ſenſation, and to be thence communicated to the brain.

It is to be obſerved, that although Boſcovich maintains, that the very firſt elements of matter are void of extenſion; yet he allows, that of theſe elements, combined in a certain manner, may be formed extended particles of various figures, the parts of which may be ſo coherent as to be inſeparable by any power in nature. By theſe means the opinion of thoſe philoſophers who are ſo fond of extended particles, may be in ſo far gratified. Nay, the Peripatetics may, if they pleaſe, adopt Boſcovich's inextended atoms for their *Materia Prima* without any inconſiſtency; and his repulſive and attractive forces may ſerve for their *ſubſtantial forms*. And as God can make impreſſions on our ſenſes independently of the atoms, their abſolute accidents may in ſome ſenſe be admitted. Nor would ſome ſuch extraordinary exertions of Divine Power favour idealiſm in the ordinary courſe of nature.

34 Reconciliation of this with other ſyſtems,

But what is of more conſequence, it is more than probable, that had Newton lived to be acquainted with the Boſcovichian theory, he would have paid to it a very great regard. This we may conjecture from what he ſays in his laſt queſtion of optics; where, after having mentioned thoſe things which might be explained by an attractive force, ſucceeded by a repulſive one on a change of the diſtances, he adds, "And if all theſe things are ſo, then all nature will be very ſimple, and conſiſtent with itſelf, effecting all the great motions of the heavenly bodies by the attraction of gravity, which is mutual between all thoſe bodies, and almoſt all the leſs motions of its particles by another certain attractive and repulſive force, which is mutual between thoſe particles." And a little after, treating of the elementary particles, he ſays: "Now it ſeems that theſe elementary particles not only have in themſelves the *vis inertiæ*, and thoſe paſſive laws of motion which neceſſarily ariſe from that force, but that they likewiſe perpetually receive a motion from certain active principles: ſuch as gravity, and the cauſe of fermentation, and of the coheſion of bodies. And I conſider theſe principles, not as occult qualities, which are feigned to flow from the ſpecific forms of things, but as univerſal laws of nature, by which the things themſelves were formed. For that truly ſuch principles exiſt, the phenomena of nature ſhew, although what may be their cauſes has not as yet been explained. To affirm that every ſpecies of things is endued with ſpecific occult qualities, by which they have a certain power, is indeed to ſay nothing; but to deduce two or three general principles of motion from the phenomena of nature, and then to explain how the properties and action of all corporeal things follow from thoſe principles, this truly would be to have made a great advancement in philoſophy, although the cauſes of thoſe principles were not as yet known. Wherefore I do not heſitate to maintain the above ſaid principles of motion, ſeeing they extend widely through all nature." From this paſſage we may ſafely conclude, that the great Britiſh philoſopher would have been highly pleaſed, had he ſeen all nature ſo well explained by the one ſimple law of forces propoſed by the Raguſan.

35 Eſpecially that of Newton.

36 Compariſon of this ſyſtem to the key of a cypher.

Boſcovich himſelf was ſo fully convinced of the truth of his ſyſtem, that he was wont to make uſe of the following compariſon: When a letter has been written in occult characters, and we are endeavouring to decypher it, we make various ſuppoſitions of alphabets; and when we have found one according to which the whole letter comes to have a reaſonable meaning, agreeable to all the circumſtances of time, place, perſons, and things, we can entertain no doubt of our having diſcovered the true key of the cypher—ſo, ſaid he, my ſyſtem explains ſo well all the phenomena to which it has been properly applied, that I muſt flatter myſelf that I have diſcovered the true key of nature.

37 Exiſtence of God.

The being accuſtomed to contemplate ſo deeply the univerſe and the materials of which it is compoſed, made Boſcovich ſee moſt clearly the evident neceſſity of admitting an all powerful, intelligent, ſelf-exiſtent Being, for the creation of thoſe materials, and for the arrangement of them into their preſent beautiful form. He was at a loſs to find words ſtrong enough to expreſs his ſurpriſe, that there ſhould be any man, not to ſay any one pretending to the name of philoſopher, who could be ſo deaf as not to hear the voice of nature loudly proclaiming its Author from all, even the leaſt of its parts. He gives us his ſentiments on this, the moſt important of all ſubjects, in the appendix to his *Theoria*, in which he treats of God and of the ſoul of man.

38 The world cannot be the effect of chance;

There, in the firſt place, he ſhows the abſurdity of their opinion, who maintain that this world may have been the work of *chance*, the effect of a jumble of ſelf-exiſtent, ſelf-moving atoms: becauſe chance is an empty word without a real meaning. Whatever exiſts has its determinate cauſe, and can only be called *fortuitous* by us on account of our ignorance of that cauſe. Beſides this, though the number of atoms compoſing this world is finite, yet their poſſible combinations are many times *infinitely infinite*: for they may be placed in infinite places of an infinite line; of theſe lines there is an infinite number in every *plane*, and of theſe planes there is an infinite number in ſpace. Again, theſe points may have an infinite number of velocities in an infinite number of directions. From all this it is evident, that the combinations in which the points of matter may be, is infinite in a high degree, whereas *duration* can be infinite in only one dimenſion. Hence it is infinitely improbable that ever the preſent combination of things could come out by chance. And this is ſo much the more infinitely improbable, becauſe the diſorderly, chaotic combinations are infinitely more than the regular ones. The whole of matter might roll about in a blind motion for a boundleſs eternity, without ever being capable to produce one ſingle muſhroom.

Moreover, had matter been in motion from all eternity, every atom would have deſcribed an infinite line, and then a part of that line would be aſſignable at an infinite diſtance from the point of ſpace in which the atom is at preſent: but an infinite line can never be run over; therefore the atom could never have come to its preſent place; and therefore the ſuppoſition is abſurd. Nothing ſucceſſive can be eternal with a *paſt* eternity, though it can continue without end. God alone can be eternal and actually infinite, but his eternity and infinity are beyond our comprehenſion.

39 Nor have exiſted from eternity.

Neither can the world have exiſted of itſelf in any thing like to its preſent form from all eternity; for matter is perfectly indifferent to numberleſs ſtates, and to

Boscovich's System of Natural Philosophy.

to its present state it must be determined. This present state is perfectly incapable of determining itself, because this determination must be previous to its existence. It must be determined by the preceding state, which is also incapable of determining itself, and for its determination we must have recourse to the state before. Thus, though we go back to eternity, we shall still find a nullity of determination: now an infinite sum of *nothing* is *nothing*; and therefore as the present state of things could have no determination, it could not possibly exist.

It is therefore evident that there must be a Determiner extrinsic to the material world. This Determiner must have an infinite knowledge of all the possible combinations, and an infinite elective creative power to chuse and create freely the combination he pleased, in that point of eternity that he chose, with all the numberless circumstances that are agreeable to him.

40 Attributes of God which appear in the creation.

And here what a vast field of contemplation is laid open to a philosophic mind! What a truly infinite knowledge was requisite to foresee so many ends, and so many means requisite for obtaining those ends, as are contained in the creation! Let us consider light, for example, which was to be emitted for so many ages from so many luminous bodies, with so great velocity, so as to penetrate so many mediums with different degrees of reflectibility and refrangibility, with so many other wonderful qualities; at the same time so many bodies were to be perfectly fitted for reflecting this light in a certain manner, and the animal eye was to be so formed as to have a picture of visible objects painted on the bottom of it.—How many particular combinations were necessary for all this? What shall we say of the so many herbs, flowers, trees, and animal bodies as there are on this our earth? All their kinds and species, all the series of their individuals, all their parts and particles, were foreseen, intended, and contrived, by one act of the Divine Mind. Again, how wonderful are the heavenly bodies, of what surprising magnitude, moving in the most beautiful order, at an immense distance from one another? To say nothing of the numberless creatures that are beyond the reach of the best telescope, or below that of the microscope. He who reflects ever so little on these things, must necessarily see the most evident proofs of an infinite power, wisdom, and providence; and he must be filled with admiration and awful respect for the Creator and Ruler of the universe.

41 Natural religion.

Nor are we unconcerned spectators of this grand scene. God has been pleased to make us enter deeply into his great plan of creation. He singled us out among an infinite number of possible human beings, in order to call us into existence at a fixed period; and he has made a vast number of his creatures contribute to the formation of these wonderful machines, our bodies, as likewise to our nourishment, to our preservation, to our necessities, conveniences, and gratifications. Every moment that we exist we are enjoying a great number of benefits, expressly designed for us by that Supreme Being. This evidently demands from us the highest degree of gratitude, love, and obedience.

42 Revelation.

Let us go a step still farther: Is it not very reasonable to suppose, that our God, who affords us so many instances of his beneficence towards us in the natural order, will also, out of compassion to our weakness and ignorance, have favoured us with a more full and explicit manifestation of himself, of our duties towards him, and of his intentions concerning us? According to Boscovich and all true philosophers, reason itself alone, and true philosophy, point out to us the probability at least of God's having given us a still better and surer guide, by whose direction we may attain to that perfect happiness which we naturally thirst after, and to which we must have been designed by our Maker. This is probable from reason alone; and of this great fact we are ascertained by unquestionable authority.

Boshmen ‖ Boston.

BOSHMEN have been generally described as a distinct race of Hottentots, who are enemies to the pastoral life, (see *Boshies-Men*, Encycl.) This M. Vaillant affirms to be a mistake; and we think he has completely proved that it is so. "These infamous wretches (says he) do not form a particular nation, nor are they a people who have had their origin in the places where they are now found. *Boshmen* is a name composed of two Dutch words, which signify *bush-men*, or *men of the woods*; and it is under this appellation that the inhabitants of the Cape, and all the Dutch in general, whether in Africa or America, distinguish those malefactors or assassins who desert from the colonies, in order to escape punishment. In a word, they are what in the British and French West India islands are called *Maroon Negroes*. These Boshmen, therefore, far from being a distinct species, are only a promiscuous assemblage of mulattoes, negroes, and mastizos, of every species, and sometimes of Hottentots and basters (see Baster, *Supplement*), who all differing in colour, resemble each other in nothing but in villany. They are land pirates, who live without laws and without discipline, abandoned to the utmost misery and despair; base deserters, who have no other resources but plundering and crimes. They retire to the steepest rocks and the most inaccessible caverns, and there they pass their lives. From these elevated places they command an extensive prospect over the surrounding plains, lie in wait for the unwary traveller and the scattered flocks, pour down upon them with the velocity of an arrow, and suddenly falling upon the inhabitants and their cattle, slaughter them without distinction. Loaded with booty, and whatever they can carry with them, they then repair to their gloomy caves, which they never quit till, like the lions, hunger again impels them to fresh massacres. But as treachery always marches with a trembling step, and as the presence of one resolute person is sufficient to overawe whole troops of these banditti, they carefully shun those plantations where they are certain that the owners themselves reside. Artifice and cunning, the usual resources of timid souls, are the only means which they employ, and the only guides that accompany them in their expeditions."—*Vaillant's Travels into the Interior Parts of Africa.*

BOSTON, (Encyclopædia.) The following more accurate description is from Dr Morse's Gazetteer.

Boston, The capital of the state of Massachusetts, the largest town in New England, and the third in size and rank in the United States, lies in 42. 23. 15. N. lat. and 70. 58. 53. W. long. This town, with the towns of Hingham, Chelsea and Hull, constitute the county of Suffolk; 176 miles S. W. of Wiscasset, 61 S. by W. of Portsmouth, 164 N. E. of New-Haven, 252 N. E. of New-York, 347 N. E. of Philadelphia, and 500 N. E. of the city of Washington. Boston

Boston. ton is built upon a peninfula of irregular form at the bottom of Maffachufetts Bay, and is joined to the main land by an ifthmus on the fouth end of the town leading to Roxbury. It is two miles long but is of unequal breadth: the broadeft part is 726 yards. The peninfula contains about 700 acres (other accounts fay 1000) on which are 2376 dwelling houfes. The number of inhabitants in 1790 was 18,038, but the increafe has been very confiderable fince. The town is interfected by 97 ftreets, 36 lanes, and 26 alleys, befides 18 courts, &c. moft of thefe are irregular, and not very convenient. State-ftreet, Common-ftreet, and a few others, are exceptions to this general character; the former is very fpacious, and being on a line with Long Wharf, where ftrangers ufually land, exhibits a flattering idea of the town.

Here are nineteen edifices for public worfhip, of which nine are for Congregationalifts, three for Epifcopalians, and two for Baptifts; the Friends, Roman Catholics, Methodifts, Sandemanians and Univerfalifts have one each. Moft of thefe are ornamented with beautiful fpires, with clocks and bells. The other public buildings are the State-Houfe, Court-Houfe, two Theatres, Concert Hall, Faneuil Hall, Gaol, an Alms-Houfe, a Work-Houfe, a Bridewell and Powder Magazine. Franklin Place, adjoining Federal-ftreet Theatre, is a great ornament to the town; it contains a monument of Dr. Franklin from whom it takes its name, and is encompaffed on two fides with buildings, which, in point of elegance, are not exceeded, perhaps, in the United States. Here are kept in capacious rooms, given and fitted up for the purpofe, the Bofton Library, and the valuable Collections of the Hiftorical Society. Moft of the public buildings are handfome, and fome of them are elegant. A magnificent State-Houfe is now erecting in Bofton, on the S. fide of Beacon Hill, fronting the Mall, the corner-ftone of which was laid with great formality and parade on the 4th of July, 1795; and which over-tops the monument on Beacon Hill.

The Market Place, in which Faneuil Hall is fituated, is fupplied with all kinds of provifions which the country affords. The fifh market in particular, by the bounteous fupplies of the ocean and rivers, not only furnifhes the rich with the rareft productions, but often provides the poor with a cheap and grateful repaft.

Bofton Harbor, is formed by Point Alderton on the S. and by Nahant Point on the N. The harbor is capacious enough for 500 veffels to ride at anchor in good depth of water; whilft the entrance is fo narrow as fcarcely to admit two fhips abreaft. It is variegated with about forty iflands, of which fifteen only can be properly called fo; the others being fmall rocks or banks of fand, flightly covered with verdure. Thefe iflands afford excellent pafturage, hay and grain, and furnifh agreeable places of refort in fummer to parties of pleafure. Caftle Ifland is about three miles from the town; its fortifications, formerly called Caftle William, defend the entrance of the harbor. It is garrifoned by about fifty foldiers, who ferve as a guard for the convicts, who are fent here to hard labour. The convicts are chiefly employed in making nails.

The Light-Houfe ftands on a fmall ifland on the N. entrance of the channel, (Point Alderton and Nantafket Heights being on the S.) and is about 65 feet high. Bofton. To fteer for it from Cape Cod, the courfe is W. N. W. when within one league of the Cape; from Cape Cod to the Light-Houfe is about 16 leagues; from Cape Ann the courfe is S. W. diftant 10 leagues. A cannon is lodged and mounted at the Light Houfe to anfwer fignals.

Only feven of the iflands in the bay are within the jurifdiction of the town, and taxed with it, viz. Noddle's, Hog, Long, Deer, Spectacle, Governor's and Apple Iflands.

The wharves and quays in Bofton are about eighty in number, and very convenient for veffels. Long Wharf, or Bofton Pier, in particular, extends from the bottom of State-ftreet 1743 feet into the harbor in a ftraight line. The breadth is 104 feet. At the end are 17 feet of water at ebb tide. Adjoining to this wharf on the north is a convenient wharf called Minot's T, from the name of its former proprietor and its form. Veffels are fupplied here with frefh water from a well furrounded by falt water, which has been dug at a great expenfe. Long Wharf is covered on the north fide with large and commodious ftores, and in every refpect exceeds any thing of the kind in the United States. In February, 1796, a company was incorporated to cut a canal between this harbor and Roxbury, which is nearly completed.

The view of the town, as it is approached from the fea, is truly beautiful and picturefque. It lies in a circular and pleafingly irregular form round the harbour, and is ornamented with fpires, above which the monument of Beacon Hill rifes pre eminent; on its top is a gilt eagle bearing the arms of the Union, and on the bafe of the column are infcriptions, commemorating fome of the moft remarkable events of the late war. Beacon Hill is the higheft ground on the peninfula, and affords a moft delightful and extenfive profpect. The common below it contains about 45 acres always open to refrefhing breezes; on its eaft fide is the Mall, a very pleafant walk above 500 yards in length, adorned with rows of trees, to which an addition of about 100 yards has been lately added. Charles River and Weft Bofton bridges are highly ufeful and ornamental to Bofton; and both are on Charles River, which mingles its waters with thofe of Myftic River, in Bofton harbor. Charles River bridge connects Bofton with Charleftown in Middlefex county, and is 1503 feet long, 42 feet broad, ftands on 75 piers, and coft the fubfcribers 50,000 dollars. It was opened June 19, 1787.

	Feet long.
Weft Bofton bridge ftands on 180 piers, is	3483
Bridge over the gore, 14 piers,	275
Abutment Bofton fide,	$87\frac{1}{2}$
Caufeway,	3344
Diftance from the end of the Caufeway to Cambridge meeting-houfe,	7810
Width of the Bridge,	40

This beautiful bridge exceeds the other as much in elegance as in length, and coft the fubfcribers 76,700 dollars. Both bridges have draws for the admiffion of veffels, and lamps for the benefit of evening paffengers.

Seven Free Schools are fupported here at the public expenfe, in which the children of every clafs of citizens may freely affociate together. The number of fcholars

Boston. ſcholars is computed at about 900, of which 160 are taught Latin, &c. There are beſides theſe many private ſchools.

The principal ſocieties in the Commonwealth hold their meetings in this town, and are, the Marine Society, American Academy of Arts and Sciences, Maſſachuſetts Agricultural Society, Maſſachuſetts Charitable Society, Boſton Epiſcopal Charitable Society, Maſſachuſetts Hiſtorical Society, Society for propagating the Goſpel, Maſſachuſetts Congregational Society, Medical Society, Humane Society, Boſton Library Society, Boſton Mechanic Aſſociation, Society for the aid of Immigrants, Charitable Fire Society, and ſeven reſpectable Lodges of free and accepted Maſons.

The foreign and domeſtic trade of Boſton is very conſiderable, to ſupport which there are three Banks, viz. the Branch of the United States Bank, the Union, and the Maſſachuſetts Bank; the latter conſiſts of 800 ſhares of 500 dollars, equal to 400,000; the capital of the Union Bank is, 1,200,000 dollars, 400,000 of which is the property of the State. In 1748, 500 veſſels cleared out of this port for, and 430 were entered from, foreign parts. In 1784, the entries of foreign and coaſting veſſels were 372, and the clearances 450. In 1794, the entries from foreign ports were 567. In 1795, theſe entries amounted to 725, of which the ſhips were 96, barques 3, ſnows 9, polacre 1, brigs 185, dogger 1, ſchooners 362, ſhallop 1, and ſloops 65. The principal manufactures conſiſt of rum, loaf-ſugar, beer, ſail-cloth, cordage, wool and cotton cards, playing cards, pot and pearl aſhes, paper hangings, hats, plate, glaſs, tobacco, and chocolate. There are thirty diſtilleries, two breweries, eight ſugar houſes, and eleven ropewalks.

Eight years ago, the intercourſe with the country barely required two ſtages and twelve horſes, on the great road between this and New-Haven, diſtant 164 miles; whereas there are now twenty carriages and one hundred horſes employed. The number of the different ſtages that run through the week from this town is upwards of 20, eight years ago there were only three.

Attempts have been made to change the government of the town from its preſent form to that of a city; but this meaſure, not according with the democratic ſpirit of the people, has as yet failed. At an annual meeting in March, nine Selectmen are choſen for the government of the town; at the ſame time are choſen a Town Clerk, a Treaſurer, 12 Overſeers of the Poor, twenty-four Firewards, twelve Clerks of the Market, twelve Scavengers, twelve Conſtables, beſides a number of other officers. If the inhabitants do not reap all the advantages they have a right to expect from their numerous officers, it is not for want of wholeſome laws for the regulation of the weights, meaſures and quality of proviſions, or other branches of police, but, *becauſe the laws are not put in execution.*

Beſides thoſe called Trained Bands, there are four other military companies in Boſton, viz. the Ancient and Honourable Artillery Company, the Cadets, Fuſiliers and Artillery Company. The Ancient and Honourable Artillery Company was incorporated in 1638, and the election of a captain and officers of it for the year is on the firſt Monday in June annually, which is obſerved here as a day of feſtivity. Several officers in the American army, who ſignalized themſelves in the late war, received their firſt knowledge of tactics in this military ſchool.

Boſton || Boſwell.

Boſton was ſettled as early as 1631, from Charleſtown; it was called Shaumut by the Indians; Trimountain by the ſettlers in Charleſtown, from the view of its three hills; and had its preſent name in token of reſpect to the Rev. Mr Cotton, a miniſter of Boſton in England, and afterwards miniſter of the firſt church here. Boſton was greatly damaged by an earthquake in October 29, 1727, and ſince that time has ſuffered ſeverely by numerous fires, the houſes being moſtly built of wood. The laſt large fire happened July 30, 1794, and conſumed 96 houſes, rope-walks, &c. and the account of loſſes given in by the ſufferers amounted to 209,861 dollars.

It was in Boſton that the Revolution originated which gave independence to America, and from thence flew like an electrical ſhock throughout the Union. It ſuffered much at the commencement of the war, by the loſs of an extenſive trade, and other calamities. Boſton feels a pride in having given birth to Benjamin Franklin, and a number of other patriots, who were among the moſt active and influential characters in effecting the revolution.

BOSWELL (James), known to the learned world as the author of a life of Dr Johnſon and of ſeveral other valuable works, was born, we believe, at Auchinleck in Ayrſhire, in 1740. The family from which he ſprung was ancient and honourable. At the time of his birth his father was a well employed lawyer at the Scotch bar; but was afterwards raiſed to the dignity of Judge, and filled that important ſtation with acknowledged learning, probity, and honour. His title was Lord Auchinleck, taken from his family inheritance; and he died in 1782: on which occaſion Dr Johnſon wrote an elegant and inſtructive letter to the ſubject of this brief memorial; of which we ſhall tranſcribe a paſſage that alludes to ſome ſlight domeſtic differences, which did not happen in vain, ſince they gave riſe to ſuch ſalutary advice:

"Your father's death had every circumſtance that could enable you to bear it. It was at a mature age, and it was expected; and as his general life had been pious, his thoughts had, doubtleſs, for many years paſt, been turned upon eternity. That you did not find him ſenſible muſt doubtleſs grieve you: his diſpoſition towards you was undoubtedly that of a kind, though not of a fond father. Kindneſs, at leaſt actual, is in our own power, but fondneſs is not; and if, by negligence or imprudence, you had extinguiſhed his fondneſs, he could not at will rekindle it. Nothing then remained between you but mutual forgiveneſs of each other's faults, and mutual deſire of each other's happineſs."

The occaſion of this family diſſention is unknown to us. It might originate in the difference of their political principles, Mr Boſwell being a zealous Tory, and his father, as he repreſents him, a rancorous Whig; or it may have ariſen from the celebrated Douglas cauſe, which ſet many friends at variance in Scotland, and in which Lord Auchinleck and his ſon took oppoſite ſides. The Judge gave his vote on the bench for the Duke of Hamilton; and the advocate (for Mr Boſwell was then at the bar) was ſo keen a partizan of Douglas, that when the cauſe was finally decided by the Houſe of Peers,

Peers, he got poffeffion of a Chinefe *gong*, and, at the head of a number of young men and boys patrolled the ftreets of Edinburgh, and made a loud and exulting noife at the windows of his father's houfe, where there was no fymptom difplayed of the general joy.

In 1762 Mr Bofwell made his firft journey to London; where, under the aufpices of Dodfley the bookfeller, he publifhed, "The Cub at Newmarket, a Tale." By the title of *Cub* he meant to characterize himfelf, as the reader will perceive in the following lines, which we fhall give as a fpecimen of the poem:

> Lord Eglintoune, who loves, you know,
> A little dafh of whim, or fo,
> By chance a curious Cub had got,
> On Scotia's mountains newly caught.

During his ftay in London, Mr Bofwell was introduced to Dr Johnfon, with whom it is well known he continued to live in intimacy from that time till Johnfon's death in 1784; and this intimacy procured him the friendfhip of Burke, Goldfmith, Sir Jofhua Reynolds, and many other men of eminence, who compofed what was called *The Literary Club*. In the latter end of 1765 he became acquainted with General Paoli when on his travels; and after his return he publifhed, in 1768 or 1769, his account of Corfica, with the "Journal of a Tour to that Ifland."

Of this work, which gained him fome diftinction in the world, his great friend Johnfon writes thus: "Your hiftory is like all other hiftories, but your journal is in a very high degree curious and delightful. There is between the hiftory and the journal that difference which there will always be found between notions borrowed from without and notions generated within. Your hiftory was copied from books; your journal rofe out of your own experience and obfervation. You exprefs images which operated ftrongly upon yourfelf, and you have impreffed them with great force upon your readers. I know not whether I could name any narrative by which curiofity is better excited or better gratified."

In 1770 Mr Bofwell, who was then in good practice at the Scotch bar, married an amiable woman, by whom he had two fons and three daughters, who furvived him. In 1773 he was chofen a member of the Literary Club; and in the autumn of the fame year he vifited the Hebrides in company with his illuftrious friend Johnfon; after whofe death he publifhed a very entertaining account of their tour, the places they faw, the characters with whom they converfed, and their own remarks on the different converfations. To many perfons, both in England and Scotland, this book gave great offence, as it brought before the public the unguarded talk of private focial circles; but it furely furnifhed much entertainment, as it exhibited a more faithful picture of Hebridian manners than the Britifh public had ever before feen.

In 1784, when Mr Fox's famous India bill was before Parliament, Mr Bofwell publifhed a "Letter to the People of Scotland on the Prefent State of the Nation;" in which he contends, that no charter would be fafe if that bill fhould pafs into a law; and more than infinuates, that the principle of it was equally inimical to the liberties of the fubject and to the prerogative of the king. Dr Johnfon feems to have thought of that bill as he did; for having read the letter, he writes to the author his approbation of it in the following words: "I am very much of your opinion; and, like you, feel great indignation at the indecency with which the king is every day treated. Your paper contains very confiderable knowledge of the hiftory and of the conftitution, very properly produced and applied."

In 1785 Mr Bofwell quitted the Scotch bar, and went to refide in London, where he continued till the day of his death. Having entered himfelf in one of the inns of court, and ftudied the Englifh law, he became a barrifter in England: but we have reafon to believe that his practice there was not fo fuccefsful as it had been in his own country. He enjoyed, however, more completely than he could do in Edinburgh, the converfation of the great, the wife, the witty, and the good; and fuch converfation he always valued above wealth. He frequently vifited his native country, and efpecially Auchinleck, the feat of his anceftors; and foon after his return from one of thofe vifits he was feized with a diforder which proved fatal, on Tuefday the 19th of May 1795.

Such were the principal events in the life of Mr Bofwell. Of his character, it would be difficult to fay *much more* than he has faid himfelf in his "Journal of a Tour to the Hebrides;" and which may, with fome propriety, be copied here:

"I have given a fketch of Dr Johnfon. My readers may wifh to know a little of his fellow-traveller. Think, then, of a gentleman of ancient blood; the pride of which was his predominant paffion. He was then in his 33d year, and had been about four years happily married. His inclination was to be a foldier; but his father, a refpectable Judge, had preffed him into the profeffion of the law. He had travelled a good deal, and feen many varieties of human life. He had thought more than any body fuppofed, and had a pretty good ftock of general learning and knowledge. He had all Dr Johnfon's principles, with fome degree of relaxation. He had rather too little than too much prudence; and his imagination being lively, he often faid things of which the effect was very different from the intention. He refembled fometimes

'The beft good man, with the worft-natur'd mufe.'

"He cannot deny himfelf the vanity of finifhing with the encomium of Dr Johnfon, whofe friendly partiality to the companion of this tour reprefents him as one 'whofe acutenefs would help my inquiry, and whofe gaiety of converfation, and civility of manners, are fufficient to counteract the inconveniences of travel, in countries lefs hofpitable than we have paffed."

Few of Mr Bofwell's friends, we believe, could add much to this candid confeffion. His enemies, if he had any, might dwell upon his failings; but his failings were few, and injurious to no perfon. In his character good nature was predominant. He appeared to entertain fentiments of benevolence to all mankind, and to be incapable of *intentionally* injuring a human being. His converfation-talents were always pleafing, and often fafcinating. But can we wonder at this in him who, with a capacity to learn, had been the companion of Johnfon for more than 20 years? His attachment to the Doctor for fo long a period was a meritorious perfeverance in the defire of knowledge. To it the world is indebted for the moft finifhed picture of an eminent man that ever was executed. We know there are objections to the *mode* of giving the life of Johnfon. It has been thought that ignorance has been wantonly expofed, and the privacy of focial life endangered. We fhall not enter deeply into this queftion. All that we can certainly affirm is, that the work has been read with avidity and pleafure; and that he who does not wifh to read it again may be fufpected to be deficient in tafte and in temper.

Mr Bofwell has been accufed of vanity; but when this accufation is brought againft him, it fhould not be forgotten that he enjoyed advantages which rendered that confpicuous in him from which no man can claim an exemption. We know not the man who would not have been vain to poffefs fo much of Dr Johnfon's converfation, and proud to give it to the world, in hopes that he who venerated Johnfon would not be unthankful to his biographer. From the Doctor, however, he appeared to his friends to have imbibed a portion of melancholy, of which indeed he complained himfelf during the laft two or three years of his life; and he flew for relief where perhaps it is beft to be found, to the fociety of the learned and the gay. Here, as he confeffes, he had rather *too little* than too much *prudence*;" and, with more attachment to the activity of rural life, he might, probably, have lengthened his days. But as his "belief in revelation was unfhaken," and his religious impreffions deep, and recurring frequently, let us hope that he has now attained that ftate from which imperfection and calamity are alike excluded.

BOTANY-BAY, See *New Holland*, Encycl.; and *New South Wales* in this Supplement.

BOTETOURT, a county in Virginia, on the Blue Ridge, W. of which are the Sweet Springs, about 42 miles from the Warm Springs. Its chief town is Fincaftle.—*Morse.*

BOUDOIR, LE, a fmall ifland in the Pacific Ocean, S. lat. 17. 52. W. long. from Paris, 15. 25.; difcovered April 2, 1768, by Bouganville. This ifland, the year before, had been difcovered by Wallis, and named *Ofnaburg*.—The natives call it *Maitea*, according to the report of Capt. Cook, who vifited it in 1769. Quiros difcovered this ifland in 1606, and called it *la Dezana*.—*ib.*

BOUGUER (Peter), an eminent mathematician and mechanical philofopher, was born at Croific, in Lower Bretagne, on the 10th of February 1698. His father John Bouguer, who was likewife a confiderable mathematician, was then profeffor royal of hydrography at that port; and under him young Bouguer ftudied mathematics, and the application of them to fhip-building, almoft from the period when he began to fpeak; fo that he was a proficient in thefe fciences before he had reached beyond the years of childhood. He was, however, removed from Croific to the Jefuits college at Vannes, where at 13 years of age, he triumphed, in a public conteft, over a profeffor of mathematics, who had advanced a mathematical propofition erroneoufly. Two years after this he loft his father, whom he was appointed to fucceed in the office of hydrographer, after being publicly examined, and giving the moft complete proof of his being duly qualified to fill the vacant chair. He was indeed qualified by prudence as well as by fcience; for however furprifing it may be, he filled it both with dignity and with abilities, though then not more than 15 years of age.

In the years 1727, 1729, and 1731, he gained the prizes fucceffively propofed by the Academy of Sciences for effays on the beft way of equipping fhips with mafts, on the beft method of obferving at fea the height of the ftars, and on the moft advantageous way of obferving the declination of the magnetic needle or the variation of the compafs. In 1729 he publifhed an *Optical Effay upon the Gradation of Light*, in which he examined the intenfity of light, and determined its degrees of diminution in paffing through different pellucid mediums, and particularly in traverfing the earth's atmofphere. Of this effay, which was written upon a fubject that till then had not attracted the attention of philofophers, the reader will find fome account in the *Encyclopædia*, under the title Optics, n° 32, &c.

In 1730 Bouguer was removed from the port of Croific to that of Havre. In 1731 he obtained, in the Academy of Sciences, the place of affociate geometrician, vacant by the promotion of Maupertuis to that of penfioner; and in 1735 he was promoted to the office of penfioner aftronomer. The fame year he was fent on the commiffion to South America, along with Meffrs Godin, Condamine and Jeuffieu, to determine the meafure of the degrees of the meridian, and the figure of the earth. In this painful and troublefome bufinefs of ten years duration, chiefly among the lofty Cordelier mountains, our author, befides attending to the object of the voyage, made many fcientific obfervations, viz. on the effect of the Cordeliers on the polarity of the magnetic needle; on the expanfion and contraction of metals and other fubftances, by the fudden and alternate changes of heat and cold among thofe mountains; and on the refraction of the atmofphere from the tops of the fame, with the fingular phenomenon of the fudden increafe of the refraction, when the ftar can be obferved below the line of the level. He likewife afcertained the laws of the denfity of the air at different heights, from obfervations made at different points of thofe enormous mountains; he difcovered that the mountains have an effect upon a plummet, though he did not affign the quantity of that effect; he found out a method of eftimating the errors committed by navigators in determining their route; gave a new conftruction of the log for meafuring a fhip's way; and made feveral other ufeful improvements. M. Bouguer made at different times fome important experiments on the famous reciprocation of the pendulum; he invented in 1747 the heliometer (fee that article *Encycl.*); and made many difcoveries relating to the intenfity of light (for which fee Optics-*Index*, Encycl.) His unremitting application to ftudy undermined his health, and he died on the 15th of Auguft 1758, in the 61ft year of his age.

Of his works which have been publifhed, the chief are, 1. The Figure of the Earth, determined by the Obfervations made in South America, 1749, in 4to. 2. Treatife on Navigation and Pilotage, Paris, 1752, in 4to. This work has been abridged by M. La Caille, in one volume 8vo, 1768. 3. Treatife on Ships, their Conftruction and Motions, in 4to, 1756. 4. Optical Treatife on the Gradation of Light, firft in 1729, then a new edition in 1760, in 4to.

His papers that were inferted in the Memoirs of the

Academy are very numerous and important: as in the Memoirs for 1726, comparifon of the force of the folar and lunar light with that of candles: 1731, obfervations on the curvilinear motion of bodies in mediums; 1732, upon the new curves called the *lines of purfuit;* 1733, to determine the fpecies of conoid, to be conftructed upon a given bafe which is expofed to the fhock of a fluid, fo that the impulfe may be the leaft poffible; determination of the orbit of comets; 1734, comparifon of the two laws which the earth and the other planets muft obferve in the figure which gravity caufes them to take; on the curve lines proper to form the arches in domes; 1735, obfervations on the equinoxes; on the length of the pendulum; 1736, on the length of the pendulum in the torrid zone; on the manner of determining the figure of the earth by the meafure of the degrees of latitude and longitude; 1739, on the aftronomical refractions in the torrid zone; obfervations on the lunar eclipfe of the 8th September 1737, made at Quito; 1744, fhort account of the voyage to Peru by the members of the Royal Academy of Sciences, to meafure the degrees of the meridian near the equator, and from thence to determine the figure of the earth; 1745, experiments made at Quito and divers other places in the torrid zone, on the expanfion and contraction of metals by heat and cold; on the problem of the mafting of fhips; 1746, treatife on fhips, their ftructure and motions; on the impulfe of fluids upon the fore parts of pyramidoids, having their bafe a trapezium; continuation of the fhort account given in 1744 of the voyage to Peru for meafuring the earth; 1747, on a new conftruction of the log, and other inftruments for meafuring the run of a fhip; 1748, of the diameters of the larger planets; the new inftrument called a *heliometer*, proper for determining them, with obfervations of the fun; obfervation of the eclipfe of the moon the 8th of Auguft 1748; 1749, fecond memoir on aftronomical refractions, obferved in the torrid zone, with remarks on the manner of conftructing the tables of them; figure of the earth determined by MM. Bouguer and Condamine, with an abridgement of the expedition to Peru; 1750, obfervation of the lunar eclipfe of the 13th December 1750; 1751, on the form of bodies moft proper to turn about themfelves, when they are pufhed by one of their extremities, or any other point; on the moon's parallax, with the eftimation of the changes caufed in the parallaxes by the figure of the earth; obfervation of the lunar eclipfe the 2d of December 1751; 1752, on the operations made by feamen called *corrections;* 1753, obfervation of the paffage of Mercury over the fun the 6th of May 1753; on the dilatations of the air in the atmofphere; new treatife of navigation, containing the theory and practice of pilotage, or working of fhips; 1754, operations, &c. for diftinguifhing, among the different determinations of the degree of the meridian near Paris, that which ought to be preferred; on the direction which the ftring of a plummet takes; folution of the chief problems in the working of fhips; 1755, on the apparent magnitude of objects; fecond memoir on the chief problems in the working of fhips; 1757, account of the treatife on the working of fhips; on the means of meafuring the light.

BOURBON *Co.* in Kentucky, between Licking and Kentucky rivers, contains 7837 inhabitants, including 908 flaves.—*Morse.*

BOURBON, a poft town and capital of the above county, ftands on a point of land formed by two of the fouthern branches of Licking River; 22 miles N. E. of Lexington, 21 eafterly of Lebanon, and 749 W. S. W. from Philadelphia, and contains about 60 houfes, a Baptift church, a court-houfe and goal. There are feveral valuable mills in its vicinity.—*ib.*

BOW, is a townfhip in Rockingham co. New-Hampfhire, on the W. bank of Merrimack River, a little S. of Concord. It contains 568 inhabitants. —*ib.*

BOWDOIN, a townfhip in Lincoln co. Diftrict of Maine, on the N. eaftern bank of Androfcoggin River; diftant from York, N. eafterly, 36 miles, and from the mouth of Kennebeck River 6 miles, and 166 N. E. of Bofton. It contains 983 inhabitants.—*ib.*

BOWDOINHAM, a townfhip in Lincoln co. diftrict of Maine, feparated from Pownalborough E. and Woolwich S. E. by Kennebeck River. It has 455 inhabitants, and lies 171 miles N. E. from Bofton.—*ib.*

BOWLING *Green*, a village in Virginia, on the poft road, 22 miles S. of Fredericksburg, 48 N. of Richmond, and 25 N. of Hanover court-houfe.—*ib.*

BOXFORD, a fmall townfhip in Effex co. Maffachufetts, having 925 inhabitants. It lies on the S. E. fide of Merrimack River, 7 miles wefterly of Newburyport. In the fouthernmoft of its two parifhes is a bloomery.—*ib.*

BOYLSTON, a townfhip in Worcefter co. Maffachufetts, having 839 inhabitants; 10 miles N. E. of Worcefter, and 45 N. W. of Bofton. It was incorporated in 1786, having been a parifh of Shrewfbury fince 1742; and contains by furvey, 14,396 acres of land, well watered, and of a rich foil.—*ib.*

BRADDOCK's *Field*, the place where Gen. Braddock, with the firft divifion of his army, confifting of 1400 men, fell into an ambufcade of 400 men, chiefly Indians, by whom he was defeated and mortally wounded, July 9, 1755. The American militia, who were difdainfully turned in the rear, continued unbroken and ferved as a rear guard, and, under Col. Wafhington, the late Prefident of the U. S. A. preferved the regulars from being entirely cut off. It is fituated on Turtle Creek, on the N. E. bank of Monongahela River, 6 miles E. S. E. from Pittfburg.—*ib.*

BRADDOCK's *Bay*, on the S. fide of Lake Ontario, 42 miles W. from Great Sodus, and 65 E. from Fort Niagara.—*ib.*

BRADFORD, *Eaft* and *Weft*, are townfhips in Chefter co. Pennfylvania.—*ib.*

BRADFORD, a townfhip in Effex co. Maffachufetts, fituated on the S. fide of Merrimack River, oppofite Haverhill, and 10 miles W. of Newburyport. It has two parifhes, and 1371 inhabitants. Quantities of leather fhoes are made here for exportation; and in the lower parifh fome veffels are built. Several ftreams fall into the Merrimack from this town, which fupport a number of mills of various kinds.—*ib.*

BRADFORD, a townfhip in Hillfborough co. New-Hampfhire, containing 217 inhabitants, incorporated in 1760; 20 miles E. of Charleftown.—*ib.*

BRADFORD, a townfhip in Orange co. Vermont, on the W. bank of Connecticut River, about 20 miles above Dartmouth College, having 654 inhabitants. There is a remarkable ledge of rocks in this townfhip, as much as 200 feet high. It appears to hang over, and threaten the traveller as he paffes. The fpace between this ledge and Connecticut River is fcarcely wide enough for a road.—*ib.*

BRAINTREE, a townfhip in Orange co. Vermont, lies 75 miles N. eaftward of Bennington. It joins Kingfton weftward, Randolph on the eaftward, and contains 221 inhabitants.—*ib.*

Braintree, one of the moft ancient townfhips in Norfolk co. in the ftate of Maffachufetts, was fettled in 1625, and then called *Mount Woolafton*, from the name of its founder. It lies on a bay, 8 miles E. of S. from Bofton, and contained, before its divifion, 400 houfes and 2771 inhabitants. Great quantities of granite ftones are fent to Bofton from this town for fale. The bay abounds with fifh and fea fowl, and particularly *brants*. This town is noted for having produced, in former and latter times, the firft characters both in church and ftate; and, in diftant ages, will derive no fmall degree of fame, for having given birth to John Adams, the firft Vice-Prefident, and the fecond Prefident of the *United States of America*; a man highly diftinguifhed for his patriotifm, as a citizen; his juftice, integrity, and talents, as a lawyer; his profound and extenfive erudition, as a writer; and his difcernment, firmnefs, and fuccefs, as a foreign minifter and ftatefman.—*ib.*

BRANDON, a harbor on the N. fide of Long Ifland, New-York, 9 miles W. of Smithtown, and the fame diftance from Hampftead Plain.—*ib.*

Brandon, a townfhip in Rutland co. Vermont, fituated on both fides of Otter Creek, containing 637 inhabitants, and is about 60 miles northerly from Bennington. Here Brandon Creek empties into Otter Creek from the N. E.—*ib.*

BRANDYWINE *Creek*, falls into Chriftiana Creek from the northward, at Wilmington, in Delaware ftate, about 25 miles from its N. and N. weftern fources, which both rife in Chefter co. Pennfylvania. This Creek is famous for a bloody battle, fought Sept. 11, 1777, between the Britifh and Americans, which lafted nearly the whole day, and the latter were defeated with confiderable lofs: but it was far from being of that decifive kind which people had been led to expect, in the event of a meeting between the hoftile armies, on nearly equal terms, both as to numbers, and the nature of the ground on which each army was fituated. It was fought at Chadds Ford, and in the neighbourhood of, and on, the ftrong grounds at Birmingham church.—*ib.*

Brandywine, a townfhip in Chefter co. Pennfylvania.—*ib.*

BRANDFORD, a townfhip in New-Haven co. Connecticut, confiderable for its iron works. It lies on the S. fide of a river of the fame name, which runs into Long Ifland found, 10 miles E. from New-Haven, and 40 S. of Hartford.—*ib.*

BREAD is fo effential an article of food that every ufeful method of making it fhould be generally known. Much has accordingly been faid on that fubject *(Encycl.)* under the titles Baking, Barm, Bread, and Yeast; but, fince the laft of thefe articles was publifhed, we have feen, in Dr Townfon's *Travels in Hungary*, a method of making bread at Debretzen; of which, as it may fometimes be adopted with advantage in this country, an account may, with propriety, be inferted here.

In the baking of this bread, a fubftitute is ufed for yeaft, which is thus made: Two good handfuls of hops are boiled in four quarts of water: this is poured upon as much wheaten bran as can be well moiftened by it: to this are added four or five pounds of leaven; when this is only warm, the mafs is well worked together to mix the different parts. This mafs is then put in a warm place for 24 hours; and after that it is divided into fmall pieces, about the fize of a hen's egg, or a fmall orange, which are dried by being placed upon a board, and expofed to a dry air, but not to the fun; when dry, they are laid by for ufe, and may be kept a half year. This is the ferment; and it may be ufed in the following manner: For a baking of fix large loaves, fix good handfuls of thefe balls, broken into fragments, are taken and diffolved in feven or eight quarts of warm water. This is poured through a fieve into one end of the bread-trough, and three quarts more of warm water are poured through the fieve after it, and what remains in the fieve is well preffed out. This liquor is mixed up with fo much flour as to form a mafs of the fize of a large loaf: this is ftrewed over with flour; the fieve, with its contents, is put upon it, and then the whole is covered up warm, and left till it has rifen enough, and its furface has begun to crack: this forms the leaven. Then 15 quarts of warm water, in which fix handfuls of falt have been diffolved, are poured through the fieve upon it, and the neceffary quantity of flour is added, and mixed and kneaded with the leaven: this is covered up warm, and left for about an hour. It is then formed into loaves, which are kept in a warm room half an hour; and after that they are put in the oven, where they remain two or three hours, according to the fize. The great advantage of this ferment is, that it may be made in great quantities at a time, and kept for ufe. Might it not on this account be ufeful on board of fhips, and likewife for armies when in the field?

Bread, in whatever way it is made, is a dear article, and it may be a defirable object to many of our readers to know at what price the baker can afford to fell it. This depends upon the price of wheat, the quantity of flour which the wheat may give, the lofs at the mill, the expence of grinding, and the expence of baking.

Of the price of wheat we can fay nothing with precifion, becaufe it varies according to the goodnefs or badnefs of the crop, and other circumftances; but a bufhel of Effex wheat, Winchefter meafure, may be taken, on an average, as weighing 60 lb. Sixty pounds of wheat will yield, exclufive of the lofs in grinding and dreffing, 45½ lb. of that kind of flour which is called *feconds*; which alone is ufed, through the greateft part of England, for bread, and which makes, indeed, the beft of all bread, though not the whiteft. A peck of this flour, weighing 14 lb. will take up between fix and feven pints of water, and give 18 lb. of excellent bread; or a bufhel of flour, weighing 56 lb. will yield 72 lb. of bread. The expence of baking a bufhel of fuch flour is, in Effex and fome other Englifh counties, about ninepence; viz. yeaft, on an average, twopence; falt, before the late tax, one halfpenny; and baking, fixpence.

But

Bread.

But *ſeconds* is not all that is got from wheat. A buſhel of 60 lb. of wheat gives, beſides $45\frac{1}{2}$ lb. of ſeconds, 13 lb. of offal, i. e. of *pollards* and *bran;* for the utmoſt loſs in grinding and dreſſing a buſhel of wheat ſhould not exceed 1 pound 8 ounces. The millers, indeed, uſually reckon on two pounds of loſs; but we can ſay, with the utmoſt confidence, that the actual loſs is rather leſs than we have ſtated it. A correſpondent of ours, on whoſe accuracy we can depend, weighed, in 1795, two buſhels, Wincheſter meaſure, the one of white and the other of red wheat, and found the weight of them both to be 122 lb. This wheat was ground by his own ſervants, and it yielded $121\frac{1}{2}$ pounds of meal, ſo that there was here but $\frac{1}{2}$ lb. loſt of two buſhels, or of 122 lb. in grinding. He admits that he ſuffered the ſtones to turn too cloſe, and that the loſs ſhould therefore have been ſomewhat greater. The meal was dreſſed, as the wheat had been ground, under his own eye; and every poſſible precaution being taken to prevent his being deceived in the reſult, he had of flour, or *ſeconds*, $93\frac{1}{2}$ lb. and of bran and pollard $25\frac{1}{2}$ lb. ſo that he loſt, of two buſhels, but $2\frac{1}{2}$ lb. both in grinding and dreſſing. The offal, or bran and pollard, being dreſſed in a bolting mill, yielded as follows:

Sharps -	6 lb.	0 oz.
Fine pollard	5	8
Coarſe pollard	7	8
Broad bran	5	8
Altogether	24	8

There was loſt, therefore, in bolting, only one pound; and of the ſharps, about three pounds, if ſifted, would have been good flour. Indeed were the ſharps and fine pollard to be added to the flour, the bread would, perhaps, be better, and more wholeſome, than without ſuch addition. From theſe data, which we believe to be very accurate, it will be eaſy to calculate, if the price of wheat be given, what ſhould be the price of flour per buſhel and peck, the price of bread per pound, and the quantity of bread that ſhould be ſold for a ſhilling.

It is a fact, however, which ſhould be attended to, that loaves are not always of the ſame weight, though made of equal quantities of the very ſame dough. This was fully aſcertained ſome years ago at Paris. On a violent complaint that the bread was not always of the ſame ſtandard weight, the bakers of the city were called before the police officers. They admitted the fact, that loaves, baked at the ſame time, and in the ſame oven, were ſeldom, if ever, of the ſame weight; but they inſiſted, that they contained, each, the ſtandard quantity of dough, and that the variety of weight among them muſt proceed from ſome cauſe, which they did not pretend to aſcertain. The matter was referred to the Royal Academy of Sciences, which appointed one of its members to ſuperintend, for ſome days, the whole proceſs of baking. This being done it was found, that, of loaves baked in a large oven, thoſe were always heavieſt which occupied the centre of the oven, and that the bakers were innocent of the crime with which they were charged. The fact, we think, may eaſily be accounted for. Even in an oven there muſt be ſome condenſation of ſteam; and, from the very ſhape of the oven, the greateſt quantity muſt be condenſed towards the centre. Hence the loaves in the centre are neceſſarily wetter and heavier than thoſe round the circumference, if the plain of the oven has been equally heated.

Bread.

Bread *of Rice* might occaſionally be of great uſe in many countries during a ſcarcity of wheat; but the method of making it is not generally known. It is indeed impoſſible to make bread of the flour of rice, which is harſh and dry like ſand or aſhes, by treating it in the manner in which wheat-flour is commonly treated; and therefore it has been propoſed to mix it with an equal quantity of the flour of rye. But this method of uſing the flour of rice is a very uncertain remedy in caſe of want; ſince we can have no rice-bread if we have not rye. We are taught, however, in the *Journal des Sciences, des Lettres, et des Arts*, how to make excellent bread from rice alone, by a method which the author of the memoir ſays he learned from the natives of America.

According to this method of making the wiſhed-for bread, the firſt thing to be done to the rice is, to reduce it to flour, by grinding it in a mill, or, if we have not a mill, it may be done in the following manner: Let a certain quantity of water be heated in a ſaucepan or caldron; when the water is near boiling, let the rice we mean to reduce into flour be thrown into it: the veſſel is then to be taken off the fire, and the rice left to ſoak till the next morning. It will then be found at the bottom of the water, which is to be poured off, and the rice put to drain upon a table placed in an inclined poſition. When it is dry, it muſt be beat to powder, and paſſed through the fineſt ſieve that can be procured.

When we have brought the rice into flour, we muſt take as much of it as may be thought neceſſary, and put it into the kneading-trough in which bread is generally made. At the ſame time we muſt heat ſome water in a ſaucepan or other veſſel, and, having thrown into it ſome handfuls of rice, we muſt let them boil together for ſome time: the quantity of rice muſt be ſuch as to render the water very thick and glutinous. When this glutinous matter is a little cooled, it muſt be poured upon the rice-flour, and the whole muſt be well kneaded together, adding thereto a little ſalt, and a proper quantity of leaven. We are then to cover the dough with warm cloths, and to let it ſtand that it may riſe. During the fermentation, this paſte (which, when kneaded, muſt have ſuch a proportion of flour as to render it pretty firm) becomes ſo ſoft and liquid that it ſeems impoſſible it ſhould be formed into bread. It is now to be treated as follows:

While the dough is riſing, the oven muſt be heated: and, when it is of a proper degree of heat, we muſt take a ſtewpan of tin, or copper tinned, to which is fixed a handle of ſufficient length to reach to the end of the oven. A little water muſt be put into this ſtewpan, which muſt then be filled with the fermented paſte, and covered with cabbage or any other large leaves, or with a ſheet of paper. When this is done, the ſtewpan is to be put into the oven, and puſhed forward to the part where it is intended the bread ſhall be baked; it muſt then be quickly turned upſide down. The heat of the oven acts upon the paſte in ſuch a way as to prevent its ſpreading, and keeps it in the form the ſtewpan has given it.

In this manner pure rice-bread may be made; it

comes

comes out of the oven of a fine yellow colour, like paſtry which has yolk of eggs over it. It is as agreeable to the taſte as to the ſight; and may be made uſe of, like wheat-bread, to put into broth, &c. It muſt, however, be obſerved, that it loſes its goodneſs very much as it becomes ſtale.

It may be here remarked, that the manner in which Indian corn is uſed in ſome countries, for making bread, can only produce (and does in fact produce) very bad dough, and of courſe very bad bread. To employ it advantageouſly, it ſhould be treated like rice; and it may then be uſed, not only for making bread, but alſo for paſtry.

BREAKNECK *Hill*, oppoſite Butterhill, at the northern entrance of the highlands, in Hudſon River, about 60 miles N. of New-York. On the S. ſide of this hill, about half the diſtance as you aſcend it, the rocks are ſo ſituated as to give the ſpectator a tolerable idea of a human face, with a noſe, mouth and double chin, but without a forehead. On the noſe grows a tree of conſiderable ſize, which has the appearance only of a ſhrub.—*Morse.*

BREWING is an art of vaſt importance, and has accordingly been explained in the Encyclopædia. A few improvements, however, have been made in the art, which, though not noticed in that Work, ſeem to be worthy of general attention, and, therefore, to deſerve a place in this Supplement. The firſt, of which we ſhall give an account, is an invention of Mr WILLIAM KER of *Kerfield*, in the county of Tweedale, for the ſaving of hops, and, at the ſame time, giving to the liquor, whether ale, beer, or porter, a ſuperior flavour and quality.

The ſteam which ariſes from the boiling copper is known to be ſtrongly impregnated with the eſſential oil of the hops, in which their flavour conſiſts. Inſtead, therefore, of allowing it to eſcape and evaporate, as it does in the common mode of brewing, Mr Ker contrives to preſerve and condenſe it, by means of a winding-pipe fixed to the copper, ſimilar to the worm of a ſtill, or by a ſtraight pipe paſſing through cold water, or any other cooling medium. The oil and water, thus obtained, are returned into the worts when boiled, or the oil, after being ſeparated from the water, along with which it had been exhaled, is returned into the worts after they are boiled; and the watery part, which, after the oil is ſeparated, ſtill continues impregnated with the aromatic taſte and bitter of the hop, is returned into the next copper or boiling-veſſel; and ſo on from one copper or boiling-veſſel into another. By this proceſs a conſiderable part of the hop and flavour, which is loſt in the ordinary mode of brewing, is preſerved: the flavour of the liquor is improved by the preſervation of the finer parts of the aromatic oil: and the ale and beer are better ſecured from any tendency to acidity or putrefaction, and therefore muſt be fitter for home conſumption and exportation. For this invention, which is certainly ſimple, and we think rational, Mr Ker obtained a patent dated March 4. 1788.

On the 4th of June 1790, Mr JOHN LONG of *Longville*, in the county of *Dublin*, Ireland, obtained a patent for an improvement in brewing, reſembling in one particular, this invention of Mr Ker's. To his invention, however, he gives the name of *an entire new method*, in *all the eſſential parts*, of brewing good malt-liquor; and therefore, as it comprehends the whole proceſs of brewing, we ſhall lay it before our readers in the words of its author.

" 1. For the better extracting from malt, place near a maſh-tun a ſhallow copper or other veſſel that will readily heat; the curb of which to be on a level with the tun, and to contain from two to ſix hogſheads, according to the dimenſion of the tun, more or leſs; and, at the lower end of the copper, have a cock from two to five inches diameter, more or leſs, to conduct the heated liquor from the copper into a tube which paſſes down the external part of the tun, and enters it through an aperture about ſix inches from the bottom; then forming two revolutions, more or leſs, through the body of the tun, and communicating its heat to the wort as it paſſes through the tube; and then, at a convenient diſtance from the place it firſt entered, it runs from the tun into a ciſtern or tub, ſituate as near as convenient to the copper or heating-veſſel. In the tub or ciſtern is to be placed a pump, for the purpoſe of conveying the cooler liquor back to the copper or heating-veſſel again; there to receive the heat of 208 degrees, more or leſs (which it will require after the firſt half-hour), and then convey it through the maſhing-tun as before, and in the ſame manner, as long as the working brewer or diſtiller may think neceſſary, to raiſe the maſhing-tun to any degree of heat required. By adhering to the foregoing proceſs, the firſt liquor may, with the greateſt ſafety, be let upon the malt from 20 to 30 degrees lower than the preſent practice; by which means it operates with gentleneſs, opens and expands the malt and raw corn, and prepares it for the reception of ſharper or warmer liquor, ſo as to extract the whole of the ſaccharine quality from the malt and raw corn. By the foregoing method, the maſhing-tun, inſtead of loſing its firſt heat (which it does by the preſent practice), continues to increaſe in heat every moment, by conveying the heated liquor through the tube into the tun; by which means, at the end of two hours, the working brewer or diſtiller can have the tun brought to any degree of heat he ſhall think beſt ſuited to the different qualities of the malt or raw corn. Perſons who would wiſh to ſave expence, may heat their maſhing-tun at the ſide or bottom by a large piece of metallic ſubſtance made fire proof, and fixed therein; which, in ſome degree, will anſwer the end propoſed, but with great trouble and delay.

" 2. To prevent the wort from receiving a diſagreeable flavour while in the under-back, a tube muſt be placed at the cock of the maſhing-tun, to receive the wort as it comes off, and convey it to a great ciſtern or refrigeratory, which is ſupplied with a ſtream of water. The wort, paſſing through that medium in a ſpiral tube, ſoon loſes that heat which ſo often proves prejudicial to the brewer and diſtiller in warm weather: then paſs it from the tube into a veſſel in which pumps are placed, to return the worts into the copper for the purpoſe of boiling off. All veſſels for receiving the cold wort muſt be placed lower than the ſource whence the wort comes.

" 3. As the great object of long boiling the wort is remedied, by my invention of taking the extract from the hops in a ſeparate manner from the worts, I boil my worts no longer than from 15 to 20 minutes; and, by purfuing that method, I fave much time and fuel, and regulate my lengths accordingly.

"4. I fteep my hops, the preceding day to which they are to be ufed, in a copper or other veffel, with as much fluid, blood-warm, as will cover the hops, where it is to remain over a flow fire at leaft 14 hours, clofe covered; the copper at the tenth hour not to be of a greater heat than 175 degrees, continuing flow until the laft hour. Then I bring the copper gradually to a fimmer or flow boil; in which ftate I let it remain about 10 minutes, and then run off the fluid; and this I do at the fame time the firft wort is boiled off, that they may both pafs together through the refrigeratory into the fermentation or working-tun. After the foregoing operation, I cover the hops again with other liquor, and bring the copper to boil as foon as convenient, and let it remain in that ftate a confiderable time, until the fecond worts are boiled off. Then I pafs the hop-fluid with the wort, the fame as in the firft inftance; and, if there is a third wort, I boil my hops a third time with fmall worts and pafs it off as before; by which means I gradually obtain the whole of the effential oil and pleafing bitter from the hops, which is effectually preferved in the beer.

"5. To cool worts. When the wort is boiled off, it is conducted from the cock of the copper or boiler into a tube of a proper dimenfion, which paffes the wort from the cock to the large ciftern or refrigeratory, and there performs feveral revolutions, in a fpiral manner, through the fame tube; which is immerfed in conftant fupply of cold water, where it lofes the greateft part of its heat in a fhort time, and thence continues a ftraight courfe through the tube, a little elevated and of a fuitable length, placed in brick work, until it meets a fmall refrigeratory, fupplied with colder water from a refervoir made for that purpofe at the head of the works; whence a continual ftream runs on the furface of the tube down to the great refrigeratory, cooling the wort as it paffes, in order to enable the working brewer or diftiller to fend it into the backs or working-tuns at whatever degree of heat he fhall think proper. There is no other difference between brewer and diftiller in this procefs, but that the diftiller immediately paffes the ftrong wort from the mafhing-tun to the back, through the fame machinery above inferted, and the tubes may be made of lead, or any other metallic fubftance.

"6. To enable me to brew in the warm fummer months, I fink my backs or working tuns at leaft to a level with the ground, but if deeper the better, and cover them clofely by an arch made of bricks, or other materials, that will totally exclude the atmofpheric air from them. I place them as near as poffible to a fpring or fand-drain, as their depth will naturally draw the water thence, which muft be fo contrived as to pafs or flow round the backs or tuns. I then introduce a large tube, which paffes through the tuns, and keeps the wort feveral degrees lower than can poffibly be done by the prefent practice; by which means I can produce a complete fermentation even in the dog-days.

"7. In cold or frofty weather, if the tun and backs fhould lofe the firft heat, intended to carry it through the procefs by the foregoing method, you may convey a fupply of warm or boiling water by the tube, which paffes through the body of the backs or tun, communicating its heat. which rifes to any degree the working brewer fhall think proper: by purfuing this method, in the coldeft feafon, I never want a fermentation."

We regret that we cannot with propriety ftate to our readers, under this article, a fummary of Mr Richardfon of Hull's *Philofophical Principles of Brewing*; for as the author has a new edition of his work in the prefs, it is our duty rather to refer to it, than to quote from a former edition, which contains not his laft improvements. See Fermentation and Malt, in this Supplement.

BRIAR *Creek*, a water of Savannah River, in Georgia. Its mouth is about 50 miles S. E by S. from Augufta, and 55 N. wefterly from Savannah. Here Gen. Prevoft defeated a party of 2000 Americans, under Gen. Afh, May 3, 1779; they had above 300 killed and taken, befides a great number drowned in the river and fwamps. The whole artillery, baggage and ftores were taken.—*Morse.*

BRIDEALE. See Scotale in this Supplement.

BRIDGE. See that article *(Encycl.)*, and Arch in this Supplement. A *wooden*-bridge, of large fpan, fhould be conftructed on the principles explained under the title Roof *(Encycl.)* See alfo Centre *(Suppl.)*

BRIDGETOWN, in Cumberland co. diftrict of Maine, having Hebron on the N. W. and Bakerftown (on the W. fide of Androfcoggin River,) on the S. E. which three fettlements lie on the northern fide of Little Androfcoggin River. It contains 329 inhabitants and lies 34 miles N. by N W. from Portland; and 156 N. E. from Bofton. Bridgetown confifts of large hills and vallies: the highland affords red oak, which are often three feet and fometimes four, in diameter; and 60 or 70 feet without any branches. The vallies are covered with rock maple, bafs, afh, birch, pine, and hemlock. There is a curiofity to be feen in Long Pond, which lies moftly in Bridgetown, which may afford matter of fpeculation to the natural philofopher.

On the eafterly fide of the pond is a cove which extends about 100 rods farther E. than the general courfe of the fhore, the bottom is clay, and fo fhoal that a man may wade 50 rods into the pond. On the bottom of this cove are ftones of various fizes, which, it is evident from various circumftances, have an annual motion towards the fhore; the proof of this is the mark or track left behind them, and the bodies of clay driven up before them. Some of thefe ftones are 2 or 3 tons weight, and have left a track of feveral rods behind them; having at leaft a common cart-load of clay before them. The fhore of the cove is lined with thefe ftones, which, it would feem, have crawled out of the water.—*Morse.*

Bridgetown, Cumberland county, New-Jerfey, lies on both fides Cohanzie Creek, 20 miles from its mouth; and veffels of 100 tons can come up here. It has about 50 houfes, and a brifk trade. Another Bridgetown is on the great ftage road, between Philadelphia and New-York, 6 miles W. of Elizabeth town.—*ib.*

Bridgetown, a poft town in Queen Annes co. Maryland, lies on the weftern fide of Tuckahoe Creek, 8 miles E. from Centreville, as far S. E. from Church Hill, and 65 S. W. from Philadelphia.

Alfo the name of a town in Kent co. in the fame ftate, fituated on the N. bank of Chefter River, (which

feparates

feparates this county from that of Ann) 7 miles S. E. from Crofs Roads; and 4 foutherly from Newmarket. —*Morse.*

BRIDGEWATER, a townfhip in Grafton co. New-Hampfhire, incorporated in 1769, and contains 281 inhabitants.—*ib.*

BRIDGEWATER, a townfhip in Somerfet co. New-Jerfey, which contains 2,578 inhabitants, including 377 flaves.—*ib.*

BRIDGEWATER, a confiderable townfhip in Plymouth co. Maffachufetts, containing 4975 inhabitants; 5 miles N. E. from Raynham; about 30 miles E. of S. from Bofton, in which large quantities of hard ware, nails, &c. are manufactured.—*ib.*

BRIDGEWATER, a townfhip in Windfor co. Vermont, about 55 miles N. E. of Bennington, containing 293 inhabitants.—*ib.*

BRIDPORT, a townfhip in Addifon co. Vermont, on the E. fhore of Lake Champlain; about 72 miles N. N. W. from Bennington. It has 449 inhabitants. —*ib.*

BRIMFIELD, a townfhip in Hampfhire co. Maffachufetts, fituated E. of Connecticut River; having 1211 inhabitants; 34 miles S. E. of Northampton, and 75 W. of Bofton.—*ib.*

BRINDLEY (James), was born at Tunfted, in the parifh of Wormhill, Derbyfhire, in 1716. His father was a fmall freeholder, who diffipated his property in company and field amufements, and neglected his family. In confequence, young Brindley was left deftitute of even the common rudiments of education, and till the age of 17 was cafually employed in ruftic labours. At that period he bound himfelf apprentice to one Bennet, a mill-wright at Macclesfield, in Chefhire, where his mechanical genius prefently developed itfelf. The mafter being frequently abfent, the apprentice was often left for weeks together to finifh pieces of works concerning which he had received no inftruction; and Bennet, on his return, was often greatly aftonifhed to fee improvements in various parts of mechanifm, of which he had no previous conception. It was not long before the millers difcovered Brindley's merits, and preferred him in the execution of their orders to the mafter or any other workman. At the expiration of his fervitude, Bennet being grown into years, he took the management of the bufinefs upon himfelf, and by his fkill and induftry contributed to fupport his old mafter and his family in a comfortable manner.

In procefs of time Brindley fet up as a mill-wright on his own account; and by a number of new and ingenious contrivances greatly improved that branch of mechanics, and acquired a high reputation in the neighbourhood. His fame extending to a wider circle, he was employed, in 1752, to erect a water-engine at Clifton, in Lancafhire, for the purpofe of draining fome coal mines. Here he gave an effay of his abilities in a kind of work for which he was afterwards fo much diftinguifhed, driving a tunnel under ground through a rock nearly 600 yards in length, by which water was brought out of the Irwell for the purpofe of turning a wheel fixed 30 feet below the furface of the earth. In 1755 he was employed to execute the larger wheels for a filk mill at Congleton; and another perfon, who was engaged to make other parts of the machinery, and to fuperintend the whole, proving incapable of completing the work, the bufinefs was entirely committed to Brindley; who not only executed the original plan in a mafterly manner, but made the addition of many curious and valuable improvements, as well in the conftruction of the engine itfelf, as in the method of making the wheels and pinions belonging to it. About this time, too, the mills for grinding flints in the Staffordfhire potteries received various ufeful improvements from his ingenuity.

In the year 1756 he undertook to erect a fteam engine, upon a new plan, at Newcaftle-under-Line; and he was, for a time, very intent upon a variety of contrivances for improving this ufeful piece of mechanifm. But from thefe defigns he was, happily for the public, called away to take the lead in what the event has proved to be a national concern of capital importance—the projecting the fyftem of canal navigation. The Duke of Bridgewater, who had formed his defign of carrying a canal from his coal-works at Worfley to Manchefter, was induced by the reputation of Mr Brindley to confult him on the execution of it; and having the fagacity to perceive, and ftrength of mind to confide in, the original and commanding abilities of this felf-taught genius, he committed to him the management of the arduous undertaking. The nature of this enterprife has already been defcribed (*Encycl.* vol. IV. p. 80); it is enough here to mention, that Mr Brindley, from the very firft, adopted thofe leading principles, in the projecting of thefe works, which he ever after adhered to, and in which he has been imitated by all fucceeding artifts. To preferve as much as poffible the level of his canals, and to avoid the mixture and interference of all natural ftreams, were objects at which he conftantly aimed. To accomplifh thefe, no labour or expence was fpared; and his genius feemed to delight in overcoming all obftacles by the difcovery of new and extraordinary contrivances.

The moft experienced engineers upon former fyftems were amazed and confounded at his projects of aqueduct bridges over navigable rivers, mounds acrofs deep valleys, and fubterraneous tunnels; nor could they believe in the practicability of fome of thefe fchemes till they faw them effected. In the execution, the ideas he followed were all his own; and the minuteft, as well as the greateft, of the expedients he employed, bore the ftamp of originality. Every man of genius is an enthufiaft. Mr Brindley was an enthufiaft in favour of the fuperiority of canal navigations above thofe of rivers; and this triumph of art over nature led him to view with a fort of contempt the winding ftream, in which the lover of rural beauty fo much delights. This fentiment he is faid to have expreffed in a ftriking manner at an examination before a committee of the Houfe of Commons, when, on being afked, after having made fome contemptuous remarks relative to rivers, what he conceived they were created for? he anfwered, "to feed navigable canals." A direct rivalry with the navigation of the Irwell and Merfey was the bold enterprize of his firft great canal; and fince the fuccefs of that defign, it has become common, all over the kingdom, to fee canals accompanying, with infulting parallel, the courfe of navigable rivers.

After the fuccefsful execution of the Duke of Bridgewater's canal to the Merfey, Mr Brindley was employed in the revived defign of carrying a canal from that river

river to the Trent, through the counties of Chefter and Stafford. This undertaking commenced in the year 1766: and from the great ideas it opened to the mind of its conductor, of a fcheme of inland navigation which fhould connect all the internal parts of England with each other, and with the principal fea-ports, by means of branches from this main ftem, he gave it the emphatical name of the *grand trunk*. In executing this, he was called upon to employ all the refources of his invention, on account of the inequality and various nature of the ground to be cut through: in particular, the hill of Harecaftle, which was only to be paffed by a tunnel of great length, bored through ftrata of different confiftency, and fome of them mere quickfand, proved to be a moft difficult, as well as expenfive, obftacle, which, however, he completely furmounted. While this was carrying on, a branch from the grand trunk, to join the Severn near Bewdley, was committed to his management, and was finifhed in 1772. He alfo executed a canal from Droitwich to the Severn; and he planned the Coventry canal, and for fome time fuperintended its execution; but on account of fome difference in opinion he refigned that office. The Chefterfield canal was the laft undertaking of the kind which he conducted, but he only lived to finifh fome miles of it. There was, however, fcarcely any defign of canal-navigation fet on foot in the kingdom, during the latter years of his life, in which he was not confulted, and the plan of which he did not either entirely form, or revife and improve. All thefe it is needlefs to enumerate; but, as an inftance of the vaftnefs of his ideas, it may be mentioned, that, on planning a canal from Liverpool to join that of the duke of Bridgewater at Runcorn, it was part of his intention to carry it, by an aqueduct bridge, acrofs the Merfey, at Runcorn Gap, a place where a tide, fometimes rifing fourteen feet, rufhes with great rapidity through a fudden contraction of the channel. As a mechanic and engineer, he was likewife confulted on other occafions; as with refpect to the draining of the low lands in different parts of Lincolnfhire and the Ifle of Ely, and to the cleanfing of the docks of Liverpool from mud. He pointed out a method, which has been fuccefsfully practifed, of building fea-walls without mortar; and he was the author of a very ingenious improvement of the machine for drawing water out of mines by the contrivance of a lofing and a gaining bucket.

The intenfity of application which all his various and complicated employments required, probably fhortened his days; as the number of his undertakings, in fome degree, impaired his ufefulnefs. He fell into a kind of chronic fever, which, after continuing fome years, with little intermiffion, at length wore out his frame, and put a period to his life on September 27. 1772, in the 56th year of his age. He died at Tunhurft, in Staffordfhire, and was buried at New Chapel in the fame county.

In appearance and manners, as well as in acquirement, Mr Brindley was a mere peafant. Unlettered, and rude of fpeech, it was eafier for him to devife means for executing a defign than to communicate his ideas concerning it to others. Formed by nature for the profeffion he affumed, it was there alone that he was in his proper element; and fo occupied was his mind with his bufinefs, that he was incapable of relaxing in any of the common amufements of life. As he had not the ideas of other men to affift him, whenever a point of difficulty in contrivance occurred, it was his cuftom to retire to his bed, where, in perfect folitude, he would lie for one, two, or three days, pondering the matter in his mind till the requifite expedient had prefented itfelf. This is that true infpiration which poets have almoft exclufively arrogated to themfelves, but which men of original genius in every walk are actuated by, when, from the operation of the mind acting upon itfelf, without the intrufion of foreign notions, they create and invent.

A remarkably retentive memory was one of the effential qualities which Mr Brindley brought to his mental operations. This enabled him to execute all the parts of the moft complex machine in due order, without any help of models or drawings, provided he had once accurately fettled the whole plan in his mind. In his calculations of the powers of machines, he followed a plan peculiar to himfelf; but, indeed, the only one he could follow without inftruction in the rules of art. He would work the queftion fome time in his head, and then fet down the refult in figures. Then taking it up in this ftage, he would again proceed by a mental operation to another refult; and thus he would go on by ftages till the whole was finifhed, only making ufe of figures to mark the feveral refults of his operations. But though, by the wonderful powers of native genius, he was thus enabled to get over his want of artificial method to a certain degree, yet there is no doubt that when his concerns became extremely complicated, with accounts of various kinds to keep, and calculations of all forts to form, he could not avoid that perplexity and embarraffment which a readinefs in the proceffes carried on by pen and paper can alone obviate. His eftimates of expence have generally proved wide of reality; and he feems to have been better qualified to be the contriver, than the manager, of a great defign. His moral qualities were, however, highly refpectable. He was far above envy and jealoufy, and freely communicated his improvements to perfons capable of receiving and executing them; taking a liberal fatisfaction in forming a new generation of engineers able to proceed with the great plans in the fuccefs of which he was fo deeply interefted. His integrity and regard to the advantage of his employers were unimpeachable. In fine, the name of Brindley will ever keep a place among that fmall number of mankind who form eras in the art or fcience to which they devote themfelves, by a large and durable extenfion of its limits.

BRISSOT (J. P.), acted fo confpicuous a part in the French revolution, that a fair detail of the principal events of his life would undoubtedly be acceptable to all our readers. A fair detail, however, of fuch a life, we believe it impoffible at prefent to give; for characters like Briffot's are almoft always mifreprefented both by their friends and by their enemies; and till the troubles which they have excited, or in which they have been engaged, have long fubfided, the impartial truth is nowhere to be found.

In a fulfome panegyric, under the denomination of *The Life of J. P. Briffot*, faid to be written by himfelf, we are told, that he was born January 14, 1754, and that his father was a *traiteur*, or "the keeper of an eating-houfe," but in what place we are not informed.

Our

Briffot. Our anthor, however, affures us, that the old man was in eafy circumftances, and that he employed all the means refulting from them to give to his numerous family a good education. The fubject of this memoir was intended for the bar; but not relifhing the ftudies neceffary to fit him for the profeffion of the law, or, if we choofe to believe him, having a mind too *pure* and *upright* for the ftudy of *chicane*, he relinquifhed the purfuit after five years of drudgery!

To relieve his wearinefs and difguft, he applied himfelf, he fays, to literature and the fciences. The ftudy of the languages was above all others his favourite purfuit. Chance brought him acquainted with two Englifhmen on their travels through France: he learned their language; and this circumftance, he tells us, decided his fate.

" It was at the commencement of my paffion for that language (continues he) that I made the metamorphofis of a diphthong in my name, which has fince been imputed to me as fo heinous a crime. Born the thirteenth child of my family, and the fecond of my brothers in it, I bore, for the fake of diftinction, according to the cuftom of Beauce, the name of a village in which my father poffeffed fome landed property. This village was called *Ouarville*, and Ouarville became the name by which I was known in my own country. A fancy ftruck me that I would caft an Englifh air upon my name: and accordingly I fubftituted, in the place of the French diphthong *ou*, the *w* of the Englifh, which has precifely the fame found." For this puerile affectation, which was certainly not criminal, he juftifies himfelf by the example of the literati of the 16th and 17th centuries, who made no fcruple of Grecifing and Latinifing their appellatives.

Having profecuted his ftudies for two years, he had an application from the Englifh proprietor of a paper then much in circulation, and intitled *Le Courier de l'Europe*. This man having drawn upon himfelf an attack from government, felt and yielded to the neceffity of printing his paper at Boulogne-fur-mer. It was his wifh to render it interefting to the French in the department of mifcellaneous intelligence; which he therefore wifhed to fubmit to the fuperintendency and arrangement of Briffot, who reprefents himfelf as for fome moments hefitating. The profeffion of a journalift, fubject to a licenfer, was repugnant to his principles; yet it fecured his independence, and put into his power the means of profecuting an inveftigation of conftitutions and of the fciences. After fome ridiculous reafoning from the original ftations of *Bayle*, *Poftel*, and *Rouffeau*, he at laft accepted of the employment, and became enamoured of it, " becaufe (fays he) it enabled me to ferve talents and virtue, and, as it were, to inoculate the French with the principles of the Englifh conftitution.

This employment, however, did not laft for any length of time. The plan of the proprietor of the *Courier* was overthrown by adminiftration, and Briffot quitted Boulogne to return to his firft ftudies. Having informed us of this fact, he makes an extravagant pretence to unfullied virtue, and calls upon the inhabitants of the city which he had left to bear witnefs, not only that he had *no vices*, but that he had not even the *feeds* of any one of the vices which his adverfaries, it feems, had laid to his charge.

" Doubtlefs (fays he), too eager to publifh my ideas, I conceived that the proper moment had arrived, and I felt an inclination to commence with an important work. Revolting, from the very inftant of my beginning to reflect, againft religious and political tyranny, I folemnly protefted, that thenceforward I would confecrate my whole life to their extirpation. Religious tyranny had fallen under the redoubled ftrokes of Rouffeau, of Voltaire, of Diderot, and of D'Alembert. It became neceffary to attack the fecond;" and this was a tafk which the vanity of Briffot led him to confider as referved for him.

What Voltaire and his friends meant by religious tyranny, and how they conducted their attacks againft it, are matters, alas! too well known to all Europe; and as our author chofe thefe philofophers for his guides, we might infer, without much degree of miftake, what he underftood by political tyranny, and by what means he meditated its extirpation. But he has not left us to make this difcovery by inference.

" It became neceffary (fays he) to break in pieces the political idol, which under the name of *monarchy*, practifed the moft violent defpotifm; but to attack it openly, was to expofe the affailant without the poffibility of ferving mankind. It was by a fide blow that it was to be wounded moft effectually;" and therefore he refolved to begin his operations by attacking fome of thofe abufes which might be reformed without apparently fhaking the authority of the prince.

Our readers, at leaft the fober part of them, will probably think, that this mode of attack is not peculiar to Briffot, but that it has been practifed, or attempted to be put in practice, by afpiring demagogues in all ages and countries, who have uniformly begun their career of innovation by exciting the public mind againft thofe abufes in government, of which the exiftence cannot wholly be denied. The fubject to which our author thought fit to call the attention of his countrymen, was the criminal jurifprudence: a fubject, fays he, which, with the exception of fome particulars that had been fuccefsfully inveftigated by Beccaria and Servan, no writer had thoroughly confidered in a philofophical point of view. Thinking himfelf fully equal to this tafk, he drew up a general plan; and in the year 1780 publifhed his Theory of Criminal Laws, in two vols 8vo. This work, favourably received by foreigners, applauded by fome journalifts, and pulled to pieces by others, procured him the friendfhip of the warmeft advocates for human liberty, in whofe opinion the defects of his plan were highly pardonable, on account of the energy confpicuous in his remarks. This publication was foon followed by two difcourfes which gained the prize in 1782 at the Academy of Chalons-fur-Marne; the one upon the reform of the criminal laws, and the other on the reparation due to innocent perfons unjuftly accufed.

It is natural to fuppofe that the government beheld with an evil eye thefe writings, which, under pretext of dragging into light the abufes of the criminal laws, infinuated dangerous principles on the nature of government in general.

His next work was intitled, *A Philofophical Library of the Criminal Laws*, in 10 vols; the true object of which was to diffeminate in France thofe principles of liberty

Briſſot. liberty which guided the Engliſh and the Americans in framing and expounding their laws.

But the ſtudy of legiſlation and politics had not entirely drawn him off from that of other ſciences; ſuch as chemiſtry, phyſics, anatomy, theology, &c. Theſe he conſtantly cultivated with ardour; but acknowledges that in each he met with obſcurities, and that in every quarter truth eſcaped from his reſearches. He therefore ſat down to inveſtigate the nature of truth, and the proper method of attaining to it in every department of reſearch; and the reſult of his labours was a kind of *novum organum*, by which he ſeems to have expected that Bacon's work would be buried in oblivion; and to this important volume he gave the title of *Concerning Truth; or Thoughts on the Means of attaining Truth in all the Branches of Human Knowledge*. This volume was meant as nothing more than the introduction to a greater work, in which he propoſed to inveſtigate what is *certain* in knowledge and what *doubtful*, and then to ſtrike the balance of the account.

He was prevented, however, from completing his plan, which he regrets exceedingly; for, as he affirms, with *becoming modeſty*, his work would certainly have amended its readers! But the French government happened to think otherwiſe; his aim, which, he ſays, was to lead mankind to reflect on their rights, was perceived, and he was accuſed to the miniſter as a ſeditious writer. The career of genius was ſtopped by the dread of the Baſtile; and he was obliged to take refuge in London. There it was his wiſh to create *a univerſal confederation of the friends of liberty and truth*, and to eſtabliſh a *centre of correſpondence and union* with the learned and the politicians of Europe. This dark deſign, however, was fruſtrated by the treachery, as it would appear, of his aſſociates, who had bound themſelves, he ſays, by the moſt *ſacred oaths*, to aſſiſt him, and had offered to ſign articles *even with their own blood*.

Finding himſelf unable to proceed directly to the object which he had in view, he reſolved to *enlighten his* countrymen gradually, and to begin with exciting their love and admiration of the Engliſh conſtitution. That conſtitution, which he had inveſtigated on the ſpot, appeared to him a model for thoſe ſocieties which were deſirous of changing their form of government. It was but little known, he ſays, in France (the work of *De Lolme* being at that time only in the hands of the learned); and to make it known was to make it beloved, was to render it deſired. But the French miniſters ſtood upon their guard, and it became neceſſary to *deceive* them. He reſolved therefore to bring forward a journal, written actually in London, and profeſſing to contain only a *deſcription of the ſciences and arts of England*, whilſt the greater part of it was to be occupied in reality by an inveſtigation of the *Engliſh conſtitution*.

After many difficulties, the miniſtry granted a privilege for this journal, being publiſhed in London, to be reprinted in Paris; and it firſt appeared in 1784. "In the twelve numbers which have been publiſhed (ſays the author), the friends of liberty muſt have perceived, that if, on the one ſide, I endeavoured to inculcate more juſt ideas than had hitherto been entertained concerning this celebrated iſland; ſo, on the other, I reſolutely made my advances toward that important end which has perpetually preſided over all my labours, *the univerſal emancipation of men*."

His affairs calling him at this time to Paris, he was arreſted and conveyed to the Baſtile on the 12th of July 1784. In this conduct of the government we cannot perceive any thing very tyrannical or arbitrary, ſince he confeſſes, that in the 16th page of the firſt number of his Journal, he had ſuffered the *ſecret and favourite aim*, which always guided his pen, to become diſcernible. He was, however, diſcharged from priſon on the 5th of September, and returned with increaſed zeal to his former employments. Briſſot.

"This perſecution (ſays he), far from extinguiſhing the ardour of my wiſhes to inculcate the principles of freedom, ſerved only to inflame it the more." Accordingly, in 1785, he publiſhed two letters to the Emperor Joſeph II. *concerning the right of emigration, and the right of people to revolt*. The firſt of theſe letters, which, though well known in Germany, were in France ſuppreſſed by the *police*, was occaſioned by what the author calls the ridiculous and barbarous edict againſt emigration; and the ſecond by the puniſhment of *Horiah* the chief of the *Walachian* inſurgents. In this laſt letter he lays it down as a maxim, that all people under ſuch a government as that of the *Walachians*, have from nature a ſacred *right* to revolt, a right which they can and ought to exerciſe. In the ſame ſpirit he brought out, in 1786, his Philoſophical Letters on the Hiſtory of England, in 2 vols, and A Critical Examination of the Travels of the Marquis de Chatelleux in North America.

The French revolution appearing to him extremely diſtant, notwithſtanding all his efforts to haſten it, he reſolved to leave France for the purpoſe of ſettling in America. His project received the approbation of ſeveral, whoſe ſentiments were congenial with his own. But as it was thought imprudent to tranſport numerous families to a country ſo far off, without thoroughly knowing it, Briſſot was engaged to proceed thither, to examine the different places, to obſerve the inhabitants, and to diſcover where and in what manner the eſtabliſhment they had propoſed might be moſt advantageouſly fixed. He had ſome time before inſtituted a ſociety at Paris for accompliſhing the abolition of the negro trade, and for ſoftening the condition of the ſlaves. At the period of his departure, this ſociety conſiſted of a conſiderable number of diſtinguiſhed members, and he was commiſſioned to carry the firſt fruits of their labours to America. His ſtay there, however, was not ſo long as he was deſirous of making it. In the beginning of 1789 he was recalled by the news of the French revolution, which he conceived might probably produce a change in his own meaſures and in thoſe of his friends. This idea added to other circumſtances, accelerated his return. The fire had blazed forth in his native country. Hope (ſays he) animated every heart; the moſt diſtinguiſhed champions had engaged in the conteſt; I too became deſirous to break a lance, and I publiſhed my *Plan of Conduct for the Deputies of the People*."

This, and other works of a ſimilar kind, of which he loudly boaſts the merits, raiſed him high in the favour of the republican part of the nation, and he became preſident of his diſtrict; where he acted, according to his own account, with great uprightneſs in the municipality, in the firſt committee of enquiries, and as an elector. At laſt he became a member, firſt of the *National Aſſembly*, and after its diſſolution, of the *Sanguinary*

Briftol. *nary Convention*; and by fome means or other got to be the leader of a party called fometimes the *Girondifts*, and fometimes the *Briffotines*. From that period the principal events of his life were involved with the public tranfactions of the nation, of which we have given an account in the *Encyclopædia* under the title Revolution (fee that article, n° 101—182.) The Girondift faction was denounced by the Mountain, and Briffot fuffered by the guillotine on the 30th of November 1793. He fell indeed by a very unjuft fentence; but his fall was the natural confequence of that anarchical tyranny under which no man had contributed more than he to fubject his native country.

BRISTOL, a townfhip in Lincoln co. Diftrict of Maine, having 1718 inhabitants; diftant 204 miles N. E. from Bofton, and 8 N. of Pemaquid Point. —*Morse*.

Bristol, a county in the fouthern part of Maffachufetts, E. of a part of the ftate of Rhode Ifland. It has 15 townfhips, of which Taunton is the chief; and 31,709 inhabitants. The great fachem Phillip refided here; and it was called by the Indians *Pawkunnawkutt;* from which the nation derived the name; but were fometimes ftyled the *Wampoaags*.—*ib*.

Bristol, *Co*. in Rhode Ifland ftate, contains the townfhips of Briftol, Warren, and Barrington; having 3211 inhabitants, inclufive of 98 flaves. It has Briftol co in Maffachufetts, on the N. E. and Mount Hope bay E.—*ib*.

Bristol, a fea-port town, and chief of the above county, lies on the weftern fide of the peninfula called Briftol neck, and on the E. fide of Briftol bay; including Popafquafh neck, and all the N. and E. part of Briftol neck, to Warren, N.; and to Mount Hope bay, E. It is about 3 miles from Rhode Ifland; the ferry from the S. end of the townfhip being included, which is little more than half a mile broad; 13 miles northerly from Newport, 24 S. E. from Providence, and 63 from Bofton.—Briftol fuffered greatly by the ravages of the late war; but is now in a very flourifhing ftate, having 1406 inhabitants, inclufive of 64 flaves. It is beautiful for fituation—a healthful climate—rich foil, and a commodious, fafe harbor. Onions, in confiderable quantities, and a variety of provifions and garden ftuff, are raifed here for exportation. N. lat. .,0. 40.—*ib*.

Bristol, a townfhip in Hartford co. Connecticut, 16 miles W. of the city of Hartford.—*ib*.

Bristol, a town in Bucks co. Pennfylvania, 11 miles S. S. E. from Newtown, and 20 N. E. from Philadelphia. It ftands on Delaware River, oppofite Burlington, in New-Jerfey; and has about 50 or 60 houfes. It is a great thoroughfare, and is noted for its mills of feveral kinds.—*ib*.

Bristol, a townfhip in Philadelphia county.—*ib*.

Bristol, a fmall town in Charles county, Maryland.—*ib*.

Bristol, a townfhip in Addifon co. Vermont, E. of Vergennes, having 211 inhabitants.—*ib*.

Bristol *Bay*, on the N. W. coaft of N. America, is formed by the peninfula of Alafka on the S. and S. E. and by Cape Newnham on the N.; and is very broad and capacious. A river of the fame name runs into it from the E.—*ib*.

Brookfield || Brown.

BROOKFIELD, in the S. W. part of Worcefter co. Maffachufetts, is among the firft towns as to age, wealth and numbers, in the county; containing 3100 inhabitants. The great poft road from Bofton to N. York runs through it. It is 64 miles W. of Bofton and 27 W of Worcefter. The Indian name of this town was *Quaboag*. The river which ftill retains the name paffes through it; and like its other ftreams and ponds, abounds with various kinds of fifh. Here is iron ore, and large quantities of ftone which yield copperas, and have a ftrong vitriolic quality. This town was fettled by people from Ipfwich, in 1660, and was incorporated in 1673.—*ib*.

Brookfield, a townfhip in Orange co. Vermont, has 421 inhabitants, and lies 80 miles northerly from Bennington.—*ib*.

Brookfield, a townfhip in Lincoln co. diftrict of Maine, 14 miles above Norridgewalk on Kennebeck River, and was formerly called *Seven mile Brook*.—*ib*.

Brookfield, a town in Montgomery co. New-York. By the ftate cenfus of 1796, 160 of its inhabitants are electors.

Brookfield, a townfhip in Fairfield co. Connecticut, 6 miles N. N. E. from Danbury.—*ib*.

BROOKHAVEN, a townfhip in Suffolk co. Long Ifland, New-York, containing 3,224 inhabitants. Of thefe 233 are flaves; and by the ftate cenfus of 1796, 535 only are electors. The compact part of the town contains about 40 houfes, an Epifcopalian, and a Prefbyterian church. It is 60 miles E. of New-York.—*ib*.

BROOKLYN, a townfhip in Kings co. New-York, on the W. end of Long Ifland, having 1603 inhabitants; of thefe 405 are flaves; and 224 are electors, by the ftate cenfus of 1796. Here are a Prefbyterian church, a Dutch Reformed church, a powder magazine, and fome elegant houfes which lie chiefly on one ftreet. Eaft River, near a mile broad, feparates the town from New-York.—*ib*.

Brooklin, a townfhip in Wyndham co. Connecticut, about 20 miles N. of Norwich.—*ib*.

BROTHERTON, an Indian village adjoining New-Stockbridge, (N. York) inhabited by about 150 Indians, who migrated from different parts of Connecticut, under the care of the Rev. Mr Occom. Thefe Indians receive an annuity of 2160 dollars, which fum is partly appropriated to the purpofe of maintaining a fchool, and partly to compenfate a fuperintendant, to tranfact their bufinefs, and to difpofe of the remainder of their money for their benefit.—*ib*.

BROWN (Dr John), author of the *Elementa Medicinæ*, &c. was born in the village of Dunfe, or, as fome fay, Lintlaws, in the county of Berwick, in the year 1735-6. His parents were of mean condition, but much refpected in the neighbourhood for the integrity of their lives. His father gained his livelihood in the humble capacity of a day-labourer; while his mother contributed her fhare towards the fupport of the family by the profits arifing from a milch cow.

Such were the perfons who, in an obfcure part of the country, gave birth to a fon deftined, at a future period, to make a diftinguifhed figure in the republic of letters; and from whom originated a fyftem of the animal economy, which, whatever be its real merits, has undoubtedly produced a confiderable revolution in the practice of medicine.

Brown.

At the age of three or four years, young Brown was put to a reading ſchool in Dunſe, which he himſelf commemorates as the place rather of his education than of his nativity. Here, under the tuition of an old woman, he very early began to exhibit marks of that ſtrength of mind for which he was afterwards ſo eminently diſtinguiſhed. In the ſhort period of a year he became able to read with facility any part of the Bible, and acquired over his claſs-fellows that ſuperiority which he ever after maintained both at ſchool and college.

It was almoſt immediately after his entrance into this ſchool, that his inſatiable deſire of reading commenced; and ſo unremitting was his application, that he is ſaid never to have been found, even at thoſe hours which children much more advanced in life devote to amuſement, without a book in his hand.

While he was making this rapid progreſs in the rudiments of literature, he ſuffered what muſt have appeared to be a very heavy loſs in the death of his father; but his mother ſoon afterwards married a worthy man of the ſame name, whoſe care and attention ſupplied the place of a father to her ſon. This man being a weaver, deſigned to educate his ſon-in-law to the ſame buſineſs, and began to inſtruct him in his art when he was about nine years of age, but the taſte which young Brown had already acquired for letters, made him look with diſguſt on the inſipid employment of a weaver. His ſtep-father was no tyrant, and his mother was affectionate. They were both proud of the talents which at ſo early a period of life had appeared in their ſon, and they felt no inclination to ſtruggle with the invincible averſion which he expreſſed to the buſineſs for which they intended him.

Another circumſtance, however, contributed in no ſmall degree to make them recal their original reſolution. They were both of that ſect of religioniſts which in Scotland are called Seceders (ſee Seceders, *Encycl.*); and it was ſuggeſted to them by ſome perſons of their own perſuaſion, who had remarked the uncommon abilities of the boy, that he might one day prove an able ſupport and promoter of their tenets as a preacher. He was accordingly, much to his ſatisfaction, taken away from the buſineſs to which he had conceived ſuch a diſtaſte, and ſent to the grammar-ſchool of Dunſe, which was taught at that time by a gentleman of the name of Cruickſhank, eminent for his grammatical knowledge. Here he appears to have ſpent ſome years with uncommon advantage and happineſs; during which he was eſteemed by all the country round as a kind of prodigy. Like Johnſon, and many other men of the higheſt celebrity, he united in the ſame perſon uncommon powers of mind, with no leſs ſtrength of body, as indeed his appearance indicated; and in his youth he inſured his own perſonal importance among his ſchool-fellows, by excelling them not leſs in athletic exerciſes than in the taſks preſcribed by their maſter. He was particularly fond, when a boy, of practiſing the pugiliſtic art; and indeed until the laſt period of his life he was obſerved by his friends always to view an exhibition of that kind with peculiar reliſh. He alſo prided himſelf much in being a ſtout walker; and mentions his having, in one day, accompliſhed, when but fifteen years of age, a journey of fifty miles between Berwick-upon-Tweed and Morpeth in Northumberland. When farther advanced in life, he travelled on foot from four in the afternoon of one day to two in the afternoon of next day, with the ſhort interval of one hour's reſt! But as one of his biographers very juſtly obſerves, "we have ſeen that he could make a more rational uſe of his ſtrength than merely to ſtake it againſt time and ſpace.*"

His early years while at ſchool were marked by the moſt rigid attachment to his ſect. So ſtrict indeed were his religious ſentiments, if a boy of ten or eleven can be ſaid to have any ſentiments deſerving to be called religious, that he would have conceived the holding of any communion with the eſtabliſhed church as a kind of profanation. An event, however, happened, ſome time between the eleventh and thirteenth years of his age, which produced a total and unexpected revolution in his religious opinions. At a meeting of the provincial ſynod of Merſe and Teviotdale, he was prevailed upon, though not without manifeſting much reluctance, to accompany a party of his ſchool-fellows to the pariſh church of Dunſe. The conſequence of this tranſgreſſion, as he had dreaded, was an immediate ſummons to appear before the ſeſſion of the Seceding congregation; to which, through pride, not chooſing to attend, in order to preclude a formal expulſion, he voluntarily abjured their tenets, and openly avowed his apoſtacy to the eſtabliſhment.

All changes in religion which are not the conſequence of candid inveſtigation are dangerous. He who leaves one ſect he knows not why, will quickly abandon, with as little reaſon, that to which in a fit of paſſion he had haſtily joined himſelf. From the moment of his quitting the communion of the Seceders, Brown's religious ardour ſuffered a gradual abatement; and though, to pleaſe his mother, he continued to proſecute his ſtudies with a view to the office of a clergyman in the church of Scotland, his opinions became daily more and more lax, and his life of courſe leſs and leſs regular. It was, however, a conſiderable time before he admitted, in their full extent, thoſe principles of irreligion which he afterwards avowed; for upon his firſt peruſing the Eſſays of Mr Hume, though his own zeal was then much cooled, he expreſſed great indignation at their dangerous tendency.

At the age of twelve years he had been employed by Mr Cruickſhank as a kind of uſher in the ſchool of Dunſe; and that gentleman having declared that his knowledge of the Latin language was equal to his own, his fame as a ſcholar was ſo ſpread over the country, that at the age of thirteen he was entruſted with the education of a gentleman's ſon in the neighbourhood, when he quitted the ſchool and his beloved maſter. In his new ſituation, however, he remained not long. Dr Beddoes conjectures, that to the ſtiffneſs of pedantry he added the ſourneſs of a bigot, and was therefore a diſagreeable inmate of the family. That a boy of thirteen, proud of his talents, and prouder of his learning, ſhould have the ſtiffneſs of a pedant, is indeed extremely probable; it was the natural conſequence of the praiſe with which he had been honoured by Mr Cruickſhank: but there is reaſon to believe that of his original bigotry few traces now remained. The real cauſe of his diſmiſſion from the family, we are aſſured, was his pride; and as it muſt have been the pride of parts, it confirms the firſt part of Dr Beddoes's conjecture.

It ſeems he was much diſpleaſed that, when company were

* Dr Beddoes.

were at dinner, he was not defired to remain after the cloth was removed; and yet if he was then only thirteen years of age, it is not eafy to conceive for what purpofe he fhould have ftaid. He could not poffibly know much of the world, or of any thing likely to employ the converfation of country-gentlemen; and we cannot help thinking, that the mafter of the houfe would have treated his guefts with rudenefs had he detained among them a raw boy to liften to every unguarded expreffion which might efcape them over their wine. It would appear, however, that he was not unwilling to give the tutor of his fon an opportunity of difplaying his abilities, when fuch fubjects were introduced as he knew him to have ftudied; for a difpute having arifen, one day after Brown had retired to his own room, concerning the decrees of Providence, he fent to requeft his opinions on that abftrufe fubject. By the meffenger Brown returned a verbal anfwer, that "the decrees of Providence are very unjuft, for having made blockheads lairds."

Mr Cruickfhank had fome time before requefted him to return to the fituation which he had formerly held in the fchool of Dunfe; and we cannot wonder that, immediately after making this infolent anfwer, he found it convenient to comply with his requeft. He was now about fifteen, and he continued in the fchool till the 20th year of his age; during which time, from the conftant habit of teaching the Latin and Greek languages, he acquired a wonderful facility in reading both thefe languages, and in writing the former, though he wrote not with tafte.

About this time it occurred to him that he might turn his claffical acquirements to more account, by becoming a private teacher of languages in Edinburgh. To that city he accordingly repaired, where, while he obtained a livelihood as a teacher, he propofed at the fame time to purfue his theological ftudies at the univerfity. But an accident happened to him here which made him altogether change the plan he had come upon; and the death of his mother, after a refidence of fome time in Edinburgh, abfolved him, as he thought, from the promife which he had made to her of appearing one day in the pulpit. Shortly after an unfuccefsful competition for one of the chairs then vacant in the high-fchool, an application was made to a friend of his for a proper perfon to turn a medical thefis into Latin. Brown was recommended. He was limited to a certain time; within which it appeared fcarce practicable to perform the tafk. He accomplifhed it, however, and in fuch a ftyle of grammatical correctnefs and purity as far exceeded the general run of fuch productions. On this being remarked to him by his friends, he obferved, "that he now knew his ftrength, and was ambitious of riding in his carriage as a phyfician." He therefore determined to apply himfelf with ardour to the ftudy of medicine, to which this accidental circumftance alone directed his attention. Accordingly, at the commencement of the next winter feffion, he addreffed a Latin letter to each of the medical profeffors, and by them was prefented with tickets of admittance to their feveral claffes.

From fuch a favourable beginning, being of a very fanguine difpofition, he conceived the moft flattering expectations of his future fuccefs; and indeed for fome time he feems to have lived in affluent circumftances. His attainments were fo various, and in fuch requeft in Edinburgh, that as a fingle man he could fcarcely fail to gain a competent living; for during the laft five years of his refidence under Mr Cruickfhank, to a thorough acquaintance with ancient hiftory, he had added a very confiderable knowledge of mathematics; in which, among other branches of fcience, he never had any objection to give inftructions. In the acquifition of that variety of knowledge which he poffeffed, he was greatly affifted by a moft tenacious memory; to the retentivenefs of which an old fchool-fellow bears teftimony, by affirming, that "after once reading over the leffon, confifting of two octavo pages in Latin, he would lay afide the book, and prelect the whole over without miftaking a fingle word."

Brown, already in eafy circumftances for an individual, faw, or thought he faw, in the eftablifhment of a boarding-houfe for ftudents a refource which would enable him to maintain a family; and in expectation of realifing this profpect, he married in 1765, the daughter of a refpectable tradefman in Edinburgh. The diftinguifhed attention at that time paid him by Dr Cullen, in whofe family he had become a neceffary perfon, contributed in all probabillity to ftrengthen his hopes that his houfe would be filled with proper boarders through the Doctor's recommendation. His fuccefs in this way for fome time anfwered his moft fanguine expectations; and his circumftances at one period were fo flourifhing, that he is faid to have kept a one-horfe chaife.

It was, perhaps, the greateft misfortune that could have befallen Brown, that he poffeffed, in a high degree, thofe talents which make a man's company fought after by the gay and the diffipated: He was capable of "fetting the table in a roar." We need not therefore wonder at his frequently neglecting more neceffary purfuits to enjoy the conviviality of the numerous friends who courted his company; or that drinking and diffipation became habitual to him. He was as deficient in point of prudence as he excelled in genius. His houfe was filled with refpectable boarders; but as he lived too fplendidly for an income at beft but precarious, he became gradually involved in debt, and his affairs were ftill more embarraffed by the burden of a numerous family. Soon after he began to be involved in thefe difficulties, he fuffered an additional lofs in being deprived of the patronage of Dr Cullen, in confequence of a difagreement that had taken place between them. This enmity, which had for fome time before fecretly fubfifted, probably from mutual jealoufy, was a length excited into an open rupture; firft, by Dr Cullen's not exerting his intereft in procuring for Brown the theoretical chair of medicine, then vacant in confequence either of the death or refignation of Dr Alexander Monro Drummond; and, fecondly, by his rejecting, fome time after, Brown's petition for admittance into the Edinburgh Philofophical Society.

In 1776 Brown was elected prefident of the Medical Society; and the fame honour was again conferred on him in 1780. He was led on, in the gradual manner he himfelf defcribes in his mafterly preface to the *Elementa Medicinæ*, to the difcovery of his new doctrine; which, on dropping all correfpondence with his former friend and benefactor, he now, for the firft time, began to illuftrate in a courfe of public lectures; and in thefe he difplayed equal ingenuity and philofophical profundity.

dity. Much about the time of which we now ſpeak, he publiſhed the firſt edition of the *Elementa Medicinæ;* a work which certainly proves its author to have been a man of uncommon genius and originality of thought. The circumſtances in which this work was compoſed reflect great honour on his abilities. He never retired to his ſtudy; but, totally abſorbed in his own ideas, wrote with the greateſt tranquillity amidſt the noiſe of ten children, occaſionally ſettling their childiſh differences.

In the year 1779, though he had ſtudied medicine ten or twelve years at the univerſity of Edinburgh, he was prevailed upon by his friends to take a degree at St Andrews, where he gave a conſpicuous proof of his facility in Latin compoſition. He wrote a theſis, or inaugural diſſertation, in the tavern while the cloth was laying for dinner; and one of his companions, who was ſinging beſide him, having uttered a falſe note, or ſung out of time, Mr Brown, in the middle of his writing, ſtopped to ſhew him how the ſong ought to be ſung, and then inſtantly proceeded in his theſis.

His family having now become ſo numerous as to render keeping a boarding houſe inconvenient, he had already for ſome time given it up, and depended for ſupport entirely on his practice as a phyſician and his public lectures. At this time, the diſputes between the Cullenians and the Brunonians (as the young men now ſtyled themſelves) were carried on with ſuch acrimony on both ſides, in the different ſocieties, that it was not unuſual for them to terminate in duels; and there exiſts at this day, on the records of the Medical Society, a law which it was thought expedient to enact, by which a member who challenges another for any thing ſaid in public debate incurs the penalty of expulſion.

Obſerving the ſtudents of medicine frequently to ſeek initiation into the myſteries of free-maſonry, Dr Brown thought their youthful curioſity afforded him a chance of proſelytes. In 1784, he inſtituted a meeting of that fraternity, and intitled it *the Lodge of the Roman Eagle.* The buſineſs was conducted in the Latin language, which he ſpoke with the ſame fluency as Scotch; and he diſplayed much ingenuity in turning into Latin all the terms uſed in maſonry.

As the terms on which he lived with his brethren of the faculty were ſuch that he obſtinately avoided meeting them even in conſultation, we may conclude that his own private practice was but limited. His friends affirmed, perhaps without ſufficient proof, that cabals were formed againſt him, and every advantage taken of the errors he was led to commit by his own imprudence. After a long ſeries of ſtruggles, therefore, hoping to meet with that encouragement among the Engliſh of which he had been diſappointed in his own country, he put in practice a plan upon which he had long meditated, and removed in 1786 with part of his family to London. Immediately on his arrival, an incident befel him, which Dr Beddoes ſays he has heard the late Mr Murray, bookſeller in Fleet-ſtreet, relate as a proof of his ſimplicity. The peculiarity of his appearance, as he moved along a (a ſhort ſquare figure, with an air of dignity, in a black ſuit, which heightened the ſcarlet of his cheeks and noſe) fixed the attention of ſome *gentlemen* in the ſtreet. They addreſſed him in the dialect of his country. His heart, heavy as it muſt have been, from the precariouſneſs of his ſituation, and diſtance from his accuſtomed haunts, expanded at theſe agreeable ſounds. A converſation enſued; and the parties, by common conſent, adjourned to a tavern. Here the ſtranger was kindly welcomed to town; and, after the glaſs had circulated for a time, ſomething was propoſed by way of ſober amuſement—a game at cards, or whatever the Doctor might prefer. The Doctor had been too civilly treated to demur; but his purſe was ſcantily furniſhed, and it was neceſſary to quit his new friends in ſearch of a ſupply. Mr Murray was a perſon to whom he had recourſe: the reader will not wonder that his interference ſhould have ſpoiled the adventure.

A London ſharper, of another denomination, afterwards tried to make advantage by the Doctor. This was an ingenious ſpeculator in public medicines. He thought a compoſition of the moſt powerful ſtimulants might have a run, under the title of *Dr Brown's exciting pill;* and, for the privilege of his name, offered him a ſum in hand by no means contemptible, as well as a ſhare of the contingent profits. Poor Brown, needy as he was, ſpurned at the propoſal.

After this period, his life affords little variety of incident. Like Avicenna, his time ſeems to have been ſpent between his literary purſuits and his pleaſures. A ſplendid manner of living, without an income to ſupport it, had become habitual to him: The conſequence was, that, from inability to diſcharge certain debts he had contracted, he was thrown into the king's bench priſon; from which, however, he was, not long afterwards, releaſed by the exertions of a few firm friends, particularly Mr Maddiſon of Charing-croſs, a gentleman univerſally reſpected for his well known benevolence. As a proof of the activity he was ſtill capable of exerting, it will be ſufficient to mention, that he accompliſhed the tranſlation of his *Elementa,* with the addition of the ſupplementary notes, within 23 days, having been informed that a tranſlation of the ſame was about to be publiſhed by another perſon.

Shortly before his death, the ambaſſador of the king of Pruſſia, in the name of his maſter, made Dr Brown an offer of a ſettlement in the court of Berlin; during the negociation of which, he was unexpectedly cut off by an apoplexy early in the morning of the 7th of October 1788, the day ſucceeding that on which he had delivered to a company of thirteen gentlemen the greater part of the introductory lecture to his ſecond courſe. At his death, he was between 52 and 53 years of age. His remains were interred in the church-yard of St James's, Picadilly; and the only monument left behind him to tranſmit his name to poſterity is his own works; which, when perſonal prejudice no longer ſhall prevail againſt their ingenious author, cannot fail to procure him all that deſerved celebrity which they have already, in part, obtained in the different countries of Europe.

In 1787, he publiſhed his "Obſervations," without his name, which he afterwards, however, refers to in the Elements as his own. The "Enquiry," ſaid to be written by Dr Jones, and which was compoſed in as ſhort a time as the generality of men would tranſcribe a work of its extent, we can affirm, from undoubted authority, to be his production.

This ſketch of the life of the unfortunate Dr Brown would be of very little value, if not followed by a view of of his fyftem ; but to give a complete view of that fyftem would far exceed the limits within which, in a work like this, fuch articles muft be confined. We truft, therefore, that our readers will be fatisfied with an abftract ; and as we are neither the partifans nor opponents of the Doctor, and not very partial to any medical *fyftem* whatever, we fhall content ourfelves with inferting, in this place, the view which Dr Beddoes has given of Dr Brown's fundamental propofitions in the valuable obfervations which he has prefixed to his edition of the Elements of Medicine.

" The varied ftructure of organized beings (fays Dr Beddoes), it is the bufinefs of anatomy to explain. Confcioufnefs, affifted by common obfervation, will diftinguifh animated from inanimate bodies with precifion more than fufficient for all the ends of medicine. The caufe of gravitation has been left unexplored by all prudent philofophers ; and Brown, avoiding all ufelefs difquifition concerning the caufe of vitality, confines himfelf to the phenomena which this great moving principle in nature may be obferved to produce. His moft general propofitions are eafy of comprehenfion.

" 1. To every animated being is allotted a certain portion only of the quality or principle on which the phenomena of life depend. This principle is denominated *excitability*.

" 2. The excitability varies in different animals, and in the fame animal at different times. As it is more intenfe, the animal is more vivacious or more fufceptible of the action of exciting powers.

" 3. Exciting powers may be referred to two claffes. 1. External, as heat, food, wine, poifons, contagions, the blood, fecreted fluids, and air. 2. Internal ; as the functions of the body itfelf, mufcular exertion, thinking, emotion and paffion.

" 4. Life is a forced ftate ; if the exciting powers are withdrawn, death enfues as certainly as when the excitability is gone.

" 5. The excitement may be too great, too fmall, or in juft meafure.

" 6. By too great excitement, weaknefs is induced, becaufe the excitability becomes defective ; this is *indirect debility :* when the exciting powers or ftimulants are withheld, weaknefs is induced; and this is *direct debility*. Here the excitability is in excefs.

" 7. Every power that acts on the living frame is ftimulant, or produces excitement by expending excitability. Thus, although a perfon, accuftomed to animal food, may grow weak if he lives upon vegetables, ftill the vegetable diet can only be confidered as producing an effect, the fame in kind with animal, though inferior in degree. Whatever powers, therefore, we imagine, and however they vary from fuch as are habitually applied to produce due excitement, they can only weaken the fyftem by urging it into too much motion, or fuffering it to fink into languor.

" 8. Excitability is feated in the medullary portion of the nerves, and in the mufcles. As foon as it is any where affected, it is immediately affected every where; nor is the excitement ever increafed in a part, while it is generally diminifhed in the fyftem ; in other words, different parts can never be in oppofite ftates of excitement.

" I have already fpoken of an illuftration, drawn up by Mr Chriftie from a familiar operation, to facilitate the conception of Brown's fundamental pofitions. I introduce it here as more likely to anfwer its purpofe than if feparately placed at the end of my preliminary obfervations. ' Suppofe a fire to be made in a grate, filled with a kind of fuel not very combuftible, and which could only be kept burning by means of a machine containing feveral tubes, placed before it, and conftantly pouring ftreams of air into it. Suppofe alfo a pipe to be fixed in the back of the chimney, through which a conftant fupply of frefh fuel was gradually let down into the grate, to repair the wafte occafioned by the flame, kept up by the air machine.

' The grate will reprefent the human frame ; the fuel in it, the matter of life—the excitability of Dr Brown, and the fenforial power of Dr Darwin ; the tube behind, fupplying frefh fuel, will denote the power of all living fyftems, conftantly to regenerate or reproduce excitability ; while the air machine, of feveral tubes, denotes the various ftimuli applied to the excitability of the body ; and the flame drawn forth in confequence of that application reprefents life, the product of the exciting powers acting upon the excitability.

' As Dr Brown has defined life to be *a forced ftate*, it is fitly reprefented by a flame forcibly drawn forth from fuel little difpofed to combuftion, by the conftant application of ftreams of air poured into it from the different tubes of a machine. If fome of thefe tubes are fuppofed to convey pure or dephlogifticated air, they will denote the higheft clafs of exciting powers, opium, mufk, camphor, fpirits, wine, tobacco, &c. the diffufible ftimuli of Dr Brown, which bring forth for a time a greater quantity of life than ufual, as the blowing in of pure air into a fire will temporarily draw forth an uncommon quantity of flame. If others of the tubes be fuppofed to convey common or atmofpheric air, they will reprefent the ordinary exciting powers, or ftimuli, applied to the human frame, fuch as heat, light, air, food, drink, &c. while fuch as convey impure and inflammable air may be ufed to denote what have formerly been termed fedative powers, fuch as poifons, contagious miafmata, foul air, &c.

' The reader will now probably be at no lofs to underftand the feeming paradox of the Brunonian fyftem ; that food, drink, and all the powers applied to the body, though they fupport life, yet confume it ; for he will fee, that the application of thefe powers, though it brings forth life, yet at the fame time it waftes the excitability or matter of life, juft as the air blown into the fire brings forth more flame, but waftes the fuel or matter of fire. This is conformable to the common faying, " the more a fpark is blown, the brighter it burns, and the fooner it is fpent." A Roman poet has given us, without intending it, an excellent illuftration of the Brunonian fyftem, when he fays,

" *Balnea, vina, Venus, confumunt corpora noftra ;*
" *Sed vitam faciunt balnea, vina, Venus.*

" Wine, warmth, and love, our vigour drain ;
" Yet wine, warmth, love, our life fuftain."

Or to tranflate it more literally,

" Baths, women, wine, exhauft our frame ;
" But life itfelf is drawn from them."

' Equally eafy will it be to illuftrate the two kinds of of debility, termed *direct* and *indirect*, which, according to Brown are the cause of all diseases. If the quantity of stimulus, or exciting power, is proportioned to the quantity of excitability, that is, if no more excitement is drawn forth than is equal to the quantity of excitability produced, the human frame will be in a state of health, just as the fire will be in a vigorous state when no more air is blown in than is sufficient to consume the fresh supply of fuel constantly poured down by the tube behind. If a sufficient quantity of stimulus is not applied, or air not blown in, the excitability in the man, and the fuel in the fire, will accumulate, producing direct debility; for the man will become weak, and the fire low. Carried to a certain degree, they will occasion death to the first, and extinction to the last. If, again, an over proportion of stimulus be applied, or too much air blown in, the excitability will soon be wasted, and the matter of fuel almost spent. Hence will arise indirect debility, producing the same weakness in the man, and lowness in the fire, as before, and equally terminating, when carried to a certain degree, in death and extinction.

'As all the diseases of the body, according to Dr Brown, are occasioned by direct or indirect debility, in consequence of too much or too little stimuli, so all the defects of the fire must arise from direct or indirect lowness, in consequence of too much or too little air blown into it. As Brown taught that one debility was never to be cured by another, but both by the more judicious application of stimuli, so will be found the case in treating the defects of the fire. If the fire has become low, or the man weak, by the want of the needful quantity of stimulus, more must be applied, but very gently at first, and increased by degrees, lest a strong stimulus applied to the accumulated excitability should produce death; as in the case of a limb benumbed with cold (that is, weakened by the accumulation of its excitability in consequence of the abstraction of the usual stimulus of heat), and suddenly held to the fire, which we know from experience is in danger of mortification, or as in the case of the fire becoming very low by the accumulation of the matter of fuel, when the feeble flame, assailed by a sudden and strong blast of air, would be overpowered and put out, instead of being nourished and increased. Again, if the man or the fire have been rendered indirectly weak, by the application of too much stimulus, we are not suddenly to withdraw the whole, or even a great quantity of the exciting powers or air, for then the weakened life and diminished flame might sink entirely; but we are by little and little to diminish the overplus of stimulus, so as to enable the excitability, or matter of fuel, gradually to recover its proper proportion. Thus a man who has injured his constitution by the abuse of spirituous liquors is not suddenly to be reduced to water alone, as is the practice of some physicians, but he is to be treated as the judicious Dr Pitcairn of Edinburgh is said to have treated a Highland chieftain, who applied to him for advice in this situation. The Doctor gave him no medicines, and only exacted a promise of him, that he would every day put in as much wax into the wooden *queich*, out of which he drank his whisky, as would receive the impression of his arms. The wax thus gradually accumulating, diminished daily the quantity of the whisky, till the whole *queich* was filled with wax; and the chieftain was thus gradually, and without injury to his constitution, cured of the habit of drinking spirits.

'These analogies might be pursued farther; but my object is solely to furnish some general ideas, to prepare the reader for entering more easily into the Brunonian theory, which I think he will be enabled to do after perusing what I have said. The great excellence of that theory, as applied, not only to the practice of physic, but to the general conduct of the health, is, that it impresses on the mind a sense of the impropriety and danger of going from one extreme to another. The human frame is capable of enduring great varieties, if time be given it, to accommodate itself to different states. All the mischief is done in the transition from one state to another. In a state of low excitement we are not rashly to induce a state of high excitement, nor when elevated to the latter, are we suddenly to descend to the former, but step by step, and as one who from the top of a high tower descends to the ground. From hasty and violent changes, the human frame always suffers; its particles are torn asunder, its organs injured, the vital principle impaired, and disease, often death, is the inevitable consequence.

'I have only to add, that though in this illustration of the Brunonian system (written several years ago), I have spoken of a tube constantly pouring in fresh fuel, because I could not otherwise convey to the reader a familiar idea of the power possessed by all living systems, to renew their excitability when exhausted; yet it may be proper to inform the student, that Dr Brown supposed every living system to have received at the beginning its determinate portion of excitability; and, therefore, although he spoke of the exhaustion, augmentation, and even renewal of excitability, I do not think it was his intention to induce his pupils to think of it as a kind of fluid substance existing in the animal, and subject to the law by which such substances are governed. According to him, excitability was an unknown *somewhat*, subject to peculiar laws of its own, and whose different states we were obliged to describe (though inaccurately) by terms borrowed from the qualities of material substances.'

"The Brunonian system has frequently been charged with promoting intemperance. The objection is serious; but the view already given of its principles shews it to be groundless. No writer had insisted so much upon the dependence of life on external causes, or so strongly stated the inevitable consequences of excess. And there are no means of promoting morality upon which we can rely, except the knowledge of the true relations between man and other beings or bodies. For by this knowledge we are directly led to shun what is hurtful, and pursue what is salutary: and in what else does moral conduct, as far it regards the individual, consist? It may be said that the author's life disproves the justness of this representation: his life, however, only shews the superior power of other causes, and of bad habits in particular; and I am ready to acknowledge the little efficacy of instruction when bad habits are formed. Its great use consists in preventing their formation; for which reason popular instruction in medicine would contribute more to the happiness of the human species, than the complete knowledge of every thing which is attempted to be taught in education,

tion, as it is conducted at prefent. But though the principles of the fyftem in queftion did not correct the propenfities of its inventor, it does not follow that they tend to produce the fame propenfities in others."

BROWNSVILLE, or *Redftone Old fort*, is a flourifhing poft-town in Fayette co. Pennfylvania; on the S. eaftern bank of Monongahela River; between Dunlap and Redftone creeks; and next to Pittfburg is the moft confiderable town in the weftern parts of the ftate. The town is regularly laid out, contains about 100 houfes, an Epifcopalian, and Roman Catholic church, a brewery and diftillery. It is connected with Bridgeport, a fmall village on the oppofite fide of Dunlap creek, by a bridge 260 feet long. Within a few miles of the town are 4 Friends' meeting-houfes, 24 grift, faw, oil, and fulling mills. The trade and emigration to Kentucky, employ boat builders here very profitably; above 100 boats of 20 tons each, are built annually. Byrd's Fort formerly ftood here, on the S. fide of the mouth of Redftone Creek, in N. lat. 39. 58. W. long. 81 12½; 37 miles foutherly from Pittfburg; 13 S. by E. of Wafhington, and 341 W. of Philadelphia.—*Morse*.

BRUCE (James, Efq; F. R. S.), the celebrated Abyffinian traveller, was born, 1730, at Kinnaird houfe, in the parifh of Larbert and county of Stirling. His defcent by both parents was ancient and honourable; and of that defcent he was, perhaps, too proud. His grandfather was —— Hay, Efq; of Woodcockdale, in the county of Linlithgow, who, marrying Mifs Bruce, the heirefs of Kinnaird, gave the name of *Bruce* to all his defcendants.

Perhaps this change of name may have taken place in obedience to the deed by which the eftate of Kinnaird was fettled on Mrs Hay's children; but it is a change which, in a country like Scotland, where antiquity of defcent is highly valued, any man would voluntarily have adopted, who had married the heirefs of fuch a family. The Bruces of Kinnaird had been in poffeffion of that eftate for three centuries: they were defcended from a younger fon of Robert de Bruce, the competitor with Baliol for the crown of Scotland. It would readily occur, that the knowledge of fuch a defcent would be beft preferved by continuing the name of their great anceftor; and we have reafon to believe, that the fubject of this memoir was not much delighted when put in mind, as he frequently was, that, though the heir of the line, he was not the *male* heir of that branch of the illuftrious family.

As he was allied to royalty by his father and grandmother, through his mother he was related to fome of the moft refpectable families in the kingdom. She was the daughter of James Graham, Efq; of Airth, dean of the faculty of advocates, and judge of the high court of admiralty in Scotland, by Marion daughter of James Hamilton, Efq; of Pencaitland; and to a man of our traveller's turn of mind, there can be no doubt but that it muft have afforded much fatisfaction to think, that no family ranks higher in Scotland than thofe of Bruce, Graham, and Hamilton. In him, however, it was weaknefs to be proud, if indeed he was proud, of family; for the talents beftowed upon him by nature, or to fpeak more properly, by nature's God, would have made him great though he had been born on a dunghill. He would indeed have been, in all probability, much greater than he was, had he not been in poffeffion of the phantom of birth to gratify much of his ambition; for the facility with which he maftered every ftudy in which he engaged, would have carried him quickly to the top of the moft honourable profeffion.

Mr Bruce was inftructed in grammatical learning at the fchool of Harrow on the Hill, in the county of Middlefex, where he gave the moft unequivocal proofs of genius, and acquired a very confiderable knowledge of the Greek and Latin languages. It was cuftomary with him to perform, not only his own exercifes, but alfo the exercifes of fuch of his companions as were not equal to the tafk themfelves. Among thefe was his maternal uncle, who was frequently indebted to his affiftance, and, on one occafion, produced a copy of verfes of his compofition, which excited, not only the applaufe, but the admiration of their mafter. Mr Graham, who was but a few months older than Mr Bruce, had, for fome tranfgreffion (we know not what), been punifhed, as boys in the great fchools in England are often punifhed, by having a tafk fet him, which he foon found himfelf unable to perform. His nephew defired him to be under no uneafinefs, promifing to furnifh him with the verfes before the time at which they were to be given in. He was as good as his word; but the mafter of the fchool foon difcovering that they were not the performance of Mr Graham, exclaimed, that the author of thefe verfes, whoever he was, might apply to himfelf the words of Horace,

——*Sublimi feriam fidera vertice.*

While Mr Bruce was at Harrow, and for a year or two after he had left it, he was of a very delicate frame, and appeared to his friends to be threatened with a confumption. The truth is, that he was uncommonly tall for his age, and felt all the feeblenefs of joints and other bodily weakneffes to which overgrown boys are generally fubject. His father intended him for the profeffion of the law; and, upon his return from Harrow, he was entered into the univerfity of Edinburgh, where he went through a regular courfe of ftudy to fit him for being inrolled in the body of advocates; but for fome reafon, which we do not perfectly know, he relinquifhed the ftudy of law for the purfuits of trade; and, going to London, entered into partnerfhip with a wine-merchant of the name of Allen, whofe daughter he married.

That lady falling into a bad ftate of health, Mr Bruce took her abroad, in hopes that travelling would be attended with beneficial effects; but in thefe he was difappointed, as fhe died within a year after her marriage. He was induced, in order to difpel his grief, to continue his travels; during which his father dying (at Edinburgh, 4th May 1758), the inheritance of his anceftors devolved upon him, and he returned to Britain. Some of his fubfequent tranfactions fhall now be related in his own words.

"Every one will remember that period, fo glorious to Britain, the latter end of the miniftry of the late earl of Chatham. I was then returned from a tour through the greateft part of Europe, particularly thro' the whole of Spain and Portugal, between whom there was then the appearance of an approaching war.

"I was about to retire to a fmall patrimony I had received from my anceftors, in order to embrace a life of ftudy and reflection, nothing more active appearing within my power, when chance threw me unexpectedly into a very fhort and very defultory converfation with Lord Chatham.

" It was a few days after this, that Mr Wood, then under fecretary of ftate, my zealous and fincere friend, informed me that Lord Chatham intended to employ me upon a particular fervice; that, however, I might go down for a few weeks to my own country to fettle my affairs, but, by all means, to be ready upon a call. Nothing could be more flattering to me than fuch an offer, when fo young; to be thought worthy by Lord Chatham of any employment, was doubly a preference. No time was loft on my fide; but juft after receiving orders to return to London, his lordfhip had gone to Bath, and refigned his office.

" This difappointment, which was the more fenfible to me that it was the firft I had met with in public life, was promifed to be made up to me by Lord Egremont and Mr George Grenville. The former had been long my friend; but unhappily he was then far gone in a lethargic indifpofition, which threatened, and did very foon put a period to his exiftence. With Lord Egremont's death my expectations vanifhed. Further particulars are unneceffary; but I hope that, at leaft in part, they remain in that breaft where they naturally ought to be, and where I fhall ever think, not to be long forgotten, is to be rewarded.

" Seven or eight months were paffed in an expenfive and fruitlefs attendance in London, when Lord Halifax was pleafed, not only to propofe, but to plan for me a journey of confiderable importance, and which was to take up feveral years. His lordfhip faid, that nothing could be more ignoble than, at fuch a time of life, at the height of my reading, health, and activity, I fhould, as it were, turn peafant, and voluntarily bury myfelf in obfcurity and idlenefs; that though war was now drawing faft to an end, full as honourable a competition remained among men of fpirit, which fhould acquit themfelves beft in the dangerous line of ufeful adventure and difcovery.

" He obferved, that the coaft of Barbary, which might be faid to be juft at our door, was yet but partially explored by Dr Shaw, who had only illuftrated (very judicioufly indeed) the geographical labours of Sanfon; that neither Dr Shaw nor Sanfon had been, or pretended to be, capable of giving the public any detail of the large and magnificent remains of ruined architecture, which they both vouch to have feen in great quantities, and of exquifite elegance and perfection, all over the country. Such had not been their ftudy, yet fuch was really the tafte that was required in the prefent times. He wifhed, therefore, that I fhould be the firft, in the reign juft now beginning, to fet an example of making large additions to the royal collection; and he pledged himfelf to be my fupport and patron, and to make good to me, upon this additional merit, the promifes which had been held forth to me by former minifters for other fervices.

" The difcovery of the fource of the Nile was alfo a fubject of thefe converfations, but it was always mentioned to me with a kind of diffidence, as if to be expected from a more experienced traveller. Whether this was but another way of exciting me to the attempt I fhall not fay; but my heart, in that inftant, did me juftice to fuggeft, that this too was either to be atchieved by me, or to remain as it had done for thefe laft 2000 years, a defiance to all travellers, and an opprobrium to geography.

" Fortune feemed to enter into this fcheme. At the very inftant, Mr Afpinwall, very cruelly and ignominioufly treated by the dey of Algiers, had refigned his confulfhip, and Mr Ford a merchant, formerly the dey's acquaintance, was named in his place. Mr Ford was appointed, and, dying a few days after, the confulfhip became vacant. Lord Halifax preffed me to accept of this as containing all forts of conveniences for making the propofed expedition.

" This favourable event finally determined me. I had all my life applied unweariedly, perhaps with more love than talent, to drawing, the practice of mathematics, and efpecially that part neceffary to aftronomy. The tranfit of Venus was at hand. It was certainly known that it would be vifible once at Algiers, and there was great reafon to expect it might be twice. I had furnifhed myfelf with a large apparatus of inftruments, the completeft of their kind, for the obfervation. In the choice of thefe, I had been affifted by my friend Admiral Campbell, and Mr Ruffel, fecretary to the Turkey Company: every other neceffary had been provided in proportion. It was a pleafure now to know that it was not from a rock or a wood, but from my own houfe at Algiers, I could deliberately take meafures to place myfelf in the lift of men of fcience of all nations, who were then preparing for the fame fcientific purpofe.

" Thus prepared, I fet out for Italy, through France; and though it was in time of war, and fome ftrong objections had been made to particular paffports, folicited by our government from the French fecretary of ftate, Monfieur de Choifeul moft obligingly waved all fuch exceptions with regard to me, and moft politely affured me, in a letter accompanying my paffport, that thofe difficulties did not in any fhape regard me, but that I was perfectly at liberty to pafs through, or remain in, France, with thofe that accompanied me, without limiting their number, as fhort or as long a time as fhould be agreeable to me.

" On my arrival at Rome, I received orders to proceed to Naples, there to await his majefty's further commands. Sir Charles Saunders, then with a fleet before Cadiz, had orders to vifit Malta before he returned to England. It was faid that the grand mafter of that order had behaved fo improperly to Mr Harvey (afterwards Lord Briftol) in the beginning of the war, and fo partially and unjuftly between the two nations in the courfe of it, that an explanation on our part was become neceffary. The grand mafter no fooner heard of my arrival at Naples, than, gueffing the errand, he fent off Chevalier Mazzini to London, where he at once made his peace and his compliments to his majefty upon his acceffion to the throne.

" Nothing remained now but to take poffeffion of my confulfhip. I returned, without lofs of time, to Rome, and from thence to Leghorn, where having embarked on board the Montreal man of war, I proceeded to Algiers.

" While at Naples, I received from flaves, redeemed from the province of Conftantine, accounts of magnificent ruins they had feen while traverfing that country with

with their mafter the Bey. I faw the abfolute neceffity there was for affiftance, without which it was impoffible for any one man, however diligent and qualified, to do any thing but bewilder himfelf. All my endeavours, however, had hitherto been unfuccefsful to perfuade any Italian to put himfelf wilfully into the hands of a people conftantly looked upon by them in no better light than pirates. At laft Mr Lumifden, by accident, heard of a young man who was then ftudying architecture at Rome, a native of Bologna, whofe name was Luigi Balugani. I can appeal to Mr Lumifden as to the extent of this perfon's practice and knowledge, and that he knew very little when firft fent to me. In the twenty months which he ftaid with me at Algiers, by affiduous application to proper fubjects under my inftruction, he became a very confiderable help to me, and was the only one that ever I made ufe of, or that attended me for a moment, or ever touched one reprefentation of architecture in any part of my journey."

Our traveller, when in Spain, had endeavoured to find accefs to that immenfe collection of Arabic manufcripts which were perifhing in the duft of the efcurial; but in vain. "All my fuccefs (fays he) in Europe terminated in the acquifition of thofe few printed Arabic books that I had found in Holland; and thefe were rather biographers than general hiftorians, and contained little in point of general information. The ftudy of thefe, however, and of Maracci's Koran, had made me a very tolerable Arab; a great field was opening before me in Africa to complete a collection of manufcripts, an opportunity which I did not neglect.

"After a year fpent at Algiers, conftant converfation with the natives while abroad, and with my manufcripts within doors, had qualified me to appear in any part of the continent without the help of an interpreter. Ludolf had affured his readers, that the knowledge of any oriental language would foon enable them to acquire the Ethiopic; and I needed only the fame number of books to have made my knowledge of that language go hand in hand with my attainments in the Arabic. My immediate profpect of fetting out on my journey to the inland parts of Africa, had made me double my diligence; night and day there was no relaxation from thefe ftudies, although the acquiring any fingle language had never been with me either an object of time or difficulty."

At Algiers Mr Bruce was detained longer than he expected, in confequence of a difpute with the Dey concerning Mediterranean paffes. This being adjufted, he proceeded to Mahon, and from Mahon to Carthage. He next vifited Tunis and Tripoli, and travelled over the interior parts of thefe ftates. At Bengazi, a fmall town on the Mediterranean, he fuffered fhipwreck, and with extreme difficulty faved his life, though with the lofs of all his baggage. He afterwards failed to the ifles of Rhodes and Cyprus, and proceeding to Afia Minor, travelled through a confiderable part of Syria and Paleftine, vifiting Haffia, Latikea, Aleppo, and Tripoli; near which laft city he was again in imminent danger of perifhing in a river. The ruins of Palmyra and Baalbec were next carefully furveyed and fketched by him; and his drawings of thefe places are depofited in the king's library at Kew; "the moft magnificent prefent in that line," to ufe his own words, "ever made by a fubject to his fovereign."

It is much to be regretted that Mr Bruce publifhed no particular account of thefe various journeys; from the nature of the places vifited, and the abilities of the man, much curious and ufeful information might have been expected. Some manufcript accounts of different parts of them are faid to have been left by him, but whether in fuch a ftate as to be fit for publication, we have not learned.

In thefe various travels fome years were paffed; and Mr Bruce now prepared for the grand expedition, the accomplifhment of which had ever been neareft his heart, the difcovery of the fources of the Nile. In the profecution of that dangerous object, he left Sidon on the 15th of June 1768, and arrived at Alexandria on the 20th of that month. He proceeded from thence to Cairo, where he continued to the 12th of December following, when he embarked on the Nile; and in a very extraordinary boat, called a *canja*, of which he fays the main-fail yard was about 200 feet in length, he failed up that river as far as Syene, vifiting in the courfe of his voyage the ruins of Thebes, and the place where Memphis once ftood, now known by the name of *Metrahenny*. Leaving Kenne on the Nile, 16th February 1769, he croffed the defert of the Thebaid to Coffeir on the Red Sea, and arrived at Jidda on the 3d of May. In Arabia Felix he remained, not without making feveral excurfions, till the 3d of September, when he failed from Loheia, and arrived on the 19th at Mafuah, where he was detained near two months by the treachery and avarice of the Naybe of that place. It was not till the 15th of November that he was allowed to quit Arkeeko, near Mafua; and he arrived on the 15th of February 1770 at Gondar, the capital of Abyffinia, where he ingratiated himfelf with the moft confiderable perfons of both fexes belonging to the court. This he accomplifhed by being a phyfician in the city, a foldier in the field, a courtier everywhere, demeaning himfelf as confcious that he was not unworthy of being a companion to the firft of their nobility, and the king's gueft, which is there a character, as it was with eaftern nations of old, to which a certain fort of confideration is due. "To this I may add (fays he), that, being in the prime of life, of no ungracious figure, having an accidental knack, which is not a trifle, of putting on the drefs, and fpeaking the language eafily and gracefully, I cultivated, with the utmoft affiduity, the friendfhip of the fair fex, by the moft modeft and refpectful diftant attendance and obfequioufnefs in public, abating juft as much of that in private as fuited their humours and inclination;" and jealoufy being a paffion unknown in Abyffinia, he thus acquired from the ladies great fupport at court.

Several months were employed in attendance on the king, and in an unfuccefsful expedition round the lake of Dambea. Towards the end of October Mr Bruce fet out for the fources of the Nile; at which long defired fpot he arrived on the 14th of November; and his feelings on the accomplifhment of his wifhes cannot better be expreffed than in his own words:

"It is eafier to guefs than to defcribe the fituation of my mind at that moment; ftanding in that fpot which had baffled the genius, induftry, and inquiry, of ancients and moderns for the courfe of near 3000 years. Kings had attempted this difcovery at the head of armies, and each expedition was diftinguifhed from the laſt only by the difference of the numbers which had periſhed, and agreed alone in the diſappointment which had uniformly, and without exception, followed them all. Fame, riches, and honour, had been held out for a ſeries of ages to every individual of thoſe myriads thoſe princes commanded, without having produced one man capable of gratifying the curioſity of his ſovereign, or wiping off this ſtain upon the enterpriſe and abilities of mankind, or adding this deſideratum for the encouragement of geography. Though a mere private Briton, I triumphed here in my own mind over kings and their armies; and every compariſon was leading nearer and nearer to the preſumption, when the place itſelf where I ſtood, the object of my vain glory, ſuggeſted what depreſſed my ſhort-lived triumphs."

If theſe triumphs were ſhort-lived, they were equally ill-founded; for if the ſource of the Nile was ſeen by Mr Bruce, there can be no doubt of its having been likewiſe ſeen by the Portugueſe jeſuits. Of this we have elſewhere brought forward ſufficient proof; and the candid reader, who ſhall take the trouble to compare the extract printed at the bottom of this page (A), with our traveller's account of theſe coy fountains, as it ſtands in his own book or in our article Nile *(Encycl.)*, will be convinced that it was ridiculous in Mr Bruce, and is equally ridiculous in his friends, to pretend that he *diſcovered* what had baffled the genius of inquiry for the courſe of near 3000 years.

It was not, however, the conſciouſneſs of having been anticipated by the jeſuits (for theſe he without ceremony calls a ſet of liars), but the proſpect of danger to be encountered on his return to Europe, that caſt ſuch a damp on his preſent enjoyment. " I was but a few minutes (ſays he) arrived at the ſource of the Nile, through numberleſs dangers and ſufferings, the leaſt of which would have overwhelmed me, but for the continual goodneſs and protection of Providence; I was, however, but then half through my journey, and all thoſe dangers which I had already paſſed awaited me again on my return. I found a deſpondency gaining ground faſt upon me, which blaſted the crown of laurels I had too raſhly woven for myſelf."

When he returned to reſt the night of that diſcovery, repoſe was ſought for in vain. " Melancholy reflections upon my preſent ſtate, the doubtfulneſs of my return in ſafety, were I permitted to make the attempt, and the fears that even this would be refuſed, according to the rule obſerved in Abyſſinia with all travellers who have once entered the kingdom; the conſciouſneſs of the pain that I was then occaſioning to many worthy individuals, expecting daily that information concerning my ſituation which it was not in my power to give them; ſome other thoughts perhaps, ſtill nearer the heart than thoſe, crowded upon my mind, and forbade all approach of ſleep.

" I was, at that very moment, in poſſeſſion of what had for many years been the principal object of my ambition and wiſhes; indifference which, from the uſual infirmity of human nature, follows, at leaſt for a time, complete enjoyment, had taken place of it. The marſh, and the fountains, upon compariſon with the riſe of many of our rivers, became now a trifling object in my ſight. I remembered that magnificent ſcene in my own native country, where the Tweed, Clyde, and Annan, riſe in one hill; three rivers I now thought not inferior to the Nile in beauty, preferable to it in the cultivation of thoſe countries through which they flow; ſuperior, vaſtly ſuperior to it in the virtues and qualities of the inhabitants, and in the beauty of its flocks, crowding its paſtures in peace, without fear of violence from man or beaſt. I had ſeen the riſe of the Rhine and Rhone, and the more magnificent ſources of the Soane; I began, in my ſorrow, to treat the inquiry about the ſource of the Nile as a violent effort of a diſtempered fancy,

> ' What's Hecuba to him, or he to Hecuba,
> ' That he ſhould weep for her?'

Grief and deſpondency now rolling upon me like a torrent, relaxed, not refreſhed, by unquiet and imperfect ſleep, I ſtarted from my bed in the utmoſt agony; I went to the door of my tent, every thing was ſtill; the Nile, at whoſe head I ſtood, was not capable either to promote or to interrupt my ſlumbers, but the coolneſs and ſerenity of the night braced my nerves, and chaſed away thoſe phantoms that while in bed had oppreſſed and tormented me.

" It was true that numerous dangers, hardſhips, and ſorrows, had beſet me through this half of my excurſion; but it was ſtill as true, that another Guide, more powerful than my own courage, health, or underſtanding, if any of them can be called man's own, had uniformly

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(A) " In the eaſtern part of this kingdom, on the declivity of a mountain, whoſe deſcent is ſo eaſy that it ſeems a beautiful plain, is that ſource of the Nile which has been ſought after at ſo much expence of labour, and about which ſuch variety of conjectures hath been formed without ſucceſs. This ſpring, or rather theſe two ſprings, are two holes, each about two feet diameter, a ſtone's caſt diſtant from each other. The one is about five feet and an half in depth, at leaſt we could not get our plummet farther, perhaps becauſe it was ſtopped by roots, for the whole place is full of trees: of the other, which is ſomewhat leſs, with a line of ten feet we could find no bottom, and were aſſured by the inhabitants that none ever had been found. It is believed here that theſe ſprings are the vents of a great ſubterraneous lake; and they have this circumſtance to favour their opinion, that the ground is always moiſt, and ſo ſoft that the water boils up under foot as one walks upon it. Such is the ground round about theſe fountains. At a little diſtance to the ſouth is a village named *Guix* (the *Geeſh* of Mr Bruce), through which the way lies to the top of the mountain, whence the traveller diſcovers a vaſt extent of land, which appears like a deep valley, though the mountain riſes ſo imperceptibly, that thoſe who go up or down it are ſcarce ſenſible of any declivity."—*Johnſon's Tranſlation of Father Lobo's Voyage to Abyſſinia*, Chap. X.

The only difference between Lobo's and Bruce's account of theſe fountains worthy of notice is, that the former found but *two*, while the latter found *three* holes; but Bruce ſays expreſsly, that the holes are partly artificial; and Lobo's deſcription of them indicates the ſame thing. It is therefore not improbable that there may now be four or five holes.

formly protected me in all that tedious half. I found my confidence not abated, that still the same Guide was able to conduct me to my wished-for home. I immediately resumed my former fortitude, considered the Nile as indeed no more than rising from springs as all other rivers do, but widely differing in this, that it was the palm for 3000 years held out to all the nations of the world as a *detur dignissimo*, which in my cool hours I had thought was worth the attempting at the risk of my life, which I had long either resolved to lose, or lay this discovery a trophy in which I could have no competitor, for the honour of my country, at the feet of my sovereign, whose servant I was."

How unworthy is this ranting reflection of the greatness of mind which Mr Bruce on other occasions unquestionably displayed! Had he indeed been the first European who discovered those pitiful holes from which the Nile is said to flow, his merit would not have consisted in travelling from Gondar to the village Geesh, and viewing the fountains which are at that village the objects of idolatrous adoration, but in the address with which he contrived to make himself the favourite of all the factions which agitated a barbarous and almost inhuman nation. In managing those factions, he was indeed great; but he seems to have valued himself more upon looking at three springs, of which it is far from being certain that they are the sources of the Nile (see NILE, *Encycl.*), and of which two had certainly been examined more than a century before he was born, by different missionaries from the kingdom of Portugal! This, however, he calls the object of his wishes; and having now accomplished it, he bent his thoughts on his return to his native country.

He arrived at Gondar on the 19th November 1770; but found, after repeated solicitations, that it was by no means an easy task to obtain permission to quit Abyssinia. A civil war in the mean time breaking out (no uncommon occurrence in that barbarous country), several engagements took place between the king's forces and the troops of the rebels, particularly three actions at a place called Serbraxos on the 19th, 20th, and 23d of May 1771. In each of them Mr Bruce acted a considerable part, and for his valiant conduct in the second received, as a reward from the king, a chain of gold, of 184 links, each link weighing $3\frac{1}{11}$ dwts. or somewhat more than $2\frac{1}{2}$ lbs. troy in all. At Gondar, after these engagements, he again preferred the most earnest intreaties to be allowed to return home, intreaties which were long resisted; but his health at last giving way, from the anxiety of his mind, the king consented to his departure, on condition of his engaging by oath (B) to return to him in the event of his recovery, with as many of his kindred as he could engage to accompany him.

After a residence of nearly two years in that wretched country, Mr Bruce left Gondar on the 16th of December 1771, taking the dangerous way of the desart of Nubia, in place of the more easy road of Masuah, by which he entered Abyssinia. He was induced to take this route from his knowledge and former experience of the cruel and savage temper of the Naybe of Masuah. Arriving at Teawa the 21st March 1772, he had the misfortune to find the Shekh Fidele of Atbara, the counterpart of the Naybe of Masuah, in every bad quality; by his intrepidity and prudence, however, and by making good use of his foreknowledge of an eclipse of the moon, which happened on the 17th of April, he was permitted to depart next day, and he arrived at Sennaar on the 29th of the same month.

Mr Bruce was detained upwards of four months at that miserable and inhospitable place; the inhabitants of which he describes in these expressive words: "War and treason seem to be the only employment of these horrid people, whom heaven has separated by almost impassable deserts from the rest of mankind, confining them to an accursed spot, seemingly to give them an earnest in time of the only other worse which he has reserved to them for an eternal hereafter." This delay was occasioned by the villany of those who had undertaken to supply him with money; but at last, by disposing of 178 links of his gold chain, the well-earned trophy of Serbraxos, he was enabled to make preparation for his dangerous journey though the deserts of Nubia.

He left Sennaar on the 5th of September, and arrived on the 3d of October at Chendi, which he quitted on the 20th, and travelled through the desert of Gooz, to which village he came on the 26th of October. On the 9th of November he left Gooz, and entered upon the most dreadful and dangerous part of his journey; the perils attending which he has related with a power of pencil not unworthy of the greatest masters. All his camels having perished, Mr Bruce was under the necessity of abandoning his baggage in the desert, and with the greatest difficulty reached Assouan upon the Nile on the 29th of November.

After some days rest, having procured fresh camels, he returned into the desert, and recovered his baggage, among which is particularly to be remarked a quadrant (of three feet radius) supplied by Louis XV. from the Military Academy at Marseilles; by means of which noble instrument, now deposited in the museum at Kinnaird, Mr Bruce was enabled with precision and accuracy to fix the relative situations of the several remote places he visited.

On the 10th of January 1773, after more than four years absence, he arrived at Cairo, where, by his manly and generous behaviour, he so won the heart of Mahomet Bey, that he obtained a firman, permitting the commanders of English vessels belonging to Bombay and Bengal to bring their ships and merchandise to Suez, a place far preferable in all respects to Jidda, to which they were formerly confined. Of this permission, which no European nation could ever before acquire, many English vessels have since availed themselves; and it has proved peculiarly useful both in public and private dispatches. Such was the worthy conclusion of his memorable journey through the desert; a journey which, after many hardships and dangers, terminated in obtaining this great national benefit.

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(B) With regard to this oath, Mr Bruce says, that he hopes the difficulty of performing it extinguished the sin of breaking it; and that, at any rate, it being merely personal, his engagement to return ceased with the death of the king, of which he received intelligence during his stay at Sennaar.

Bruce.

At Cairo Mr Bruce's earthly career had nearly been concluded by a diforder in his leg, occafioned by a worm in the flefh. This accident kept him five weeks in extreme agony, and his health was not re-eftablifhed till a twelvemonth afterwards, at the baths of Porretta in Italy. On his return to Europe, Mr Bruce was received with all the admiration due to fo exalted a character. After paffing fome confiderable time in France, particularly at Montbard, with his friend the Comte de Buffon, by whom he was received with much hofpitality, and is mentioned with great applaufe, he at laft revifited his native country, from which he had been upwards of twelve years abfent.

It was now expected that he would take the earlieft opportunity of giving to the world a narrative of his travels, in which the public curiofity could not but be deeply interefted. But feveral circumftances contributed to delay the publication; and what thefe were will be beft related in his own words:

"My friends at home gave me up for dead; and as my death muft have happened in circumftances difficult to have been proved, my property became as it were a *hæreditas jacens*, without an owner, abandoned in common to thofe whofe original title extended no further than temporary poffeffion.

"A number of law-fuits were the inevitable confequences of this upon my return. To thefe difagreeable avocations, which took up much time, were added others ftill more unfortunate. The relentlefs ague, caught at Bengazi, maintained its ground, at times, for a fpace of more than 16 years, though every remedy had been ufed, but in vain; and what was worft of all, a lingering diftemper had ferioufly threatened the life of a moft near relation (his fecond wife), which, after nine years conftant alarm, where every duty bound me to attention and attendance, conducted her at laft, in very early life, to her grave."

Amidft the anxiety and the diftrefs thus occafioned, Mr Bruce was by no means neglectful of his private affairs. He confiderably improved his landed property, inclofing and cultivating the wafte grounds, and he highly embellifhed his paternal feat, making many additions to the houfe, one in particular of a noble mufeum, filled with the moft precious ftores of oriental literature, large collections of drawings made, and curious articles obtained, during his far extended peregrinations. An excellent ftratum of coal at Kinnaird drew much of his attention; he erected fteam engines of the moft approved conftruction; and placed his coalliery on fuch a footing that, at the period of his deceafe, it produced about 2000l. a-year.

The termination of fome law-fuits, and of other bufinefs, which had occupied much of his time, having at length afforded leifure to Mr Bruce to put his materials in order, his greatly defired and long expected work made its appearance in 1790, in five large quarto volumes, embellifhed with plates and charts. It is unneceffary, and might be tedious, to enter at prefent into any critic or analyfis of this celebrated work. It is univerfally allowed to be replete with much curious and ufeful information; and to abound in narratives which at once excite our admiration and intereft our feelings. The very fingular and extraordinary picture which it gives of Abyffinian manners, ftartled the belief of fome; but thefe manners, though ftrange in the fight of an European, are little more than might be expected in fuch a barbarous country; and had an enlightened philofopher vifited Scotland in the times of our earlieft monarchs, he might perhaps have witneffed and related fcenes, different indeed from what Mr Bruce faw in Abyffinia, but which to us would have feemed equally ftrange.

A more ferious objection to the truth of Mr Bruce's narrative was ftarted by an anonymous, but able, critic,* in an Edinburgh newfpaper, foon after the publication, from the account of two aftronomical phenomena, which *could not poffibly have happened*, as Mr Bruce afferts. The firft of thefe is the appearance of the new moon at Furfhout, during Mr Bruce's ftay in that place, which he mentions to have been from the 25th December 1768 to the 7th of January 1769; and on a particular day in that interval afferts, that the new moon was feen by a fakir, and was found by the ephemerides to be three days old; whereas it is certain that the moon changed on the 8th of January 1769. The other phenomenon appears equally impoffible. At Teawa Mr Bruce fays he terrified the Shekh by foretelling that an eclipfe of the moon was to take place at four afternoon of the 17th of April 1772; that accordingly, foon after that hour, he faw the eclipfe was begun; and when the fhadow was half over, told the Shekh that in a little time the moon would be totally darkened. Now, by calculation, it is certain, that at Teawa this eclipfe muft have begun at 36 minutes paft four, and the moon have been totally covered at 33 minutes paft five; while the fun fet there a few minutes paft fix, before which time the moon, then in oppofition, could not have rifen: fo that as the moon rofe totally eclipfed, Mr Bruce could not fee the fhadow half over the difk, nor point it out to the Shekh. To thefe objections, which appear unfurmountable, Mr Bruce made no reply, though in converfation he faid he would do it in the fecond edition of his book.

* Suppofed to be Dr Rotheram, profeffor of natural philofophy in the univerfity of St Andrew's.

Thefe are miftakes which can hardly be accounted for by attributing them to the inaccuracy of his notes, or indeed to any caufe which we are inclined to name; and perhaps he has fallen into a miftake of the fame kind in his account of the enormous main-fail yard of the *canja*, in which he failed up the river Nile. To every man who has but dipped into the fcience of mechanics, it is known that a beam of wood 200 feet in length, muft be of proportional thicknefs, or it would fall in pieces by its own weight. This thicknefs muft be greatly increafed, to enable it to bear the ftrain occafioned by a prodigious fail filled with wind; and thofe only who have been at the Nile, and have feen the canjas, can fay, whether thefe veffels, or indeed any veffels which can be employed on the river, would not be overfet by yards,

———To equal which, the talleft pine
Hewn on Norwegian hills, to be the maft
Of fome great admiral, were but a wand.

The language of the work is in general harfh and unpolifhed, though fometimes animated. Too great a difplay of vanity runs through the whole, and the apparent facility with which the traveller gained the moft familiar accefs to the courts, and even to the harams of the fovereigns of the countries through which he paffed, is apt to create in readers fome doubts of the accuracy of of the narration. Yet there appears upon the whole ſuch an air of manly veracity, and circumſtances are mentioned with a minuteneſs ſo unlike deceit, that theſe doubts are overcome by the general impreſſion of truth, which the whole detail irreſiſtibly faſtens upon the mind. The character of Ras Michael has often ſtruck us, as containing very ſtrong internal evidence of its having been taken from nature; for it is ſuch a character, at once extraordinary and conſiſtent, as neither Mr Bruce, nor perhaps any writer ſince Shakeſpeare, had genius to feign.

The firſt impreſſion of the book being almoſt diſpoſed of, Mr Bruce had ſtipulated with an eminent bookſeller in London for a ſecond edition to be publiſhed, we think in 8vo; and he was buſy in preparing that edition for the preſs when death removed him from this tranſitory ſtage. On the 26th of April 1794 he entertained ſome company at Kinnaird-houſe with his uſual hoſpitality and elegance. About eight o'clock in the evening, when his gueſts were ready to depart, he was handing one of the ladies down ſtairs, when, having reached the ſeventh or eighth ſtep from the bottom, his foot ſlipped, and he fell down headlong. He was taken up ſpeechleſs; his face, particularly the forehead and temples, being ſeverely cut and bruiſed, and the bones of his hands broken. He continued in a ſtate of apparent inſenſibility for eight or nine hours, and expired on Sunday the 27th, in the 64th year of his age.

Mr Bruce's ſecond wife, whom he married on the 20th May 1776, was Mary, eldeſt daughter of Thomas Dundas, Eſq; of Carron-hall, by Lady Janet Maitland, daughter of Charles ſixth Earl of Lauderdale. By that lady, who, after a ſevere and lingering indiſpoſition, died in 1784, he had three children, of whom one ſon and one daughter ſurvive him.

Mr Bruce's perſon was large, his height exceeding ſix feet, his bulk being in proportion to his height; and at the period when he entered on his dangerous expedition, he was equally remarkable for ſtrength and for agility. To thoſe who never beheld him, the engraved medallion in the title pages of the firſt and third volumes of his Travels will convey ſome idea of his features. He excelled in all manly accompliſhments, being trained to exerciſe and fatigue of every kind. He was a hardy, practiſed, and indefatigable ſwimmer; and his long reſidence among the Arabs had given him a more than ordinary facility in managing the horſe. In the uſe of fire arms he was ſo unerring, that in innumerable inſtances he never failed to hit the mark; and his dexterity in handling the ſpear and lance on horſeback was alſo uncommonly great. He was maſter of moſt languages; and was ſo well ſkilled in oriental literature, that he reviſed the New Teſtament in the Ethiopic, Samaritan, Hebrew, and Syriac, making many uſeful notes and remarks on difficult paſſages. He had applied from early youth to mathematics, drawing, and aſtronomy, and had acquired ſome knowledge of phyſic and ſurgery. His memory was aſtoniſhingly retentive, and his mind vigorous. He was dexterous in negociation, a maſter of public buſineſs, and animated with the warmeſt zeal for the glory of his king and country. Such, at leaſt, is *his own* repreſentation of his character; and though an impartial judge would probably make conſiderable abatement for the natural bias of a man drawing his own portrait, yet it cannot be denied, that in perſonal accompliſhments Mr Bruce equalled, if not exceeded, moſt of his contemporaries.

Thus accompliſhed, he could not but be eminently fitted for an attempt ſo full of difficulty and danger as what he called the diſcovery of the ſources of the Nile: no one who peruſes his account of the expedition, can fail to pay an unfeigned tribute of admiration to his intrepidity, manlineſs, and uncommon dexterity, in extricating himſelf out of ſituations the moſt dangerous and alarming, in the courſe of his long and hazardous journey; not to mention his conduct during his reſidence in Abyſſinia, his behaviour at Maſuah, Teawa, and Sennaar, evinces the uncommon vigour of his mind: but it was chiefly during his paſſage through the Nubian deſert that his fortitude, courage, and prudence, appeared to the greateſt advantage. Of his learning and ſagacity, his delineation of the courſe of Solomon's fleet from Tarſhiſh to Ophir, his account of the cauſe of the inundations of the Nile, and his comprehenſive view of the Abyſſinian hiſtory, afford ample proofs. It muſt indeed be confeſſed, that in his account of the inundations of the Nile, as well as in his delineation of the courſe of Solomon's fleet, he has not the merit of originality; but on both theſe occaſions he has ſtated the hypotheſis which he maintains with greater clearneſs, and ſupported it with more plauſible arguments, than any other author whoſe writings have fallen into our hands; and it was ſurely to his honour, that as ſoon as he learned that his hypotheſis reſpecting Ophir and Tarſhiſh had been controverted by Dr Doig of Stirling, he earneſtly courted the acquaintance of that eminent ſcholar.

After his return to his own country, he reſided moſtly at Kinnaird; and till he became corpulent, ſpent much of his time in the various ſports of the field, in which he engaged with great ardour. Though ſtudious in youth, and at all times a ſtranger to intemperance and diſſipation, he read but little in his later years; and ſeemed to find his chief pleaſure in converſation, eſpecially the converſation of well-informed ladies. In his friendſhips he ſometimes appeared to be capricious, attaching himſelf to men in whoſe heads and hearts no other perſon could perceive a charm for a mind like his. Though in his own dealings he was always juſt and honourable, he was too ready to apprehend unfairneſs in others, and to expreſs ſuch apprehenſions with undue warmth. To ſtrangers he was often arrogant, and ſometimes inſolent; but in his own family he was an affectionate huſband, a kind father, an agreeable entertainer, and to his ſervants a maſter perhaps too indulgent. In converſation, as well as in his writings, he embraced every opportunity of expreſſing a deep and lively ſenſe of the care of a ſuperintending Providence, without which he was convinced that there could be no ſafety in human ſtrength or human foreſight. His belief of the Chriſtian religion reſted on the ſureſt grounds; and ſuch was his veneration for the ſacred writings, that for ſome years before his death they ſeemed to occupy all the time which he gave to ſtudy. He read no ſermons, however elegant; and diſſuaded others from ſuch reading. "Read the Bible (ſaid he), and you will ſoon perceive the emptineſs of the moſt applauded ſermons."

BRUNSWICK, a maritime county in Wilmington diſtrict, N. Carolina, containing 3071 inhabitants, of whom

whom 1511 are slaves. It is the most southerly county of the state, having S. Carolina on the S. W. and bounded by Cape Fear River on the E. Smithville is the seat of Justice.—*Morse.*

Brunswick, the chief town in the above county, situated on the W. side of Cape Fear River; it was formerly the best built in the whole state, and carried on the most extensive trade. It lies 30 miles above the capes, about 9 miles N. of Fort Johnson, 17 S. W. of Wilmington, and was formerly the seat of government. In 1780, it was burnt down by the British, and has now only 3 or 4 houses and an elegant church in ruins.—*ib.*

Brunswick, a township in Essex co. Vermont, on the W. bank of Connecticut River, opposite Stratford, in New-Hampshire.—*ib.*

Brunswick, a city in Middlesex co. New-Jersey, is situated on the S. W. bank of Rariton River, in a low situation; the most of the houses being built under a hill which rises W. of the town. It has between 200 and 300 houses, and about 2500 inhabitants, one half of whom are Dutch. Queen's College was in this city, but is now extinct as a place of instruction. There is a considerable inland-trade carried on here. One of the most elegant and expensive bridges in America, has been built over the river opposite this city. Brunswick is 18 miles N. E. of Princetown, 60 N. E. from Philadelphia, and 35 S. W. from New-York. N. lat. 40 30. W. long. 74. 30.—*ib.*

Brunswick, in Cumberland co. district of Maine, contains 1387 inhabitants, and lies N. E. of Portland 30 miles, and of Boston 151. It is in N. lat. 43. 52. on the S. side of Merry Meeting Bay, and partly on the S. western side of Androscoggin River. Bowdoin College is to be established in this town.—*ib.*

Brunswick, the chief town of Glynn co. Georgia, is situated at the mouth of Turtle River, where it empties into St Simon's sound, N. lat. 31. 10. It has a safe harbor, and sufficiently capacious to contain a large fleet. Although there is a bar at the entrance of the harbor, it has depth of water for the largest ship that swims. The town is regularly laid out, but not yet built. From its advantageous situation, and from the fertility of the back country, it promises to be one of the most commercial and flourishing places in the state. It lies 19 miles S. of Darien; 60 S. S. W. from Savannah, and 110 S. E. from Louisville. —*ib.*

Brunswick *Co.* in Virginia, lies between Nottaway and Meherrin rivers, and is about 38 miles long, and 35 broad, and contains 12,827 inhabitants, including 6776 slaves.—*ib.*

BUCK-wheat, a species of Polyganum (see that article *Encycl.*), was first introduced into Europe about the end of the 15th or the beginning of the 16th century. According to some botanists, who lived at that period, its native country is the northern parts of Asia, whence it was brought to Germany and France, where, about the year 1587, it was the common food of the poor.

A new species of this grain, or, to speak perhaps more properly, a variety of this species, has been for some time known under the name of *Siberian* buck-wheat, which appears to have considerable advantages over the former. It was sent from Tartary to St Petersburgh by the German botanists, who travelled thro' that country in the beginning of the present century; and it has thence been dispersed over all Europe. Linnæus received the first seeds of it in 1737 from Garber the botanist, and described the plant in his *Hortus Cliffortionus*. After this it was mentioned by Ammann in 1739: but it must have been earlier known in Germany; for in 1733 it was growing in the garden of Dr Ehrhart at Memmingen. In Siberia this plant sows itself for four or five years by the grains that drop; but at the end of that period the land becomes so full of tares that it is choaked, and must be sown afresh. Even in the economical gardens of Germany, it is propagated in the same manner; and in that country it is in some places found growing wild, though it is nowhere cultivated in the neighbourhood. In the United States it is cultivated very extensively and is found a valuable article, whether for manure, for sheltering young clover, or for a crop of grain, which is much used for bread and also for feeding cattle.

BUCKS *Co.* in Pennsylvania, lies S. W. from Philadelphia. It is separated from Jersey by Delaware River, on the S. E. and N. E. and has Northampton co. on the N. W. It contains 25,401 inhabitants, including 114 slaves. Bucks is a well cultivated county, containing 411,900 acres of land, and is divided into 27 townships, the chief of which is Newtown. It abounds with lime stone, and in some places are found iron and lead ore. There is a remarkable hill in the N. end of the county called Haycock, in the township of the same name. It is 15 miles in circumference, having a gradual ascent, and from its summit is a delightful prospect. The waters of Tohickon Creek wash it on all sides except the west.—*Morse.*

BULAM, or Bulama, as it is more usually called, forms part of the Archipelago, or cluster of islands, lying on the western or windward coast of Africa, and known by the name of the *Bissaos* or *Bissagos*, which are supposed to have been celebrated by the ancients under the appellation of the *Hesperides*. It is situated at the mouth of the Rio Grande, in 11° N. Lat. and 15° W. Long. from the meridian of London; and is between seventeen and eighteen leagues long, and from four to five broad.

This island has become an interesting object to the inhabitants of Great Britain, in consequence of its having been purchased in the year 1792 by a society instituted for the same humane purposes with those which gave rise to the Sierra-Leone company (see *Sierra-Leone*, Encycl.). The Bulam association was formed towards the latter end of the year 1791; and they were induced to pitch upon that island as the most eligible tract for their intended colony, in consequence of the flattering description given of its climate, soil, and harbours, by M. Brue, formerly director-general of the French African companies.

The gentlemen originally appointed as trustees for managing the concerns of the association at home were, *Paul Le Mesurier*, M. P.; *James Kirkpatrick*, Esq; *George Hartwell*, Esq; *Moses Ximenes*, Esq; *Sir John Riggs Miller*, Bart. and *David Scott*, Esq; M. P; and for establishing the colony, and conducting the affairs of the society abroad, the following gentlemen were nominated, viz. *Messrs H. H. Dalrymple*, *John Young*, *Sir William Halton*, Bart. *John King*, *Philip Beaver*, *Peter Clutterbuck*, Bulama. *Clutterbuck, Nicholas Bayly, Francis Brodie, Charles Drake, John Paiba, Richard Handcorne, Robert Dobbins,* and *Iſaac Ximenes.*

A ſum of L.9000 being quickly ſubſcribed for the eſtabliſhment of the intended colony, this committee failed from Spithead in three ſhips on the 11th of April 1792; and landing in due time at Bulama, they purchaſed that iſland from the kings of Canabac, who claimed it as their property. They purchaſed likewiſe from the kings of Ghinala the neighbouring iſland Arcas, and the adjacent land on the continent; and theſe ſeveral purchaſes being taken poſſeſſion of in the uſual form, a body of ſettlers, conſiſting of 49 men, 13 women, and 25 children, were left at Bulama under the ſuperintendance of Mr Beaver, with a temporary ſupply of proviſions, ſtores, plantation-tools, and merchandiſe, for trading with the neighbouring natives. It is from the diſpatches of theſe ſettlers, after having lived ſome time in Bulama, that the following account of the iſland was drawn up by Mr Johanſen.

" The climate, on the whole, may be deemed ſalubrious, and will become more ſo in proportion to the increaſe of cultivation. The mornings and evenings are temperate and pleaſant; the middle of the day is hot, but the fine ſea-breeze which then ſets in tends greatly to cool and refreſh the air. The heat of the ſun is not either ſo exceſſive or intolerable as has been generally ſuppoſed; indeed nature has moſt admirably adapted our mechanical and phyſical qualities to the exigencies of different regions; and man, who is the inhabitant of every climate, may, in ſome meaſure, render himſelf indigenous to every ſoil. Here the only danger ariſes from too ſudden an expoſure to the operation of the vertical rays of the ſun, or an exceſs of labour; both of which the firſt ſettlers ought moſt ſtudiouſly to avoid.

" It appears from Mr Beaver's obſervations at noon, between the 20th of July 1792, and the 28th of April 1793, that the thermometer, when loweſt, was at 74; the medium heat 85; and that it never exceeded 96, except at one time when it roſe to 100, during a calm that occurred in the interval between the north-eaſt breeze in the morning and the ſouth-weſt in the evening of the 19th of February 1793. The difference between the heat of noon and that of the morning and evening is from 20 to 30 degrees. On the 23d of October 1792, hail of the ſize of a pin's head fell during two minutes, although not a cloud was to be ſeen during this phenomenon. The mercury in the thermometer then ſtood at 85; the wind was at north-eaſt in the morning and ſouth-weſt in the evening.

" Immediately after ſun ſet a dew conſtantly begins to fall, which induces ſome to light a fire in their houſes; they at the ſame time put on warmer clothing. There is little or no twilight; and night and day are nearly equal: the earth has therefore time to cool during twelve hours abſence of the ſun.

" None of thoſe terrible and deſtructive hurricanes ſo frequently experienced in the Weſt Indies are to be met with here. The *tornadoes*, which ariſe chiefly from the eaſtern point of the compaſs, are but of ſhort duration, ſeldom laſting above an hour, and may be readily foreſeen ſome time previouſly to their commencement. They occur at the beginning and cloſe of the wet ſeaſon, and are highly beneficial, as they purify the air, and diſpel the noxious vapours with which it would otherwiſe abound. Bulama.

" The rains ſet in about the latter end of May or the beginning of June, and diſcontinue in October or November. They do not fall every day, for there is often a conſiderable interval of clear weather, during which the atmoſphere is beautifully ſerene; the ſhowers in the firſt and laſt month occur but ſeldom, and are far from being violent; while on the other hand, they ſometimes reſemble torrents, more eſpecially towards the middle of the ſeaſon. During the whole of this period, Europeans ſhould, if poſſible, confine themſelves to their habitations, as the rains prove injurious to health, more eſpecially if thoſe expoſed to them neglect to wipe their bodies dry, and to change their clothes immediately on their return home. It is deemed prudent alſo not to dig the earth until the expiration of a month after the return of fair weather, as this is conſidered to be unhealthy.

" During the continuance of the dry ſeaſon, a dew falls during the night, in ſufficient quantity to anſwer all the purpoſes of vegetation.

" Every ſtranger is generally here, as well as in the Weſt Indies, ſubject to a fever or *ſeaſoning*, on his arrival. This is not infectious; it proceeds perhaps from an increaſed perſpiration and a ſudden extenſion of the pores of the human body, in conſequence of the heat, by which means it is rendered more liable to imbibe the abundant exhalations that ariſe from the animal, vegetable, and mineral kingdoms; but even this, ſlight as it is, might doubtleſs be avoided by means of a proper regimen, and a ſhort ſecluſion from the full action of the open air, more eſpecially at noon, and during the evening, until the climate has been rendered familiar.

" Bulama is admirably adapted for all the purpoſes of an extenſive commerce, being not only happily ſituated at the mouth of the Rio Grande, but in the vicinity of ſeveral other navigable rivers; ſo that a trade with the internal parts of Africa is thereby greatly facilitated. The landing is remarkably eaſy and ſafe, there being no ſurge; the ebb and flow is regular, and there is an increaſe of 16 feet of water at ſpring tide. The bay oppoſite the Great Bulama is adorned with a number of iſlands, covered with trees, and forms a moſt excellent harbour, ſufficiently capacious to contain the whole navy of Great Britain, which might ride there in ſafety. The ſettlement in general is well ſupplied with water. A number of ſprings have been lately diſcovered in different places; and beſides a draw-well in the fort, which was erected for the defence of the colony, there is a ſmall ſtream, which runs into Elewſis Bay, near the new ſettlement called Heſper Elewſis: this is admirably ſituated for the ſupply of ſhipping.

" The iſland is beautifully ſurrounded, and interſperſed with woods: lofty fruit and foreſt trees, moſtly free from underwood and brambles, form a verdant belt, in ſome places two or three miles broad, which entirely encircles it, in ſuch a manner as to repreſent a plantation artificially formed around a park. Within this the fields are regularly divided by trees, ſo as to reſemble the hedge rows in England. The beach has in ſome places the appearance of gravel walks; it is fringed with mangrove trees, which forming a line with the high-water mark, dip their branches into the ſea, and thus afford nouriſhment to the oyſters that often adhere to their extremities.

Several parts of Bulama have been occaſionally cultivated by the neighbouring blacks, though they did not conſtantly reſide on it.

"The land in general riſes gradually towards the middle of the iſland, where the higheſt ſpot is from 60 to 100 feet above the level of the ſea. The ſmall hill on which the fort is ſituated is nearly of the ſame altitude.

"The ſoil is abundantly rich and deep; ſtones do not here impede the labours of the farmer; and indeed none have hitherto been diſcovered, but a ſmall ſort, reſembling pieces of ore, which are to be met with on the ſhore. There are many *ſavannahs* or natural meadows, ſo extenſive that the eye can ſcarcely deſcry their boundaries. Theſe are admirably adapted for the rearing of ſtock and feeding of cattle of every kind.

"Cotton, indigo, rice, and coffee, grow ſpontaneouſly on this coaſt; the ſugar-cane is indigenous to many parts of Africa, and might be cultivated here by the labour of freemen, in equal perfection, and to much greater advantage, than in the exhauſted iſlands of the Weſt Indies. All kinds of tropical productions, ſuch as pine-apples, limes, oranges, grapes, plums, caſſada, guava, Indian wheat, the papaw, water-melon, muſk-melon, the pumkin, tamarind, banana, and numbers of other delicious fruits, alſo flouriſh here. The adjoining territories produce many valuable ſorts of ſpices, gums, and materials for dying; all of which, it is but fair to ſuppoſe, might be readily cultivated in a kindred climate and a congenial ſoil.

"The neighbouring ſeas abound with a variety of fiſh, highly agreeable to the palate. The lion, tyger, jackall, &c. are natives of the continent; but in Bulama no animals have been diſcovered, the wolf, ſome buffaloes, a few elephants, and a ſpecies of the deer excepted.

"The woods abound with doves, guinea fowls, and a variety of birds, celebrated for the beauty of their plumage.

"The natives of this part of Africa, like all ſavages, are entirely under the dominion of their paſſions: hence the violence of their attachment to their friends, and the exceſs of their reſentment againſt their enemies. Their notions of property are very obſcure and confuſed: they have no idea of any right ariſing from occupancy or improvement. What they want, they either receive or take wherever they may happen to meet with it, and they permit others to do the ſame. They have been taught by experience, that the Europeans will not agree to this: againſt them therefore they employ every artifice that it is in the power of cunning to ſuggeſt.

"The coloniſts need not fear any attack on the part of the negroes, provided their own conduct be juſt and peaceable: for Mr Beaver, who was indeed admirably calculated by nature and habit for the ſtation he occupied, could inſure both ſafety and reſpect when the ſettlers under him were reduced to four white men, although the neighbouring nations knew that he was in poſſeſſion of commodities, for the acquiſition of which many of them had become day-labourers. He often kept from twenty to forty gromittos, or black cultivators in pay, at that very period, at about four or five bars (A) each per month. Theſe are eaſy to be procured, to almoſt any number that can poſſibly be wanted.

"Until a ſufficient quantity of ſtock and proviſions can be raiſed in the company's ſettlements, the adjacent iſlands will furniſh abundance of cattle, hogs, fowls, &c. at a very cheap rate. A horſe may be purchaſed at Goree for 1 l. 10 s. a bullock may be had from 12 s. to 18 s. ſterling: proviſions of all kinds are equally reaſonable. Honey is alſo to be procured in great plenty, and bees wax may be rendered an advantageous object of commercial ſpeculation.

"In ſhort, the acquiſition of Bulama, Arcas, and the adjacent territories, preſents the faireſt opportunity of furniſhing Europe with many valuable articles that have hitherto been brought from more remote countries, with much greater hazard, and at an increaſed expence. The intercourſe with England is eaſy, ſafe, and expeditious; for the voyage may be performed in the ſpace of three or four weeks: and by the terms of the firſt ſubſcription, a ſettler on Bulama might purchaſe 500 acres of land for L. 30 ſterling; by the terms of the ſecond, which we ſuppoſe are the terms at preſent, he might purchaſe on the iſlands of Bulama and Arcas, or on that part of the adjacent coaſt which was ceded to the ſociety by the kings of Ghinala, 200 acres for L. 50 ſterling.

"The colonization of Africa opens a noble and extenſive field to nations and to individuals. To people thoſe fertile territories, deſpoiled of their inhabitants by the ſlave-trade; to rear the productions of the climes between the tropics, by the aſſiſtance of free men; to give ample ſcope to the induſtry and exertions of thoſe who may be inclined to remove from Great Britain; and to extend the commerce and the manufactures of our native country—theſe are ſubjects which have excited the attention of the Bulama aſſociation, and now claim the aſſiſtance of the ingenious, the ſupport of the rich, and the concurrence and good wiſhes of all.

BUNCOMB, the largeſt and moſt weſtern county of North Carolina, and perhaps the moſt mountainous and hilly in the United States. It is in Morgan diſtrict, bounded W. by the ſtate of Tenneſſee; and S. by the ſtate of South Carolina. The Blue Ridge paſſes through Buncomb, and gives riſe to many large rivers, as Catabaw, Wateree, Broad River and Pacolet.—*Morse.*

BUNTING, is a bird which has been deſcribed under its generic name Emberiza *(Encycl.)*; but there is one ſpecies, the *orange-ſhouldered bunting* of Latham, of which M. Vaillant relates ſome particulars certainly not unworthy of notice in this place.

"The female of this beautiful bird (ſays he) has the ſimple colours of the ſky lark, and a ſhort horizontal tail, like that of almoſt all other birds: the male, on the contrary, is wholly black except at the ſhoulder of the wing, where there is a large red patch; and his tail is long, ample, and vertical, like that of the common cock. But this brilliant plumage and fine vertical tail ſubſiſt only during the ſeaſon of love, which continues ſix

(A) A bar is about the value of three ſhillings and ſixpence.

fix months. This period over, he lays afide his fplendid habiliments, and affumes the more modeft drefs of his mate. The moft extraordinary circumftance is, that the vertical tail alfo changes to a horizontal one, and the male fo exactly refembles the female, that it is not poffible to diftinguifh them from each other.

"The female has her turn. When fhe reaches a certain age, and has loft the faculty of propagating the fpecies, fhe clothes herfelf for the remainder of her days in the garb which the male had temporarily affumed; her tail, like his at that period, grows long, and, like his alfo, from horizontal becomes vertical.

"The birds of this fpecies affociate together, live in a fort of republic, and build their nefts near to each other. The fociety ufually confifts of about fourfcore females; but whether, by a particular law of nature, more females are produced than males, or for any other reafon of which I am ignorant, there are never more than twelve or fifteen males to this number of females, who have them in common."

According to our author, this tranfmutation is by no means confined to this particular fpecies of bunting. Many females of the feathered creation, when they grow fo old as to ceafe laying eggs, affume the more fplendid colours of the male, which they retain during the remainder of their lives. This fact is ftrikingly perceptible in thofe fpecies in which the male and female very much differ in colour, as the golden pheafant of China, for inftance. In fome fpecies, and thofe not a few, the male alone regularly changes his colour, and affumes once in a year the plumage of the female; fo that at a certain period all the birds of that fpecies appear females. "I have in my poffeffion (fays our author) fpecimens of more than fifty of thofe changing fpecies, in all their tranfitions from one hue to another; and the change is fometimes fo great, that a perfon would fuppofe himfelf to fee individuals totally different. A clofet-naturalift, for inftance, fhewed me four birds as fo many different fpecies, and even as not belonging to the fame genus, with which I was well acquainted, and which I knew to be the fame bird, only of different ages."

Such changes as thefe, could they be proved to take place occafionally among domeftic fowls, would in fome meafure account for ftrange ftories of cocks laying eggs, which we have heard related by perfons whofe general veracity was never queftioned.

BURKE (Edmund), was born in the city of Dublin on the 1ft of January 1730. His father was an attorney of confiderable knowledge in his profeffion, and of extenfive practice; and the family from which he fprung was ancient and honourable. He received the rudiments of his claffical education under Abraham Shackleton, a Quaker, who kept a private fchool or academy, as it has been called, at Bellytore, near Carlow, and is faid to have been a very fkilful and fuccefsful teacher.

Under the tuition of this mafter Burke devoted himfelf with great ardour, induftry, and perfeverance, to his ftudies; and manifefted, even from his boyifh days, a diftinguifhed fuperiority over his contemporaries. He was the pride of his preceptor, who prognofticated every thing great from his genius, and who was, in return, treated by his illuftrious pupil, for forty years, with refpect and gratitude.

From fchool Burke was fent to Trinity-college, Dublin, where it was afferted by Goldfmith and others his contemporaries, that he difplayed no particular eminence in the performance of his exercifes. Like Swift, he defpifed the logic of the fchools; and like him too, he devoted his time and his talents to more ufeful purfuits. Johnfon, though proud of being an Oxonian, did not much employ himfelf in academical exercifes; and Dryden and Milton, who ftudied at Cambridge, were neither of them ambitious of college diftinctions. Let not, however, the example of a Burke, a Johnfon, a Dryden, or a Milton, feduce into by-paths the ordinary ftudent; for though great genius either finds or makes its own way, common minds muft be content to purfue the beaten track. Shakefpeare, with very little learning, was the greateft dramatic poet that ever wrote; but how abfurd would it be to infer from this fact, that every illiterate man may excel in dramatic poetry?

Whilft at college Burke applied himfelf with fufficient diligence to thofe branches of mathematical and phyfical fcience which are moft fubfervient to the purpofes of life; and though he neglected the fyllogiftic logic of Ariftotle, he cultivated the method of induction pointed out by Bacon. Pneumatology, likewife, and ethics, occupied a confiderable portion of his attention; and whilft attending to the acquifition of knowledge, he did not neglect the means of communicating it. He ftudied rhetoric and the art of compofition, as well as logic, phyfics, hiftory, and moral philofophy; and had at an early period of his life, fays Dr Biffet, planned a confutation of the metaphyfical theories of Berkeley and Hume.

For fuch a tafk as this, we do not think that nature intended him. Through the ever-active mind of Burke ideas feem to have flowed with too great rapidity to permit him to give that patient attention to minute diftinctions, without which it is vain to attempt a confutation of the fubtleties of Berkeley and Hume. The ableft antagonift of thefe two philofophers was remarkable for patient thinking, and even *apparent* flownefs of apprehenfion; and we have not a doubt, but that if he had poffeffed the rapidity of thought which charactefifed Burke, his confutation of Hume and Berkeley would have been far from conclufive: It might have been equal to the *Effay on the Nature and Immutability of Truth*, but would not have been what we find it in *The Inquiry into the Human Mind on the Principles of Common Senfe*, and in *The Effays on the Intellectual and Active Powers of Man*.

A tafk much better fuited to Burke's talents than the writing of metaphyfical difquifitions on the fubftratum of body, prefented itfelf to him in the year 1749, and a tafk which was likewife more immediately ufeful. At that period one Lucas, a democratic apothecary, wrote a number of very daring papers againft government, and acquired by them as great popularity at Dublin as Mr Wilkes afterwards obtained by his North Briton in London. Burke, though a boy, perceived, almoft intuitively, the pernicious tendency of fuch levelling doctrines, and refolved to counteract it. He wrote feveral effays in the ftyle of Lucas, imitating it fo exactly as to deceive the public; purfuing his principles to confequences neceffarily refulting from them, and fhewing at the fame time their abfurdity and their danger.

Burke. danger. Thus was his firſt literary effort, like his laſt, calculated to guard his country againſt anarchical innovations.

Whilſt employed in treaſuring up knowledge, which at a future period was to command the admiration of liſtening ſenates, he did not neglect the means neceſſary to render himſelf agreeable in the varied intercourſe of private life. To the learning of a ſcholar he added the manners of a gentleman. His company was ſought among the gay and the faſhionable, for his pleaſing converſation and eaſy deportment; as much as among the learned, for the force and brilliancy of his genius, and the extent and depth of his knowledge. But though the object of very general regard in his native country, he had hardly any proſpect of obtaining in it an independent ſettlement. He therefore applied, ſome time after the publication of his letters expoſing the doctrines of Lucas, for the profeſſorſhip of logic, which had then become vacant in the univerſity of Glaſgow: but whether that application was made too late, or that the univerſity was unwilling to receive a ſtranger, certain it is that the vacant chair was filled by another, and that Burke was diſappointed of an office in which he was eminently qualified to excel. For many years very little attention has been paid in the univerſities of Scotland, perhaps even too little, to the Ariſtotelian logic; and the profeſſors, inſtead of employing their time in the analyſing of ſyllogiſms, deliver lectures on rhetoric and the principles of compoſition—lectures which no man was more capable of giving than the unſucceſsful candidate for the profeſſorſhip in Glaſgow.

Diſappointment of early views has frequently been the means of future advancement. Had Johnſon become maſter of the Staffordſhire ſchool, talents might have been conſumed in the tuition of boys which Providence formed for the inſtruction of men; and had Burke obtained the profeſſorſhip of logic in Glaſgow, he would have been the moſt eloquent lecturer in that univerſity, inſtead of the moſt brilliant ſpeaker in the Britiſh ſenate: but whether his talents might not have been as uſefully employed in the univerſity as in the ſenate, may perhaps be a queſtion, though there can be no queſtion whether they would have inveſted himſelf with an equal blaze of ſplendour.

Diſappointed in Glaſgow, he went to London, where he immediately entered himſelf of the Temple; and as there is reaſon to believe that he was in ſtraitened circumſtances, he ſubmitted to the drudgery of regularly writing for daily, weekly, and monthly publications, eſſays on general literature and particular politics. The profits ariſing from ſuch writings were at firſt ſmall; but they were ſo neceſſary to their author, that the intenſe application which they required gradually impaired his health, till at laſt a dangerous illneſs enſued, when he reſorted for medical advice to Dr Nugent, a phyſician whoſe ſkill in his profeſſion was equalled only by the benevolence of his heart. The Doctor, conſidering that the noiſe, and various diſturbances incidental to chambers, muſt retard the recovery of his patient, furniſhed him with apartments in his own houſe, where the attention of every member of the family contributed more than medicines to the reſtoration of his health. It was during this period that the amiable manners of Miſs Nugent, the Doctor's daughter, made a deep impreſſion on the heart of Burke; and as ſhe could not be inſenſible to ſuch merit as his, they felt for each other a mutual attachment, and were married ſoon after his recovery. Burke.

Hitherto his mental powers and acquirements were known in their full extent only to his friends and more intimate companions; but they were now made public in his firſt acknowledged work, intitled, *A Vindication of Natural Society*. The object of this performance was to expoſe the dangerous tendency of Lord Bolingbroke's philoſophy. By the admirers of that nobleman his principles were deemed inimical only to revealed religion and national churches, which they would have been glad to ſee overturned, provided our civil eſtabliſhment had been preſerved; and to the civil eſtabliſhment they perceived no danger in the writings of the author of *The Patriot King*. Mr Burke thought very differently; and endeavoured to convince them, that if his Lordſhip's philoſophy ſhould become general, it would ultimately deſtroy their rank, their conſequence, and their property, and involve the church and ſtate in one common ruin. In his ironical attack upon artificial ſociety, he makes uſe of the ſame common-place mode of unfair reaſoning which his noble antagoniſt had employed againſt religion and religious eſtabliſhments. He argues, from the incidental abuſes of political ſociety, that political ſociety muſt itſelf be evil; he goes over every form of civil polity, pointing out its defects in the moſt forcible language; and, in perfect imitation of the ſceptical philoſophy, he pulls them all down, one after another, without propoſing any thing in their ſtead. So complete is the irony, that to many not acquainted with ſuch diſquiſitions, he would appear to be ſeriouſly inveighing againſt civil government: and we have actually heard ſome of the advocates for modern innovation mention this work as a proof how different Mr Burke's opinions in politics once were from what they appear to have been when he wrote his *Reflections on the French Revolution*.

The truth, however, is, that there is no inconſiſtency between *The Vindication of Natural Society* and the lateſt publications of its illuſtrious author. At the period when that work was publiſhed, infidelity had infected only the higher orders of men, and ſuch of the lower as had got the rudiments of a liberal education. Of theſe we believe a ſingle individual was not then to be found, who ſuppoſed that ſociety could ſubſiſt both without government and without religion; and therefore whilſt they laboured to overturn the church, and to prove that Chriſtianity itſelf is an impoſture, they all pretended to be zealouſly attached to the civil government as eſtabliſhed in king, lords, and commons. Except the clergy of the eſtabliſhed church, there was no order of men whom they indiſcriminately reviled. Hence it was that not Burke only, but Warburton, and almoſt every other opponent of Lord Bolingbroke, began their defences of revelation, by ſhewing the indiſſoluble connection between the civil and eccleſiaſtical eſtabliſhments, and all the difference was, that he did, through the medium of the moſt refined irony, the very ſame thing which they had done by ſerious reaſoning.

Soon after his *Vindication of Natural Society*, Burke publiſhed *A Philoſophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful*; a work which ſoon made its author univerſally known and admired, and which has been ſtudied by every Engliſh reader of taſte.

It

Burke.

It is therefore needlefs for us to hazard any opinion either of its general merit or its particular defects. In one of the literary journals of that day, Mr Murphy urged objections againft fome of its fundamental principles, which, in our opinion, it would be very difficult to anfwer; whilft Johnfon, who was certainly a fevere judge, confidered it as a model of philofophical criticifm. "We have (faid he) an example of true criticifm in Burke's Effay on the Sublime and Beautiful. There is no great merit in fhewing how many plays have ghofts in them, or how this ghoft is better than that; you muft fhew how terror is impreffed on the mind."

In confequence of this manifeftation of Burke's intellectual powers, his acquaintance was courted by men of diftinguifhed talents, and, among others, by Johnfon and Sir Jofhua Reynolds. The literary club, which has been mentioned *(Encycl.)* in the life of Johnson, was inftituted for their entertainment and inftruction, and confifted at firft of Johnfon, Burke, Reynolds, Goldfmith, Dr Nugent, Mr Topham, Beauclerc, Sir John Hawkins, Mr Chamier, and Mr Bennet Langton, who were all men of letters and general information, though far above the reft ftood Burke and Johnfon. Of Burke indeed, Johnfon declared, upon all occafions, that he was the greateft man living; whilft Burke, on a very folemn occafion, faid of Johnfon, "He has made a chafm, which not only nothing can fill up, but which nothing has a tendency to fill up. Johnfon is dead. Let us go to the next beft—There is nobody—No man can be faid to put you in mind of Johnfon." Nor was the opinion which thefe two illuftrious men held of each other's powers peculiar to themfelves alone: all the members of the club obferved, that, in colloquial talents, they were nearly matched, and that Johnfon never difcourfed with fuch animation and energy as when his powers were called forth by thofe of Burke.

Some years before the inftitution of this club, Burke, who had devoted much of his time to the ftudy of hiftory and politics, propofed to Mr Dodfley, an eminent bookfeller, a plan of an Annual Register of the civil, political, and literary tranfactions of the times; and the propofal being acceded to, the work was begun and carried on for many years, either by Burke himfelf, or under his immediate infpection. It bears indeed internal marks of his genius, his learning, and his candour, being by much the moft elegant and impartial periodical hiftory which has perhaps appeared in any age or nation. Even when the heat of oppofition made him, in his fpeeches, fometimes mifreprefent the conduct of adminiftration, the Annual Regifter, under his management, continued to render juftice to all parties.

He ftill continued to write occafionally political effays for other publications than the Annual Regifter; and fome of thefe effays in the *Public Advertifer* having attracted the notice of the Marquis of Rockingham, that nobleman fought the acquaintance of their author. It was in the year 1765 that the firft interview took place between them; and the Marquis, who was then at the head of the treafury, offering to make Burke his own fecretary, the offer was readily accepted. On this occafion he gave a remarkable proof of difintereftednefs and delicate integrity. Through the influence of Mr Hamilton, known by the appellation of *Single-Speech* Hamilton, and long fufpected to be the author of *Junius's Letters*, he had fome time before obtained a penfion of L. 300 a year on the Irifh eftablifhment; but this penfion he now thought it incumbent upon him to refign, becaufe he had connected himfelf with a party oppofite in many things to the party whofe meafures were fupported by his friend.

During the Rockingham adminiftration he was chofen member of parliament for the borough of Wendover in the county of Bucks; and he prepared himfelf for becoming a public fpeaker, by ftudying, ftill more clofely than he had yet done, hiftory, poetry, and philofophy; and by ftoring his mind with facts, images, reafonings, and fentiments. He paid great attention likewife to parliamentary ufage; and was at much pains to become acquainted with old records, patents, and precedents, fo as to render himfelf complete mafter of the bufinefs of office. That he might communicate without embarraffment the knowledge which he had thus laborioufly acquired, he frequented, with many other men of eminence, the Robin Hood Society, where he practifed the replies and contentions of eloquence; and to acquire a graceful action, with the proper management of his voice, he was a very diligent obferver of Garric in Drury-Lane theatre. He procured his feat in 1765, and in the enfuing feffion delivered his maiden fpeech; which was fuch a difplay of eloquence as excited the admiration of the Houfe, and drew very high praife from its moft diftinguifhed member Mr Pitt, afterwards Earl of Chatham.

The principal objects which engaged the attention of the Rockingham adminiftration were the ferments in America, which was then in a ftate little fhort of rebellion, on account of the famous ftamp-act. Parliament was divided in opinion refpecting that meafure. Whilft Mr Grenville and his party (under whofe aufpices the ftamp-act had paffed into a law) were for enforcing obedience to it by coercive meafures, Mr Pitt and his followers denied that the parliament of Great Britain had a right to tax the Americans; and the marquis of Rockingham, who was hardly able to carry any meafure in oppofition to both thefe parties, had to confider, on this occafion, whofe fentiments he would adopt. By the advice, it is faid of Mr Burke, he chofe a middle courfe between the two oppofite extremes. To gratify the Americans, he repealed the ftamp-act; and to vindicate the honour of Britain, he got a law paffed declaratory of her right to legiflate for America in taxation as in every other cafe.

This meafure, whoever was its author, was certainly not the offspring either of wifdom or vigour. If the mother country had a right to legiflate in all cafes for America, obedience to the ftamp-act fhould certainly have been enforced; and the miniftry which relinquifhed an acknowledged right, to gratify the difpofition of diftant colonies, was confidered as unfit to guide the helm of a great empire. Lord Rockingham and his friends were accordingly difmiffed from office; and a new adminiftration was formed under the aufpices of Mr Pitt, now created Earl of Chatham.

Burke, in the mean time, wrote in defence of the party with which he was connected; and affumed great credit to it for compofing the diftractions of the Britifh empire by the repeal of the American ftamp-act, whilft the conftitutional fuperiority of Great Britain was preferved by the act for fecuring the dependence of

Burke. of the colonies. After defending his friends, he proceeds to attack thofe who had fucceeded them in office. Of Lord Chatham he fays—"He has once more deigned to take the reins of government into his own hand, and will, no doubt, drive with his wonted fpeed, and raife a deal of duft around him. His horfes are all matched to his mind; but as fome of them are young and fkittifh, it is faid he has adopted the new contrivance lately exhibited by Sir Francis Delaval on Weftminfter bridge: whenever they begin to fnort and tofs up their heads, he touches the fpring, throws them loofe, and away they go, leaving his lordfhip fafe and fnug, and as much at his eafe as if he fat on a woolpack."

The letter, of which this is an extract, was printed in the Public Advertifer; and is faid to have contributed, in no fmall degree, to leffen the popularity of the illuftrious ftatefman againft whom it was written. The miniftry, indeed, which he had formed, confifted of very heterogeneous materials, and was not heartily approved of by the nation. It therefore foon fell in pieces by its own difcord, and Lord Chatham retired in difguft.

The parliament being diffolved in 1768, Burke was re-elected for Wendover, and took his feat, when the houfe met, in November. The duke of Grafton was now prime minifter, and was oppofed by two powerful parties in parliament; that of the marquis of Rockingham, and that of which Mr Grenville was confidered as the leader. Thefe two parties, however, differed widely between themfelves. Mr Grenville had publifhed a pamphlet, intitled, *The Prefent State of the Nation;* in which he very ably vindicated his own meafures, and of courfe condemned the meafures of thofe who had fucceeded him; and Burke replied to him, with greater eloquence, but, perhaps, with lefs of argument, in a tract, intitled *Obfervations on the Prefent State of the Nation*, in which he makes a very high panegyric on his own patron, and the connections of the party, and animadverts with cutting feverity on their fucceffors in office.

About this period commenced the national frenzy which was excited by the expulfion of Wilkes from the houfe of commons, *for having printed and publifhed a feditious libel, and three obfcene and impious libels.* In the controverfy to which this tranfaction gave rife, Burke and Johnfon took oppofite fides. Johnfon, in his *Falfe Alarm*, contends, with great ability, that the expulfion of a member from the houfe of commons for the commiffion of a crime, amounts to a difqualification of that member from fitting in the parliament from which he is expelled; whilft Burke, though he difapproved of the conduct of Wilkes as much as his friend, laboured to prove, that nothing but an act of the legiflature can difqualify any perfon from fitting in parliament who is regularly chofen, by a majority of electors, to fill a vacant feat. It does not appear that this difference of opinion produced the fmalleft abatement of mutual regard between him and Johnfon. They both attended the weekly club, and were as much pleafed with each other as formerly.

The proceedings of the Grafton adminiftration, refpecting Wilkes and other fubjects, gave rife to the celebrated *Letters of Junius*. That thofe compofitions were, in clearnefs, neatnefs, and precifion of ftyle, infinitely fuperior to perhaps every other feries of newfpaper invectives, has never been controverted; and that they difplay a vaft extent of hiftorical and political information, is known to all who are not themfelves ftrangers to the hiftory of Great Britain. Unclaimed by any author, and fuperior to the productions of moft authors, they have been given to Burke, to his brother Richard, a man likewife of very bright talents, to Mr Hamilton, and to Lord George Germaine. We fhould hardly hefitate to adopt the opinion of thofe who afcribe them to Burke, had he not difavowed them to his friend Johnfon. "I fhould have believed Burke to be Junius (faid Johnfon), becaufe I know no man but Burke who is capable of writing thefe letters; but Burke *fpontaneoufly* denied it to me. The cafe would have been different had I *afked* him if he was the author. A man may think he has a right to deny when fo queftioned as to an anonymous publication." The difference between the ftyle of thefe letters and that of Burke's acknowledged writings, would have had no weight with us; becaufe fuch was his command of language, that he could affume, and occafionally did affume, any ftyle which he chofe to imitate. He had already fo clofely imitated the very different ftyles of Lucas and Bolingbroke as to deceive the public; and what was to hinder him from imitating the ftyle of Lord George Germaine, which certainly has a ftrong refemblance to that of Junius? We think, however, with Johnfon, that his *fpontaneous difavowal* of thefe letters ought to be held as fufficient proof that he was not their author.

Burke had now gotten a very pleafant villa near Beaconsfield in Buckinghamfhire; and being one of the freeholders of the county, he drew up a petition to the king, complaining of the conduct of the houfe of commons refpecting the Middlefex election, and praying for a diffolution of the parliament. The petition, though explicit and firm, was temperate and decorous, and as unlike to one on the fame fubject from the livery of London, as the principles of a moderate Whig are to thofe of a turbulent democrate.

About this period he ftated very clearly his own political principles in a pamphlet intitled, "Thoughts on the Caufes of the Prefent Difcontents;" and his plan for removing thefe difcontents had not a grain of democracy in its compofition. He propofed to place the government in the hands of an open ariftocracy of talents, virtue, property, and rank, combined together on avowed principles, and fupported by the approbation and confidence of the people; and the ariftocracy which he thought fitteft for this great truft, was a combination of thofe Whig families which had moft powerfully fupported the revolution and confequent eftablifhments. He expreffed, in ftrong terms, his difapprobation of any change in the conftitution and duration of parliament; and declared himfelf as averfe from an adminiftration which fhould have no other fupport than popular favour, as from one brought forward merely by the influence of the court.

In this plan there is not that wifdom or liberality which might have been expected from a man of Burke's cultivated mind and extenfive reading. The Whigs, when in power, had been as venal as the Tories; and the imprifonment of Lord Oxford, the banifhment of Atterbury bifhop of Rochefter, and the refolution of the

the houſe of commons to ſit for ſeven years, when it had been choſen by its conſtituents for no more than three, were certainly greater violations of the conſtitution than the diſqualification of Wilkes, or any other meaſure that had been carried by the court during the adminiſtrations of Grenville and the duke of Grafton. Burke ſhewed himſelf in this publication to be indeed no republican; but every ſentence of it breathed the ſpirit of party.

Lord North was now prime miniſter; and in order to tranquillize America, he propoſed, in the beginning of his adminiſtration, to repeal the obnoxious laws of his predeceſſors in office, and to reſerve the duty on tea merely to maintain the authority of parliament. The conſequences of this conduct we have detailed elſewhere (ſee Britain, *Encycl.*); and they are too well known to all our readers. The part which Burke acted during his adminiſtration will not, in our opinion, admit of any plauſible defence. It was not indeed the part of a democrate, but of a man determined to oppoſe every meaſure of thoſe in power. In the beginning of the conteſt, he certainly diſplayed more wiſdom and patriotiſm than the miniſter; for, without entering directly into the queſtion Whether the mother-country had or had not a right to tax the colonies? he contented himſelf with warning the houſe againſt dangerous innovations. "The Americans (ſaid he) have been very ſerviceable to Britain under the old ſyſtem: do not, therefore, let us enter raſhly upon new meaſures. Our commercial intereſts have been hitherto greatly promoted by our friendly intercourſe with the colonies; do not let us endanger poſſeſſion for contingency; do not let us ſubſtitute untried theories for a ſyſtem experimentally aſcertained to be uſeful."

This was undoubtedly ſound reaſoning, and everyway becoming a lover of his country: but his continued oppoſition to government, after all Europe had leagued againſt Great Britain, was a conduct which will admit of no vindication, and for which the only poſſible apology muſt be found in that ardour of temper which made his friend Hamilton ſay, on another occaſion, "Whatever opinion Burke, from any motive, ſupports, ſo ductile is his imagination, that he ſoon conceives it to be right." In his moſt violent oppoſition, however, though his expreſſions were often extravagant and indecent, he never for a moment gave his ſupport to the metaphyſical doctrine of the *impreſcriptible rights of man*, or to the actual innovations which ſome meant to introduce on the baſis of that doctrine. His upright mind was indeed ſufficiently guarded againſt theſe novelties by what he had obſerved in France during the year 1772. Whilſt he remained in that country, his literary and political eminence made him courted by all the anti-monarchical and infidel philoſophers of the time; and in the religious ſcepticiſm and political theories of Voltaire, Helvetius, Rouſſeau, and D'Alembert, he ſaw, even at that period, the probable overthrow of religion and government. His ſentiments on this ſubject he took occaſion, immediately on his return, to communicate to the houſe of commons; and to point out the conſpiracy of atheiſm to the watchful policy of every government. He profeſſed, that he was not over fond of calling in the aid of the ſecular arm to ſuppreſs doctrines and opinions; but he recommended a grand alliance among all believers againſt thoſe miniſters of rebellious darkneſs, who were endeavouring to ſhake all the works of God eſtabliſhed in beauty and in order.

The American war proving unſucceſsful, though Great Britain never made a more glorious ſtand, Lord North and his friends retired from office; and, in February 1782, a new miniſtry was formed, at the head of which was placed the marquis of Rockingham; Lord Shelburne and Mr Fox were the ſecretaries of ſtate; and Mr Burke, who was appointed pay-maſter to the forces, exulted, rather childiſhly, in the houſe of commons, on the happineſs which was to accrue, both to the king and to the people, from the able and upright conduct of the new miniſters. The time in which the greater part of them continued in office was too ſhort to permit them to do either much good or much evil.

On the 1ſt of July the marquis of Rockingham died; and the earl of Shelburne being placed at the head of the treaſury, Fox and Burke reſigned in diſguſt, and, to the aſtoniſhment of the nation, formed the famous coalition with Lord North, whoſe meaſures they had ſo long, and ſo vehemently oppoſed. In the coalition of North and Burke there would have been nothing wonderful. In the intercourſe of private life, theſe two ſtateſmen had always met on terms of friendſhip and mutual regard; they had the ſame ideas of the excellence of the conſtitution, and the ſame averſion to innovation under the name of reform; even their ſtudies and amuſements were very ſimilar, being both men of taſte and claſſical learning; and though Burke oppoſed the taxation of America by the Britiſh parliament, his oppoſition proceeded rather from motives of prudence and expediency than from any ſettled conviction that the meaſure was unconſtitutional. But the political enmity of Fox and North had proceeded, not only to perſonal abuſe, but to profeſſions of mutual abhorrence; and perhaps there was hardly an unprejudiced perſon in the kingdom who entertained not ſuſpicions, that the unexpected union of ſuch enemies was cemented by a principle leſs pure than patriotiſm.

Mr Pitt was now chancellor of the exchequer; and when he announced to the houſe of commons the peace which was concluded in January 1783, he found the terms on which it had been made ſeverely condemned by North, Fox, Burke, and all their friends. The cenſure paſſed on it by Lord North and his followers was perfectly conſiſtent with their former conduct, and with the opinions which they had uniformly maintained; but it was with no good grace that Fox and Burke, who had offered an unconditional peace to the Dutch, and ſo frequently propoſed to recognize the independence of America, condemned the peace which had been concluded by Lord Shelburne. On this, as on many other occaſions, they acted, not as enlightened politicians, but as the rancorous leaders of a party.

In conſequence of a vote of cenſure paſſed by the commons, the miniſters reſigned their employments, and were ſucceeded by the duke of Portland, Lord North, Mr Fox, Mr Burke, and their friends. Burke had his former employment of pay-maſter to the forces; Lord North and Mr Fox were ſecretaries of ſtate, and the duke of Portland was firſt lord of the treaſury. To many perſons this miniſtry had the appearance of greater ſtrength than any that had governed the kingdom ſince the time of Sir Robert Walpole; but its duration was not longer than that of the preceding. On the

the 18th of November, Mr Fox introduced his famous India-bill, into the merits of which it is foreign from our purpofe to enter: fuffice it to fay, that after being ftrongly fupported by Burke, and ably oppofed by Pitt and Dundas, it paffed the houfe of commons by a very great majority; but was loft in the houfe of peers, and viewed by the king in fuch a light, that he determined on an entire change of adminiftration.

Mr Pitt was now placed at the head of the treafury, where he has remained ever fince, notwithftanding the violent and powerful oppofition which he met with at firft from North and Fox and their coalefced friends: the voice of the nation has been on his fide; and that voice will always drown the bellowings of patriotifm.

The principal events in which Burke fignalized himfelf, fince the year 1784, were the trial of Haftings, the deliberations of the houfe on the propofed regency during the lamented illnefs of the king, and the French revolution; and on each of thefe occafions he difplayed talents which aftonifhed the nation. He has, indeed, been feverely blamed for the pertinacity with which he profecuted Mr Haftings, and his conduct has been attributed to very unworthy motives; but of this there is neither proof nor probability. The temperament of his mind was fuch, that, into whatever meafure he entered, he entered with a degree of ardour of which cooler heads can hardly form a conception. Burke was but one member of a committee which found, or thought it found, evidences of the guilt of Haftings; and, in forming his opinion, it is little likely that he fhould have been biaffed by intereft or refentment, whofe delicate fenfe of rectitude would not permit him to retain a penfion when he could no longer fupport the party of that friend who had obtained it for him.

When the eftablifhment of a regency was thought neceffary, he took the part, as it was called, of the prince of Wales, in oppofition to the plan propofed by Lord Thurlow and the minifter; and we doubt not but he was actuated by the pureft principles: but the language which he ufed in the houfe was vehement, and fome of his expreffions were highly indecent. Our regard for his memory makes us wifh to forget them.

Soon after the recovery of the king, the attention of Burke was attracted to the moft momentous event of modern times;—an event which has convulfed all Europe, and of which, from the very firft, his fagacity forefaw the confequences. Many of his friends in parliament, as well as numbers of wife and good men out of it, augured, from the meeting of the ftates general of France, great benefit to that nation, of which the government was confidered as defpotic and oppreffive; and fome were fanguine enough to prognofticate a new and happy order of things to all the nations connected with France, when its government fhould become more free. Burke thought very differently: He was well acquainted with the genius of the French people, and with the principles of thofe philofophers, as they called themfelves, by whom a total revolution in church and ftate had long been projected; and from the commencement of their career in the conftituent affembly, when they eftablifhed, as the foundation of all legal government, the metaphyfical doctrine of *the rights of man*, he predicted that torrent of anarchy and irreligion which they have fince attempted to pour over all Europe. Fox and fome of the other leading men in oppofition affected to confider this as a vain fear; and a coolnefs took place between them and Burke, though they ftill acted together in parliament. At laft, perceiving the French doctrines of liberty and equality and atheifm, fpreading through this nation, not only among thofe who had talents for fuch difquifitions, but in clubs and focieties, of which the members could be no judges of metaphyfical reafonings, he expreffed his apprehenfion of the confequences in the houfe of commons. This brought on a violent altercation between him and Fox, who was fupported by Sheridan; and a rupture took place between thefe old friends which was never healed. He no more attended the meetings of the oppofition members; and in 1790 he publifhed his celebrated *Reflections on the French Revolution*.

By the friends of government this work was admired as the moft feafonable, as well as one of the ableft, defences of the Britifh conftitution that ever was written; whilft Fox and his friends, with the great body of Englifh diffenters, though they admitted it to be the offfpring of uncommon genius, affected to confider it as declamatory rather than argumentative, and as inconfiftent with the principles which its author had hitherto uniformly maintained. Many anfwers were written to it; of which the moft confpicuous were *Vindiciæ Gallicæ* by Mr Mac Intofh, and *The Rights of Man* by Thomas Paine. To thefe Burke deigned not to make a direct reply. He vindicated his general principles, as well as fome of his particular reafonings, in *A Letter to a Member of the National Affembly*; and he very completely evinced the confiftency of his principles in his *Appeal from the New to the Old Whigs*.

Of this great work, for great it undoubtedly is, the merits as well as the demerits have been much exaggerated; and fome have made it a queftion, Whether it has on the whole been productive of good or of harm? By the enemies of the author, it is reprefented as having given rife to the fpirit of difcontent, by exciting fuch writers as Paine and his adherents, who, but for the provocation given by *The Reflections*, might have remained in filence and obfcurity. This was from the firft a very improbable fuppofition; for the fpirit of democracy has at all times been reftlefs: but fince the appearance of Profeffor Robifon's *Proofs of a confpiracy*, and Barruel's *Hiftory of Jacobinifm*, it muft be known to every reader to be a fuppofition contrary to fact. The confpirators were bufy long before Burke wrote his *Reflections*; and the friends of order and religion are his debtors, for having fo forcibly roufed them from their flumber, and put them on their guard. With refpect to compofition, it is certainly neither fo energetic nor fo argumentative as the political tracts of Johnfon, to which fome have affected to confider it as fuperior; but it is more poetical, gives fcope for a greater difplay of the knowledge of human nature; and being written on a more interefting fubject, it has had a much greater number of readers than thofe unrivalled pieces of political controverfy.

Burke being now affociated with Mr Pitt, continued to write from time to time memorials and remarks on the ftate of France, and the alliance that was formed againft the new order of things in that diftracted country, of which fome have been publifhed fince his death; and having refolved to quit the buftle of public life as foon as the trial of Mr Haftings fhould be concluded, he

Burke. he vacated his feat when that gentleman was acquitted, and retired to his villa at Beaconsfield, where on the 2d of Auguft 1794 he met with a heavy domeftic lofs in the death of his only fon. In the beginning of the fame year he had loft his brother Richard, whom he tenderly loved: but though this reiterated ftroke of death deeply affected him, it never relaxed the vigour of his mind, nor leffened the intereft which he took in the public weal.

In this retreat, while he was labouring for the good of all around him, he was difturbed by a very unprovoked attack upon his character by fome diftinguifhed fpeakers in the houfe of peers. Soon after the death of his fon the king was gracioufly pleafed to beftow a penfion on him and Mrs Burke; and this thofe noble lords were pleafed to reprefent as the reward of what they termed the change of his principles and the defertion of his friends. The injuftice of this charge muft be obvious to every impartial mind, fince the penfion was given after he had retired from parliament, and could not by his eloquence either fupport the miniftry or gall the oppofition. He was not a man to fubmit tamely to fuch an infult. He publifhed a letter on the occafion, addreffed to a noble lord (Earl Fitzwilliam), in which he repels the attack on his character, and retaliates on thofe by whom it was made, in terms of fuch eloquent and keen farcafm, as will be read with admiration as long as the language of the letter fhall be underftood.

Burke having employed every effort which benevolence and wifdom could devife to ftimulate civilized governments to unite in oppofition to the impiety and anarchy of France, laboured likewife in private to relieve thofe who had fuffered exile and profcription from the direful fyftem. Through his influence a fchool was eftablifhed in his neighbourhood for the education of thofe whofe parents, for their adherence to principle, were rendered unable to afford to their children ufeful inftruction; and that fchool, which on his deathbed he recommended to Mr Pitt, continues to flourifh under his powerful protection.

When the appearance of melioration in the principles and government of France induced our fovereign to make overtures of peace to the French directory, Burke refumed his pen; and in a feries of letters, intitled, *Thoughts on the Profpect of a Regicide Peace*, difplayed a force of genius which is certainly not furpaffed, and perhaps not equalled, even in his far famed *Reflections on the French Revolution*. This was his laft work, and was confidered by himfelf as in its nature teftamentary.

From the beginning of June 1797 his health rapidly declined; but his underftanding exerted itfelf with undiminifhed force and uncontracted range; and his difpofitions retained all their amiable fweetnefs. On the 7th of July, when the French revolution was mentioned, he fpoke with pleafure of the confcious rectitude of his own intentions in what he had done and written refpecting it; intreated thofe about him to believe, that if any unguarded expreffion of his on the fubject had offended any of his former friends, no offence was by him intended; and he declared his unfeigned forgivenefs of all who had on account of his writings, or for any other caufe, endeavoured to do him an injury. On the day following he defired to be carried to another room; and whilft one of his friends, affifted by fome fervants, was complying with his requeft, Mr Burke faintly uttering, "God blefs you," fell back and expired in the 68th year of his age.

Burke || Burlington.

From this detail, we truft that our readers are already fufficiently acquainted with his general character. In genius, variety of knowledge, and readinefs of expreffion, Johnfon alone of all his contemporaries could be confidered as his rival; and, like that great man, he took every opportunity, efpecially during his laft illnefs, to declare his unfhaken belief of the Chriftian religion, his veneration for fincere Chriftians of all perfuafions, and his own preference of the church of England. On the worfhip of that church he had indeed through the whole of his life been a regular and devout attendant; and the tears which the poor, in the neighbourhood of his villa, fhed at his funeral, gave fufficient evidence that his faith had been productive of charity. In his public conduct, the irritability of his temper, and the ardour of his imagination, fometimes hurried him into the exceffes of a mere party-man; but we believe that his great religious and political principles never varied. He has himfelf characterifed his public conduct in the conclufion of his Reflections on the French Revolution, when he fays, that "they come from one who has been no tool of power, no flatterer of greatnefs, and who in his laft acts does not wifh to belie the tenor of his life; from one who wifhes to preserve confiftency, but who would preserve confiftency by varying his means to fecure the unity of his end; and when the equipoife of the veffel in which he fails may be endangered by overloading it upon one fide, is defirous of carrying the fmall weight of his reafons to that which may preferve the equipoife."

BURKE *Co.* in Morgan diftrict, N. Carolina, has 8118 inhabitants, including 595 flaves. Its capital is Morgantown.—*Morse.*

BURKE *Co.* in the Lower diftrict of Georgia, contains 9467 inhabitants, including 595 flaves. Its chief towns are Louifville, and Waynefborough.—*ib.*

BURKE, a townfhip in Caledonia co. in Vermont; diftant from Bennington, 134 miles N. E.—*ib.*

BURLINGTON, is a pleafant townfhip, the chief in Chittendon co. Vermont, fituated on the S. fide of Onion River, on the E. bank of Lake Champlain. It has 332 inhabitants. It is in this healthy and agreeable fituation, that the governor and patrons of the college of Vermont, intend to found a feminary of learning, where youth of all denominations may receive an education.

In digging a well about 15 rods from the bank of the river, frogs have been found, at the depth of 25 feet, where no cavities or communication with the water appeared, through which they might have paffed; and when expofed to the heat of the fun they became full of life and activity. Here ftumps of trees are found 40 feet deep. It is conjectured that thefe animals muft have been covered up fome hundred years ago, by fome inundation of the river. Burlington is 22 miles northerly of Vergennes, 122 from Bennington, and 332 in the fame direction from New-York city, N. lat. 44. 30.—*ib.*

BURLINGTON, or *Ouineafkea Bay*, on the E. fide of Lake Champlain, about 34 miles N. by E. from Crown Point,

Point, 69 S. E. from Lake St Francis in St Lawrence River, and 70 foutherly from St John's. N. lat. 44. 22.—*ib.*

Burlington *Co.* in New-Jerfey, extends acrofs from the Atlantic ocean on the S. E. to Delaware River, and part of Huntingdon co. on the N. W. in length about 60 miles. A great proportion of it is barren; about ⅛ths of it, however, is under good cultivation, and is generally level, and is pretty well watered. It has 18,095 inhabitants, including 227 flaves.—*ib.*

Burlington, city, the chief town of the above co. is under the government of a mayor, aldermen, and common council. The extent of the townfhip is 3 miles along the Delaware, and a mile back; being about 18 miles N. E. of Philadelphia, and 11 from Trenton. The ifland, which is the moft populous part, is about a mile each way. It has 4 entrances over bridges, and caufeways, and a quantity of bank meadow adjoining. On the ifland are about 160 houfes, 1000 white, and 140 black inhabitants; few of the laft are flaves. The main ftreets are conveniently fpacious, and moftly ornamented with rows of trees. The town is oppofite Briftol in Pennfylvania, where the river is about a mile wide. Under the fhelter of Mittinicunk and Burlington iflands, is a fafe harbor, commodioufly fituated for trade; but too near the opulent city of Philadelphia to admit of any confiderable increafe of foreign commerce. Burlington was firft fettled in 1677, and has an academy and free fchool. Mittinicunk Ifland belongs to the latter, and yields a yearly profit of £180. Burlington has a place of public worfhip for the Friends, and another for the Epifcopalians; the former denomination of chriftians are the moft numerous. Here is a market houfe and the beft goal in the ftate, excepting the new ftate prifon near Trenton. There is likewife a nail manufactory, and an excellent diftillery. N. lat. 40. 8.—*ib.*

Burlington, a townfhip on the eaftern fide of Unadilla River, in Otfego co. New-York, is 11 miles W. of Cooperftown. By the ftate cenfus of 1796, 438 of its inhabitants are electors.—*ib.*

BURNS (Robert), was a native of Ayrfhire, one of the weftern counties of Scotland. He was the fon of humble parents; and his father paffed through life in the condition of a hired labourer, or of a fmall farmer. Even in this fituation, however, it was not hard for him to fend his children to the parifh fchool, to receive the ordinary inftruction in reading, writing, arithmetic, and the principles of religion. By this courfe of education young Robert profited to a degree that might have encouraged his friends to deftine him to one of the liberal profeffions, had not his father's poverty made it neceffary to remove him from fchool, as foon as he had grown up, to earn for himfelf the means of fupport as a hired ploughboy or fhepherd.

The expence of education in the parifh-fchools of Scotland is fo fmall, that hardly any parents who are able to labour want the means of giving to their children at leaft fuch education as young Burns received. From the fpring labours of a ploughboy, from the fummer employment of a fhepherd, the peafant-youth often returns for a few months, eagerly to purfue his education at the parifh-fchool.

It was fo with Burns; he returned from labour to learning, and from learning went again to labour, till his mind began to open to the charms of tafte and knowledge; till he began to feel a paffion for books, and for the fubjects of books, which was to give a colour to the whole thread of his future life. On nature he foon began to gaze with new difcernment and with new enthufiafm: his mind's eye opened to perceive affecting beauty and fublimity, where, by the mere grofs peafant, there was nought to be feen but water, earth, and fky—but animals, plants, and foil.

What might perhaps firft contribute to difpofe his mind to poetical efforts is one particular in the devotional piety of the Scottifh peafantry; it is ftill common for them to make their children get by heart the Pfalms of David, in that verfion of homely rhymes which is ufed in their churches. In the morning and in the evening of every day, or at leaft on the evening of every Saturday and Sunday, thefe Pfalms are fung in folemn family-devotion, a chapter of the Bible is read, and extemporary prayer is fervently uttered. The whole books of the Sacred Scriptures are thus continually in the hands of almoft every peafant. And it is impoffible that there fhould not be occafionally fome fouls among them, awakened to the divine emotions of genius by that rich affemblage which thofe books prefent, of almoft all that is interefting in incidents, or picturefque in imagery, or affectingly fublime or tender in fentiments and character. It is impoffible that thofe rude rhymes, and the fimple artlefs mufic with which they are accompanied, fhould not occafionally excite fome ear to a fond perception of the melody of verfe. That Burns had felt thefe impulfes, will appear undeniably certain to whoever fhall carefully perufe his *Cottar's Saturday's Night;* or fhall remark, with nice obfervation, the various fragments of Scripture fentiment, of Scripture imagery, of Scripture language, which are fcattered throughout his works.

Still more interefting to the young peafantry are thofe ancient ballads of love and war, of which a great number are, in the fouth of Scotland, yet popularly known, and often fung by the ruftic maid or matron at her fpinning-wheel. They are liftened to with ravifhed ears by old and young. Their rude melody; that mingled curiofity and awe which are naturally excited by the very idea of their antiquity; the exquifitely tender and natural complaints fometimes poured forth in them; the gallant deeds of knightly heroifm, which they fometimes celebrate; their wild tales of demons, ghofts, and fairies, in whofe exiftence fuperftition alone has believed; the manners which they reprefent; the abfolute yet picturefque and expreffive, language in which they are often clothed—give them wonderful power to tranfport every imagination, and to agitate every heart. To the foul of Burns they were like a happy breeze touching the wires of an Æolian harp, and calling forth the moft ravifhing melody.

Befide all this, the Gentle Shepherd, and the other poems of Allan Ramfay, have long been highly popular in Scotland. They fell early into the hands of Burns; and while the fond applaufe which they received drew his emulation, they prefented to him likewife treafures of phrafeology and models of verfification. He got acquainted at the fame time with the poetry of Robert Fergufon, written chiefly in the Scottifh dialect, and exhibiting many fpecimens of uncommon poetical excellence. The Seafons of Thomfon too,

too, the Grave of Blair, the far-famed Elegy of Gray, the Paradife Loft of Milton, perhaps the Minftrel of Beattie, were fo commonly read, even among thofe with whom Burns would naturally affociate, that poetical curiofity, although even lefs ardent than his, could in fuch circumftances have little difficulty in procuring them.

With fuch means to give his imagination a poetical bias, and to favour the culture of his tafte and genius, Burns gradually became a poet. He was not, however, one of thofe forward children who, from a miftaken impulfe, begin prematurely to write and to rhyme, and hence never attain to excellence. Converfing familiarly for a long while with the works of thofe poets who were known to him; contemplating the afpect of nature in a diftrict which exhibits an uncommon affemblage of the beautiful and the ruggedly grand, of the cultivated and the wild; looking upon human life with an eye quick and keen, to remark as well the ftronger and leading, as the nicer and fubordinate, features of character; to difcriminate the generous, the honourable, the manly, in conduct, from the ridiculous, the bafe, and the mean—he was diftinguifhed among his fellows for extraordinary intelligence, good fenfe, and penetration, long before others, or perhaps even himfelf, fufpected him to be capable of writing verfes. His mind was mature, and well ftored with fuch knowledge as lay within his fearch: he had made himfelf mafter of powers of language, fuperior to thofe of almoft any former writer in the Scottifh dialect, before he conceived the idea of furpaffing Ramfay and Fergufon.

Hitherto he had converfed intimately only with peafants on his own level; but having got admiffion into the fraternity of free-mafons, he had the fortune, whether good or bad, to attract in the lodges the notice of gentlemen better qualified than his more youthful companions to call forth the powers of his mind, and to fhow him that he was indeed a poet. A mafonic fong, a fatirical epigram, a rhyming epiftle to a friend, attempted with fuccefs, taught him to know his own powers, and gave him confidence to try tafks more arduous, and which fhould command ftill higher burfts of applaufe.

The annual celebration of the facrament of the Lord's Supper, in the rural parifhes of Scotland, has much in it of thofe old popifh feftivals, in which fuperftition, traffic, and amufement, ufed to be ftrangely intermingled. Burns faw, and feized in it one of the happieft of all fubjects, to afford fcope for the difplay of that ftrong and piercing fagacity by which he could almoft intuitively diftinguifh the reafonable from the abfurd, and the becoming from the ridiculous; of that picturefque power of fancy, which enabled him to reprefent fcenes, and perfons, and groupes, and looks, attitude, and geftures, in a manner almoft as lively and impreffive, even in words, as if all the artifices and energies of the pencil had been employed; of that knowledge which he had neceffarily acquired of the manners, paffions, and prejudices of the ruftics around him, of whatever was ridiculous, no lefs than of whatever was affectingly beautiful in rural life.

A thoufand prejudices of Popifh, and perhaps too of ruder Pagan fuperftition, have from time immemorial been connected in the minds of the Scottifh peafantry, with the annual recurrence of the Eve of the Feftival of all the Saints or Halloween. Thefe were all intimately known to Burns, and had made a powerful impreffion upon his imagination and feelings. He chofe them for the fubject of a poem, and produced a piece which is almoft to frenzy the delight of thofe who are beft acquainted with its fubject; and which will not fail to preferve the memory of the prejudices and ufages which it defcribes, when they fhall perhaps have ceafed to give one merry evening in the year to the cottage firefide.

The fimple joys, the honeft love, the fincere friendfhip, the ardent devotion of the cottage; whatever in the more folemn part of the ruftic's life is humble and artlefs, without being mean or unfeemly—or tender and dignified, without afpiring to ftilted grandeur—or to unnatural, bufkined pathos, had deeply impreffed the imagination of the rifing poet; had, in fome fort, wrought itfelf into the very texture of the fibres of his foul. He tried to exprefs in verfe what he moft tenderly felt, what he moft enthufiaftically imagined; and produced the *Cottar's Saturday's Night*.

Thefe pieces, the true effufions of genius, informed by reading and obfervation, and prompted by its own native ardour, as well as by friendly applaufe, were foon handed about among the moft difcerning of Burns's acquaintance; and were by every new reader perufed and reperufed, with an eagernefs of delight and approbation which would not fuffer their author long to withhold them from the prefs. A fubfcription was propofed, was earneftly promoted by fome gentlemen, who were glad to intereft themfelves in behalf of fuch fignal poetical merit; was foon crowded with the names of a confiderable number of the inhabitants of Ayrfhire, who in the proffered purchafe fought not lefs to gratify their own paffion for Scottifh poefy, than to encourage the wonderful ploughman. At Kilmarnock were the poems of Burns for the firft time printed. The whole edition was quickly diftributed over the country.

It is hardly poffible to exprefs with what eager admiration and delight they were every where received.—They eminently poffeffed all thofe qualities which the moft invariably contribute to render any literary work quickly and permanently popular. They were written in a phrafeology, of which all the powers were univerfally felt; and which being at once antique, familiar, and now rarely written, was hence fitted to ferve all the dignified and picturefque ufes of poetry, without making it unintelligible. The imagery, the fentiments, were at once faithfully natural, and irrefiftibly impreffive and interefting. Thofe topics of fatire and fcandal in which the ruftic delights; that humorous imitation of character, and that witty affociation of ideas familiar and ftriking, yet not naturally allied to one another, which has force to fhake his fides with laughter; thofe fancies of fuperftition, at which he ftill wonders and trembles; thofe affecting fentiments and images of true religion, which are at once dear and awful to his heart, were all reprefented by Burns with all a poet's magic power. Old and young, high and low, grave and gay, learned or ignorant, all were alike delighted, agitated, tranfported.

In the mean time, fome few copies of thefe fafcinating poems found their way to Edinburgh; and having been read to Dr Blacklock, they obtained his warmeft approbation. In the beginning of the winter 1786-7 Burns

Burns. Burns went to Edinburgh, where he was received by Dr Blacklock with the most flattering kindness, and introduced to every man of generosity and taste among that good man's friends. Multitudes now vied with each other in patronizing the rustic poet. Those who possessed at once true taste and ardent philanthrophy were soon earnestly united in his praise; they who were disposed to favour any good thing belonging to Scotland, purely because it was Scottish, gladly joined the cry; those who had hearts and understanding to be charmed, without knowing why, when they saw their native customs, manners, and language, made the subjects and the materials of poesy, could not suppress that voice of feeling which struggled to declare itself for Burns: for the dissipated, the licentious, the malignant wits, and the freethinkers, he was so unfortunate as to have satire, and obscenity, and ridicule of things sacred, sufficient to captivate their fancies; even for the pious he had passages in which the inspired language of devotion might seem to come mended from his pen.

Thus did Burns, ere he had been many weeks in Edinburgh, find himself the object of universal curiosity, favour, admiration, and fondness. He was sought after, courted with attentions the most respectful and assiduous, feasted, flattered, caressed, treated by all ranks as the first boast of his country, whom it was scarcely possible to honour and reward to a degree equal to his merits. In comparison with the general favour which now promised to more than crown his most sanguine hopes, it could hardly be called praise at all which he had obtained in Ayrshire.

In this posture of our poet's affairs a new edition of his poems was earnestly called for. He sold the copyright for one hundred pounds; but his friends at the same time suggested, and actively promoted a subscription for an edition, to be published for the benefit of the author, ere the bookseller's right should commence. Those gentlemen who had formerly entertained the public of Edinburgh with the periodical publication of the papers of the *Mirror*, having again combined their talents in producing the *Lounger*, were at this time about to conclude this last series of papers; yet before the Lounger relinquished his pen, he dedicated a number to a commendatory criticism of the poems of the Ayrshire bard.

The subscription-papers were rapidly filled; and it was supposed that the poet might derive from the subscription and the sale of his copy-right a clear profit of at least 700 pounds.

The conversation of even the most eminent authors is often found to be so unequal to the fame of their writings, that he who reads with admiration can listen with none but sentiments of the most profound contempt. But the conversation of Burns was in comparison with the formal and exterior circumstances of his education, perhaps even more wonderful than his poetry. He affected no soft air or graceful motions of politeness, which might have ill accorded with the rustic plainness of his native manners. Conscious superiority of mind taught him to associate with the great, the learned, and the gay, without being overawed into any such bashfulness as might have made him confused in thought, or hesitating in elocution. He possessed withal an extraordinary share of plain common sense or mother-wit, which prevented him from obtruding upon persons, of whatever rank with whom he was admitted to converse, any of those effusions of vanity, envy, or self-conceit, in which authors are exceedingly apt to indulge, who have lived remote from the general practice of life, and whose minds have been almost exclusively confined to contemplate their own studies and their own works. In conversation he displayed a sort of intuitive quickness and rectitude of judgment upon every subject that arose. The sensibility of his heart, and the vivacity of his fancy, gave a rich colouring to whatever reasoning he was disposed to advance; and his language in conversation was not at all less happy than in his writings. For these reasons, those who had met and conversed with him once, were pleased to meet and to converse with him again and again.

For some time he conversed only with the virtuous, the learned, and the wise; and the purity of his morals remained uncontaminated. But, alas! he fell, as others have fallen in similar circumstances. He suffered himself to be surrounded by a race of miserable beings, who were proud to tell that they had been in company with Burns, and had seen Burns as loose and as foolish as themselves. He was not yet irrecoverably lost to temperance and moderation; but he was already almost too much captivated with their wanton rivals, to be ever more won back to a faithful attachment to their more sober charms. He now also began to contract something of new arrogance in conversation. Accustomed to be among his favourite associates what is vulgarly but expressively called *the cock of the company*, he could scarcely refrain from indulging in similar freedom and dictatorial decision of talk, even in the presence of persons who could less patiently endure his presumption.

The subscription edition of his poems, in the mean time, appeared; and although not enlarged beyond that which came from the Kilmarnock press by any new pieces of eminent merit, did not fail to give entire satisfaction to the subscribers. He was now to close accounts with his bookseller and his printer, to retire to the country with his profits in his pocket, and to fix upon a plan for his future life. He talked loudly of independence of spirit and simplicity of manners, and boasted his resolution to return to the plough; yet still he lingered in Edinburgh, week after week, and month after month, perhaps expecting that one or other of his noble patrons might procure him some permanent and competent annual income, which should set him above all necessity of future exertions to earn for himself the means of subsistence; perhaps unconsciously reluctant to quit the pleasures of that voluptuous town-life to which he had for some time too willingly accustomed himself. An accidental dislocation or fracture of an arm or a leg confining him for some weeks to his apartment, left him during this time leisure for serious reflection; and he determined to retire from the town without longer delay. None of all his patrons interposed to divert him from his purpose of returning to the plough, by the offer of any small pension, or any sinecure place of moderate emolument, such as might have given him competence without withdrawing him from his poetical studies. It seemed to be forgotten that a ploughman thus exalted into a man of letters was unfitted for his former toils, without being regularly qualified to enter the career of any new profession; and that it became incumbent

cumbent upon thofe patrons who had called him from the plough, not merely to make him their companion in the hour of riot, not fimply to fill his purfe with gold for a few tranfient expences, but to fecure him as far as was poffible from being ever overwhelmed in diftrefs in confequence of the favour which they had fhown him, and of the habits of life into which they had feduced him. Perhaps indeed the fame delufion of fancy betrayed both Burns and his patrons into the miftaken idea, that, after all which had paffed, it was ftill poffible for him to return in cheerful content to the homely joys and fimple toils of undiffipated rural life.

In this temper of Burns's mind, in this ftate of his fortune, a farm and the excife were the objects upon which his choice ultimately fixed for future employment and fupport. By the furgeon who attended him during his illnefs, he was recommended with effect to the commiffioners of excife; and Patrick Millar, Efq; of Dalfwinton, deceived, like Burns himfelf and Burns's other friends, into an idea that the poet and exciseman might yet be refpectable and happy as a farmer, generoufly propofed to eftablifh him in a farm, upon conditions of leafe which prudence and induftry might eafily render exceedingly advantageous. Burns eagerly accepted the offers of this benevolent patron. Two of the poet's friends from Ayrfhire were invited to furvey that farm in Dumfriesfhire which Mr Millar offered. A leafe was granted to the poetical farmer at that annual rent which his own friends declared that the due cultivation of his farm might eafily enable him to pay. What yet remained of the profits of his publication was laid out in the purchafe of farm-ftock; and Mr Millar might, for fome fhort time, pleafe himfelf with the perfuafion that he had approved himfelf the liberal patron of genius; had acquired a good tenant upon his eftate; and had placed a deferving man in the very fituation in which alone he himfelf defired to be placed, in order to be happy to his wifhes.

Burns, with his Jane, whom he now married, took up their refidence upon his farm. The neighbouring farmers and gentlemen, pleafed to obtain for an inmate among them the poet by whofe works they had been delighted, kindly fought his company, and invited him to their houfes. He found an inexpreffible charm in fitting down befide his wife, at his own firefide; in wandering over his own grounds; in once more putting his hand to the fpade and the plough; in forming his inclofures, and managing his cattle. For fome months he felt almoft all that felicity which fancy had taught him to expect in his new fituation. He had been for a time idle; but his mufcles were not yet unbraced for rural toil. He now feemed to find a joy in being the hufband of the miftrefs of his affections, in feeing himfelf the father of her children, fuch as might promife to attach him for ever to that modeft, humble, and domeftic life, in which alone he could hope to be permanently happy. Even his engagements in the fervice of the excife did not, at the very firft, threaten neceffarily to debafe him by affociation with the mean, the grofs, and the profligate, to contaminate the poet, or to ruin the farmer.

But it could not be: it was not poffible for Burns now to affume that fobernefs of fancy and paffions, that fedatenefs of feeling, thofe habits of earneft attention to grofs and vulgar cares, without which fuccefs in his new fituation was not to be expected. A thoufand difficulties were to be encountered and overcome, much money was to be expended, much weary toil was to be exercifed, before his farm could be brought into a ftate of cultivation, in which its produce might enrich the occupier. This was not a profpect encouraging to a man who had never loved labour, and who was at this time certainly not at all difpofed to enter into agriculture with the enthufiafm of a projector. The bufinefs of the excife too, as he began to be more and more employed in it, diftracted his mind from the care of his farm, led him into grofs and vulgar fociety, and expofed him to many unavoidable temptations to drunken excefs, fuch as he had no longer fufficient fortitude to refift. Amidft the anxieties, diftractions, and feducements which thus arofe to him, home became infenfibly lefs and lefs pleafing; even the endearments of his Jane's affection began to lofe their hold on his heart; he became every day lefs and lefs unwilling to forget in riot thofe gathering forrows which he knew not to fubdue.

Mr Millar and fome others of his friends would gladly have exerted an influence over his mind which might have preferved him in this fituation of his affairs, equally from defpondency and from diffipation; but Burns's temper fpurned all controul from his fuperiors in fortune. He refented, as an arrogant encroachment upon his independence, that tenor of conduct by which Mr Millar wifhed to turn him from diffolute conviviality, to that fteady attention to the bufinefs of his farm, without which it was impoffible to thrive in it. His croffes and difappointments drove him every day more and more into diffipation; and his diffipation tended to enhance whatever was difagreeable and perplexing in the ftate of his affairs. He funk, by degrees, into the boon companion of mere excifemen; and almoft every drunken fellow, who was willing to fpend his money lavifhly in the alehoufe, could eafily command the company of Burns. The care of his farm was thus neglected; wafte and loffes wholly confumed his little capital; he refigned his leafe into the hands of his landlord; and retired, with his family, to the town of Dumfries, determining to depend entirely for the means of future fupport upon his income as an excife-officer.

Yet during this unfortunate period of his life, which paffed between his departure from Edinburgh to fettle in Dumfriesfhire, and his leaving the country in order to take up his refidence in the town of Dumfries, the energy and activity of his intellectual powers appeared to have been not at all impaired. In a collection of Scottifh fongs, which were publifhed (the words with the mufic) by Mr Johnfon, engraver in Edinburgh, in 4 vols 8vo, Burns, in many inftances, accommodated new verfes to the old tunes with admirable felicity and fkill. He affifted in the temporary inftitution of a fmall fubfcription library, for the ufe of a number of the well-difpofed peafants in his neighbourhood. He readily aided, and by his knowledge of genuine Scottifh phrafeology and manners greatly enlightened, the antiquarian refearches of the late ingenious Captain Grofe. He ftill carried on an epiftolary correfpondence, fometimes gay, fportive, humorous, but always enlivened by bright flafhes of genius, with a number of his old friends, and on a very wide diverfity of topics. At times, as it fhould feem from his writings of this period, he reflected, with inexpreffible heart-bitternefs, on the

high

high hopes from which he had fallen; on the errors of moral conduct into which he had been hurried by the ardour of his ſoul; and in ſome meaſure by the very generoſity of his nature; on the diſgrace and wretchedneſs into which he ſaw himſelf rapidly ſinking; on the ſorrow with which his miſconduct oppreſſed the heart of his Jane; on the want and deſtitute miſery in which it ſeemed probable that he muſt leave her and their infants; nor amidſt theſe agonizing reflections did he fail to look, with an indignation half invidious, half contemptuous, on thoſe who, with moral habits not more excellent than his, with powers of intellect far inferior, yet baſked in the ſun-ſhine of fortune, and were loaded with the wealth and honours of the world, while his follies could not obtain pardon, nor his wants an honourable ſupply. His wit became from this time more gloomily ſarcaſtic; and his converſation and writings began to aſſume ſomething of a tone of miſanthropical malignity, by which they had not been before, in any eminent degree, diſtinguiſhed. But with all theſe failings, he was ſtill that exalted mind which had raiſed itſelf above the depreſſion of its original condition: with all the energy of the lion, pawing to ſet free his hinder limbs from the yet encumbering earth, he ſtill appeared *not leſs than archangel ruined!*

His morals were not mended by his removal from the country. In Dumfries his diſſipation became ſtill more deeply habitual; he was here more expoſed than in the country to be ſolicited to ſhare the riot of the diſſolute and the idle: fooliſh young men flocked eagerly about him, and from time to time preſſed him to drink with them, that they might enjoy his wicked wit. The Caledonian Club, too, and the Dumfriesſhire and Galloway Hunt, had occaſional meetings in Dumfries after Burns went to reſide there, and the poet was of courſe invited to ſhare their conviviality, and heſitated not to accept the invitation.

In the intervals between his different fits of intemperance, he ſuffered ſtill the keeneſt anguiſh of remorſe, and horribly afflictive foreſight. His Jane ſtill behaved with a degree of maternal and conjugal tenderneſs and prudence, which made him feel more bitterly the evil of his miſconduct, although they could not reclaim him. At laſt crippled, emaciated, having the very power of animation waſted by diſeaſe, quite broken-hearted by the ſenſe of his errors, and of the hopeleſs miſeries in which he ſaw himſelf and his family depreſſed; with his ſoul ſtill tremblingly alive to the ſenſe of ſhame, and to the love of virtue; yet even in the laſt feebleneſs, and amid the laſt agonies of expiring life, yielding readily to any temptation that offered the ſemblance of intemperate enjoyment, he died at Dumfries, in the ſummer of 1796, while he was yet three or four years under the age of forty, furniſhing a melancholy proof of the danger of *ſuddenly* elevating even the greateſt mind above its original level.

After his death it quickly appeared that his failings had not effaced from the minds of his more reſpectable acquaintance either the regard which had once been won by his ſocial qualities, or the reverence due to his intellectual talents. The circumſtances of want in which he left his family were noticed by the gentlemen of Dumfries with earneſt commiſeration. His funeral was celebrated by the care of his friends with a decent ſolemnity, and with a numerous attendance of mourners, ſufficiently honourable to his memory. Several copies of verſes were inſerted in different newſpapers upon the occaſion of his death. A contribution, by ſubſcription, was propoſed, for the purpoſe of raiſing a ſmall fund, for the decent ſupport of his widow, and the education of his infant children.

From the preceding detail of the particulars of this poet's life, the reader will naturally and juſtly infer him to have been an honeſt, proud, warm-hearted man; of high paſſions and ſound underſtanding, and a vigorous and excurſive imagination. He was never known to deſcend to any act of deliberate meanneſs. In Dumfries he retained many reſpectable friends even to the laſt; and it may be doubted whether any poet of the preſent age has exerciſed a greater power over the minds of his readers. Burns has not failed to command one remarkable ſort of homage, ſuch as is never paid but to great original genius; a crowd of poetaſters ſtarted up to imitate him, by writing verſes as he had done in the Scottiſh dialect; but, *O imitatores! ſervum pecus!* To write rugged rhymes, in antiquated phraſe, is not to imitate the poetry of Burns.

BURRAMPOOTER. See Sandpu, *Encycl.*

BUSHWICK, a ſmall, but pleaſant town, in King's co. Long Iſland, New-York. The inhabitants, 540 in number, are chiefly of Dutch extraction; 99 of theſe are electors.—*Morſe.*

BUTTER is a ſubſtance ſo well known, that it is needleſs to give here any definition of it. It is one of the three component parts of milk, the other two being *whey* and *cheeſe*. It is evident from the proceſſes by which butter and cheeſe are made, that theſe two parts are not completely diſſolved in the ſerum or whey, but only diffuſed through it like an emulſion. They may indeed be ſeparated from it by reſt alone, without any artificial preparation.

Butter, though uſed at preſent as food in moſt countries of Europe, was not known, or known very imperfectly, to the ancients. This, we think, is completely proved by Profeſſor Beckmann in the ſecond volume of his *Hiſtory of Inventions*. In our tranſlation of the Hebrew Scripture, there is indeed frequent mention made of butter at very early periods; but, as the Profeſſor well obſerves, the greateſt maſters of biblical criticiſm unanimouſly agree, that the word ſo tranſlated ſignifies milk or cream, or ſour thick milk, and cannot poſſibly mean what we call *butter*. The word plainly alludes to ſomething liquid which was uſed for waſhing the feet, which was drunk, and which had ſometimes the power of intoxicating; and we know that mare's milk may be ſo prepared as to produce the ſame effect. See Koumiss, *Encycl.*

The oldeſt mention of butter, the Profeſſor thinks, is in the account of the Scythians given by Herodotus (lib. iv. 2.), who ſays, that "theſe people pour the milk of their mares into wooden veſſels, cauſe it to be violently ſtirred or ſhaken by their blind ſlaves, and ſeparate the part which ariſes to the ſurface, as they conſider it as more valuable and delicious than what is collected below it." That this ſubſtance muſt have been a ſoft kind of butter, is well known; and Hippocrates gives a ſimilar account of Scythian butter, and calls it πικεριον, which Galen tranſlates by the word βουτυρον. The poet Anaxandrides, who lived ſoon after Hippocrates, deſcribing the marriage feaſt of Iphicrates, who married

married the daughter of Cotys king of Thrace, says, that the Thracians ate butter, which the Greeks at that time considered as a wonderful kind of food.

Dioscorides says, that good butter was prepared from the fattest milk, such as that of sheep or goats, by shaking it in a vessel till the fat was separated. To this butter he ascribes the same effects, when used externally, as those produced by our butter at present. He adds also, and he is the first writer who makes the observation, that fresh butter might be melted and poured over pulse and vegetables instead of oil, and that it might be employed in pastry in the room of other fat substances. A kind of soot likewise was at that time prepared from butter for external applications, which was used in curing inflammation of the eyes and other disorders. For this purpose the butter was put into a lamp, and when consumed the lamp was again filled till the desired quantity of soot was collected in a vessel placed over it.

Galen, who distinguishes and confirms in a more accurate manner the healing virtues of butter, expresly remarks, that cow's milk produces the fattest butter; that butter made from sheep's or goat's milk is less rich; and that ass's milk yields the poorest. He expresses his astonishment, therefore, that Dioscorides should say that butter was made from the milk of sheep and goats. He assures us that he had seen it made from cow's milk, and that he believes it had thence acquired its name. "Butter (says he) may be very properly employed for ointments; and when leather is besmeared with it, the same purpose is answered as when it is rubbed over with oil. In cold countries, which do not produce oil, butter is used in the baths; and that it is a real fat, may be readily perceived by its catching fire when poured over burning coals." What has been here said is sufficient to shew that butter must have been very little known to or used by the Greeks and the Romans in the time of Galen, that is, at the end of the second century.

The Professor having collected, in chronological order, every thing which he could find in the works of the ancients respecting butter, concludes, that it is not a Grecian, and much less a Roman, invention, but that the Greeks were made acquainted with it by the Scythians, the Thracians, and the Phrygians, and the Romans by the people of Germany. He is likewise decidedly of opinion, that when these two polished nations had learned the art of making it, they used it not as food, but only as an ointment, or sometimes as a medicine. "We never find it (says he) mentioned by Galen and others as a food, though they have spoken of it as applicable to other purposes. No notice is taken of it by Apicius; nor is there any thing said of it in that respect by the authors who treat on agriculture, though they have given us very particular information concerning milk, cheese, and oil."

The case, however, is now very different. It is, in this country at least, so general an article of food, that the proper methods of making and curing it have engaged the attention of some of our ablest writers on agriculture. In addition to what has been said on these subjects under the titles BUTTER and DAIRY *(Encyclopædia)*, our readers will probably be pleased with the following method of curing it, which is practised by some farmers in the parish of Udney, in the county of Aberdeen, and gives to their butter a great superiority above that of their neighbours.

Take two parts of the best common salt, one part of sugar, and one part of saltpetre; beat them up together, and blend the whole completely. Take one ounce of this composition for every sixteen ounces of butter, work it well into the mass, and close it up for use.

Dr James Anderson, from whose View of the Agriculture of the County of Aberdeen this receipt is taken, says, that he knows of no simple improvement in economics greater than this is, when compared with the usual mode of curing butter by means of common salt alone. "I have seen (continues he) the experiment fairly made, of one part of the butter made at one time being thus cured, and the other part cured with salt alone: the difference was inconceivable. I should suppose that, in any open market, the one would sell for 30 *per cent*, more than the other. The butter cured with the mixture appears of a rich marrowy consistence and fine colour, and never acquires a brittle hardness nor tastes salt; the other is comparatively hard and brittle, approaching more nearly to the appearance of tallow, and is much salter to the taste. I have ate butter cured with the above composition that had been kept three years, and it was as sweet as at first; but it must be noted, that butter thus cured requires to stand three weeks or a month before it is begun to be used. If it be sooner opened, the salts are not sufficiently blended with it; and sometimes the coolness of the nitre will then be perceived, which totally disappears afterwards."

The following observations respecting the proper method of keeping both milk and butter are by the same author, and we trust may prove useful. Speaking still of the county of Aberdeen, he says, "The pernicious practice of keeping milk in leaden vessels, and salting butter in stone jars, begins to gain ground among some of the fine ladies in this county, as well as elsewhere, from an idea of cleanliness. The fact is, it is just the reverse of cleanliness; for in the hands of a careful person nothing can be more cleanly than wooden dishes, but under the management of a slattern they discover the secret which stone dishes indeed do not.

"In return, these latter communicate to the butter and the milk, which has been kept in them, a poisonous quality, which inevitably proves destructive to the human constitution. To the prevalence of this practice I have no doubt we must attribute the frequency of palsies, which begin to prevail so much in this kingdom; for the well known effect of the poison of lead is bodily debility, palsy—death!"

BUTTERHILL, a high round hill, on the W. bank of Hudson river, at the northern entrance of the Highlands. In passing this hill, ascending the river, the passenger is presented with a charming view of New-Windsor and Newburgh.—*Morse.*

BUXTON, a township in York co. district of Maine, situated on Saco River; 16 miles N. westerly from Pepperelborough, at the mouth of that river, and 118 miles N. E. of Boston; containing 1564 inhabitants. —*ib.*

BYEFIELD, a parish in Newbury, Essex co. Massachusetts. In a quarry of lime stone here, is found the *asbestos*, or incorruptible cotton, as it is sometimes called.

 called. Beautifully variegated marble, which admits a good polish, has likewise been found in the same vicinity. Here is also a flourishing woollen manufactory established on a liberal scale; and machinery for cutting nails.—*ib.*

BYRD, FORT, lies on the eastern bank of Monongahela River; on the S. side of the mouth of Red-Stone Creek; 35 miles S. from Pittsburg, and about 29 N. W. from Ohiopyle Falls. On or near this spot stands the compact part of the town of Brownsville. N. lat. 39. 58. W. long. 81. 12.—*ib.*

BYSAK, the first month of the Bengal year, beginning in April.

C.

CABARRUS, a new county in the district of Salisbury, North-Carolina.—*Morse.*

CABIN *Point*, a small post-town in Surry co. Virginia, situated on Upper Chipoak creek, 26 miles E. S. E. of Petersburg, 87 from Portsmouth, and 329 S. S. W. of Philadelphia. N. lat. 37.—*ib.*

CACAPEHON, a river of Virginia, which runs about 70 miles N. easterly along the western side of North Ridge, and empties into Potowmack River, 30 miles N. from Frederickstown.—*ib.*

CADIZ, a town on the N. side of the island of Cuba, near 160 miles E. of Havannah, and 50 N. from Spiritu Santo.—*ib.*

CÆSARIA *River*, or *Cohansie Creek*, in New-Jersey, empties into Delaware Bay, after a S. westerly course of about 30 miles. It is navigable for vessels of 100 tons as far as Bridgetown, 20 miles from its mouth.—*ib.*

CAFFRES, the inhabitants of Caffraria, are generally confounded with the Hottentots; but, according to M. Vaillant, there is a considerable difference between the manners, customs, and even appearance of these two nations.

The Caffres, says he, are generally taller than the Hottentots, more robust, more fierce, and much bolder. Their figure is likewise more agreeable, and their countenances have not that narrowness at the bottom, nor their cheeks those prominences, which are so disagreeable among the Hottentots. A round figure, a nose not too flat, a broad forehead, and large eyes, give them an open and lively air; and if prejudice can overlook the colour of the skin, there are some Caffre women who, even in Europe, would be accounted pretty. These people do not make their faces ridiculous, by pulling out their eye-brows like the Hottentots; they tattoo themselves much, and particularly their bodies; their hair, which is frizzled very much, is never greased, but their bodies are liberally anointed, merely with a view to preserve their vigour and agility.

The men generally bestow more attention on their dress than the women, and are remarkably fond of beads and copper rings. The women wear hardly any of the ornaments in which the other savages in Africa take such delight. They do not even wear copper bracelets; but their small aprons, which are still shorter than those of the Hottentots, are bordered with a few rows of glass-beads; and in this all their luxury consists. It would appear that the Caffres are not so chaste as the Hottentots, because the men do not use a jackal to vail what nature teaches other men, even savages, to conceal. A small cowl, which covers only the glans, instead of displaying modesty, seems to announce the greatest indecency. This small covering adheres to a thong, which is fastened round their girdles, merely that it may not be lost; for a Caffre, if he be not afraid of being hurt or stung by insects, cares very little whether his cowl be in its place or not. Our author saw one Caffre, who, instead of a cowl, wore a case made of wood, and ornamented with sculpture. This was a new and ridiculous fashion, which he had borrowed from a nation of black people who lived at a great distance from Caffraria.

In the hot season the Caffres go always naked, and retain nothing but their ornaments. In cold weather they wear krosses made of calves or oxen's hides, which reach down to the ground; but whatever the weather be, both sexes go bare-headed, except that they sometimes, though rarely, fix a plume of feathers in their hair.

The Caffre huts are more spacious and higher than those of the Hottentots, and have also a more regular form. The frames of them are constructed of wooden work, well put together, and very solid, being intended to last for a long time: for the Caffres, applying to agriculture, which the free Hottentots do not, remain fixed to one spot, unless something unexpected interrupt their repose.

A more perceptible industry, an acquaintance with some of the most necessary arts of life, a little knowledge of agriculture, and a few religious dogmas, seem to announce that the Caffres approach much nearer to civilization than the Hottentots. They entertain a tolerably exalted idea of the Supreme Being and his power; they believe that the good will be rewarded, and the wicked punished, in a future state; but they have no notion of creation, which indeed was not admitted by the sages of Greece and Rome. They practise circumcision, but can give no account of its origin among them, or of the purpose for which the practice is continued.

Polygamy is used among the Caffres; and on the death of a father the male children and their mothers share the succession among them. The girls remain with

with their mothers without property of any kind until they can procure husbands. One very singular custom of the Caffres is, that they do not, in general, inter their dead, but transport them from the kraal to an open ditch, which is common to the whole horde. At this ditch savage animals feed at their leisure on the multitude of carcases which are heaped together. Funeral honours are due only to kings and the chiefs of each horde, whose bodies are covered with a heap of stones collected into the form of a dome.

This nation is governed by a general, chief, or king, whose power is very limited. He appoints, however, the subordinate chiefs over the different hordes, and through them communicates his directions or orders. The arms of the Caffre are a *club*, two feet and a half in length, and where thickest three inches in diameter, and a plain lance or *assagey*. He despises poisoned arrows, which are so much used by some of the neighbouring nations; and with his two simple weapons seeks always to meet his enemy face to face in the field. The Hottentot, on the contrary, concealed under a rock or behind a bush, deals out destruction, without being exposed to danger. The one is a perfidious tyger, which rushes treacherously on his prey; the other is a generous lion, which, having given warning of his approach, makes his attack boldly, and perishes if he prevail not against his antagonist.

CAGHNEWAGA, a tribe of Indians in Lower Canada, some of whom inhabit near Montreal.—*Morse.*

CALCAYLARES, a jurisdiction in S. America, and empire of Peru, subject to the bishop of Cusco, about 4 leagues W. of that city; exuberant in all kinds of grain and fruits, and sugar equal to any of the refined sugar of Europe. Formerly it produced 80,000 arobas; but the quantity is now said to be much less. —*ib.*

CALCULUS, in mathematics, denotes a certain way of performing investigations and resolutions, which occur on many occasions, particularly in mechanical philosophy. Thus we say, the *antecedental* calculus, the *algebraical* calculus, the *arithmetical* calculus, the *differential* calculus, the *exponential* calculus, the *fluxional* calculus, and the *integral* calculus. Of by much the greater part of these calculi some account has been given in the Encyclopædia; but there is one of them, of which no notice has been taken in that work. It is,

The Antecedental CALCULUS, a geometrical method of reasoning, without any consideration of motion or velocity, applicable to every purpose to which the much celebrated doctrine of fluxions of the illustrious Newton has been, or can be, applied. This method was invented by James Glenie, Esq; "in which (he says) every expression is truly and strictly geometrical, is founded on principles frequently made use of by the ancient geometers, principles admitted into the very first elements of geometry, and repeatedly used by EUCLID himself. As it is a branch of general geometrical proportion, or universal comparison, and is derived from an examination of the antecedents of ratios, having given consequents and a given standard of comparison in the various degrees of augmentation and diminution they undergo by composition and decomposition, I have called it the antecedental calculus. As it is purely geometrical, and perfectly scientific, I have, since it first occurred to me in 1779, always made use of it instead of the fluxionary and differential calculi, which are merely arithmetical. Its principles are totally unconnected with the ideas of motion and time, which, strictly speaking, are foreign to pure geometry and abstract science, though, in mixed mathematics and natural philosophy, they are equally applicable to every investigation, involving the consideration of either with the two numerical methods just mentioned. And as many such investigations require compositions and decompositions of ratios, extending greatly beyond the triplicate and subtriplicate, this calculus in all of them furnishes every expression in a strictly geometrical form. The standards of comparison in it may be any magnitudes whatever, and are of course indefinite and innumerable; and the consequents of the ratios, compounded or decompounded, may be either equal or unequal, homogeneous or heterogeneous. In the fluxionary and differential methods, on the other hand, 1, or unit, is not only the standard of comparison, but also the consequent of every ratio compounded or decompounded."

This method is deduced immediately from Mr Glenie's Treatise on the Doctrine of Universal Comparison or General Proportion: And as the limits of the present work will not allow us to enter upon this subject, we therefore refer our readers to the two above mentioned treatises, and to the fourth volume of the Transactions of the Royal Society of Edinburgh.

We confess, however, that we do not expect such great advantage from the employment of this calculus as the very acute and ingenious author seems to promise from it. The mathematical world is truly indebted to him for the clear and discriminating view that he has taken of the doctrine of universal comparison, and we believe it to be perfectly accurate, and in some respects new. Notwithstanding the continual occupation of mathematicians with ratios and analogies, their particular objects commonly restricted their manner of conceiving ratio to some present modification of it. Hence it seems to have happened that their conceptions of it as a magnitude have not been uniform. But Mr Glenie, by avoiding every peculiarity, has at once attributed to it all the measurable affections of magnitude, addition or subtraction, multiplication or division, and ratio or proportion. He is perhaps the first who has roundly considered ratio or proportion as an affection of ratio; and it is chiefly by the employment of this undoubted affection of ratio that he has rendered the geometrical analysis so comprehensive.

But when we view this antecedental calculus, not as a method of expressing mathematical science, but as an art, as a calculus in short, and consider the means which it must employ, and the notations which must be used, we become less sanguine in our hopes of advantage from it. The notation cannot (we think) be more simple than that of the fluxionary method, justly called *arithmetical;* and if we insist on carrying clear conceptions along with us, we imagine that the arithmetical exposition of our symbols will generally be the simpler of the two. The *science* of the antecedental calculus seems to consist in the attainable perception of all the simple ratios, whether of *magnitudes*, or *ratios*, or both, which concur to the formation of a compound and complicated ratio. Now this is equally, and more easily, attainable in the fluxionary or other arithmetical method, when the consequent is a simple magnitude. When it is not, the fame procefs is farther neceffary in both methods, for getting rid of its complication.

We apprehend that it is a miftake that the geometrical method is more abftracted than the fluxionary, becaufe the latter fuperadds to the notion of extenfion the notions of time and motion. Thefe notions were introduced by the illuftrious inventor *for the demonftration*, but never occupy the thoughts *in the ufe* of his propofitions. Thefe are *geometrical* truths, no matter how demonftrated; and when duly confidered, involve nothing that is omitted in the antecedental calculus. We even prefume to fay, that the complication of thought, in the contemplation of the ratios of ratios, is greater than what will generally arife from the additional elements, time and motion.

We do not find that any of our moft active mathematicians have availed themfelves of the advantages of this calculus, nor do we know any fpecimen that has been exhibited of its eminent advantages in mathematical difcuffions. Should it prove more fertile in geometrical expreffions of highly compounded or complicated quantities or relations, we fhould think it a mighty acquifition; being fully convinced that thefe afford to the memory or imagination an object (we may call it a fenfible picture) which it can contemplate and remember with incomparably greater clearnefs and fteadinefs than any algebraical formula. We need only appeal to the geometrical expreffions of many fluents, which are to be feen in Newton's lunar theory, in the phyfical tracts of Dr Matthew Stewart, and others who have fhewn a partiality for this method.

It would be very prefumptuous, however, for us to fay, that the accurate geometer and metaphyfician may not derive great advantages from profecuting the very ingenious and recondite fpeculations of Mr Glenie, in his doctrine of univerfal comparifon.

CALEDONIA *Co.* in Vermont, contains 24 townfhips and has Connecticut river S. E.; Orleans and Chittenden counties N. W.; Effex co. N. E.; and Orange co. of which, until lately, it formed a part, S. W.—*Morse.*

Caledonia, a port on the ifthmus of Darien, in the N. Sea, 25 leagues N. W. from the river Atrato. It was attempted to be eftablifhed by the Scotch nation in 1698, and had at firft all the promifing appearances of fuccefs; but the Englifh, influenced by narrow national prejudices, put every impediment in their way; which, joined to the unhealthinefs of the climate, deftroyed the infant colony.—*ib.*

CALENDAR, in chronology. See *(Encycl.)* Kalendar; and Revolution, n° 184.

CALI, a city of New Granada, S. America, fituated on the river Cauca. The ftaple port for this city, as alfo for thofe of Popayan, Santa Fe, and the fouthern parts of Terra Firma, is Bonaventura in the diftrict of Popayan. The road by land from that port is not paffable for beafts of burden; fo that travellers, with their baggage, are carried on the backs of Indians in a chair, with which weight they crofs rivers and mountains, being entirely flaves to the Spaniards, who thus fubftitute them in the room of horfes and mules. N. lat. 3. 15. W. long. 76. 30.—*Morse.*

CALIPPIC period, in chronology, a period of 76 years, continually recurring; at every repetition of which, it was fuppofed by its inventor Calippus, an Athenian aftronomer, that the mean new and full moons would always return to the fame day and hour.

About a century before, the golden number, or cycle of 19 years, had been invented by Meton; which Calippus finding to contain 19 of Nabonaffar's year, 4 days, and $\frac{3}{4}\frac{1}{7}\frac{1}{9}$, to avoid fractions he quadrupled it, and fo produced his period of 76 years, or 4 times 19; after which he fuppofed all the lunations, &c. would regularly return to the fame hour. But neither is this exact, as it brings them too late by a whole day in 225 years.

CALLAO, as it is called by its inhabitants, but more generally known to Europeans under the name of Campello, is a fmall ifland, which was vifited by fome of Lord Macartney's fuite on their voyage to China. In confequence of that vifit, we have the following defcription of it in Sir George Staunton's Account of the Embaffy.

" It lies oppofite to, and about eight miles to the eaftward of, the mouth of a confiderable river on the coaft of Cochin-china, on the banks of which is fituated the town of Fai-foo, a place of fome note, not far from the harbour of Turon. The bearing of the higheft peak of Callao from this harbour is about fouth-eaft, diftance thirty miles. The extreme points of the ifland lie in latitude 15° 53′, and 15° 57′ north; the greateft length is from north-weft to fouth-eaft, and is fomewhat about five miles, and the mean breadth two miles. The only inhabited part is on the fouth-weft coaft, on a flip of ground rifing gently to the eaft, and contained between the bottom of a femilunar bay and the mountains on each fide of it. Thofe mountains, at a diftance, appear as if they formed two diftinct iflands. The fouthern mountain is the higheft, and is about 1500 feet. The lower grounds contain about 200 acres. This fmall but enchanting fpot is beautifully diverfified with neat houfes, temples, clumps of trees, fmall hillocks fwelling from the plain, and richly decorated with fhrubbery and trees of various kinds; among which the elegant areca, rifing like a Corinthian column, is eminently confpicuous. A rill of clear water, oozing from the mountains, is contrived to be carried along the upper ridges of the vale, from whence it is occafionally conveyed through fluices, for the purpofe of watering the rice grounds, and appeared, though then in the dry feafon, fully fufficient for every purpofe for which it could be wanted.

" The houfes, in general, were clean and decent; a few were built with ftone, and covered with tiles. One, probably the manfion of the chief perfon of the ifland, was inclofed by a ftone wall, and the approach to it was through a gateway between two ftone pillars. The houfe was divided into a number of apartments, of which the arrangement did not feem to want either tafte or convenience. This building ftood at the head of the principal village, which confifted of about thirty habitations built of wood, chiefly the bamboo. Behind the village, and on the fide of the hill, was a cave, acceffible only by one way, through an irregular range of rocks. Within the cave, but near its mouth, was a fmall temple, commanding a view of the whole vale. Several other temples were difperfed over the plain, all of which were open in front, with a colonnade before them of round wooden pillars, painted red and varnifhed. The number of houfes on the ifland fcarcely exceeded

ceeded fixty. Behind every houfe, not immediately in the principal village, were inclofures of fugar-canes, tobacco, and other vegetables, growing in great luxuriance. The mountains were covered with verdure, and feemed well calculated for rearing goats, of which the ifland produced a few.

"Befide the principal bay, there were feveral fandy inlets, with fmall patches of level ground behind them. Boats might eafily land in any of thefe inlets; but a communication between them by land appeared to be exceedingly difficult, if not entirely prevented, by the fteep and rugged ridges which feparated them from each other. On this account very flight works, and an eftablifhment of a few men only, would be requifite for the defence of the ifland, a great part of its coaft being impregnably fortified by nature. The depth of water in the bay and road was fufficient for fhips of any burden, and there was perfect fhelter from every wind except the fouth-weft, to which quarter it was directly open. The fhort diftance however, from the continent in that direction would always prevent the fea from rifing high, though it might not be fufficiently near to break the force of the wind."

The inhabitants of this ifland are fo exceedingly fhy and afraid of ftrangers, that upon the approach of the Englifh veffel, they all, except a very few, retired on board their galleys. When the Britifh landed, therefore, they found the doors of all the houfes open, with feveral domeftic animals feeding before them, but neither man, woman, nor child within. After fome time, however, a perfon was perceived lurking among the neighbouring trees, who, finding he was obferved, came forward with reluctance and evident marks of fear. While he was yet at fome diftance, he fell upon his knees, and touched the ground with his forehead feveral times. On approaching to him, it was noticed that the firft joint of every one of his fingers and toes was wanting, and as if twifted off by violence; it was poffible that he might have thus been treated by way of punifhment for fome crime, and that he was confidered as the fitteft perfon to be expofed to the fuppofed danger of watching the movements of the ftrangers coming afhore. In a little time fome others, hidden in the thickets, finding that no mifchief was fuffered by the firft, ventured out. None of them could underftand the Chinefe interpreter; and not being able to read or write, there was no converfing with them by the medium of the Chinefe characters. Recourfe was had to hieroglyphics, and rude figures were drawn of the articles which were propofed to be purchafed; and this method fucceeded tolerably well; poultry and fruits were brought for fale, for which high prices were given, purpofely to conciliate the good will of thofe iflanders. The few that were found grew foon familiar; and one old man preffingly invited the ftrangers to his houfe, fituated upon an eminence, at a little diftance. On arriving there, he introduced them to his wife, an old woman, who, after recovering from her aftonifhment at the fight of figures fo different from thofe fhe had ever been accuftomed to behold, laid, in a neat manner, before them fome fruits, fugar, cakes, and water. On departing from the houfe, this decent and hofpitable couple made figns to teftify their defire of feeing them again."

The poffeffion of this ifland would be of fuch importance to any European nation who wifhed to trade fecurely with TUNG-QUIN and COCHIN-CHINA, that it is faid the French had formerly fome thoughts of purchafing it. Sir George Staunton, however, is of opinion, that the want of fhelter in the fouth-weft monfoon would render it of little value, without a further fettlement near it upon the main land of Cochin-china; and he thinks, that if a folid eftablifhment there could be productive of advantage to any European nation, it would neceffarily be fo to Great Britain; becaufe, befide the opening which it would make for the fale of Britifh manufactures among the people of the country, the Britifh poffeffions in Hindoftan would be fure of a very confiderable demand for their productions.

CALLAO, a fea-port town in the empire of Peru, being the port or harbor of Lima, and is fituated 2 leagues from that city. On the N. fide runs the river which waters Lima, on which fide is a fmall fuburb built only of reeds. There is another on the S. fide; they are both called Pitipifti, and inhabited by Indians. To the E. are extenfive plains, adorned with beautiful orchards watered by canals cut from the river. The town, which is built on a low flat point of land, was ftrongly fortified in the reign of Philip IV.; and numerous batteries command the port and road, which is the greateft, fineft, and fafeft in all the South Sea. There is anchorage every where in very deep water, without danger of rocks or fhoals, except one, which is 3 cables-length from the fhore, about the middle of the ifland of St Lawrence, oppofite La Galatea. The little ifland of Callao lies juft before the town. In the opening between thefe two iflands, there are two fmall iflots, or rather rocks; there is alfo a third very low, but half a league out at fea, S. S. E. from the N. W. point of the ifland of St. Lawrence. Near the fea-fide is the governor's houfe, which, with the viceroy's palace, take up two fides of a fquare; the parifh church makes a third; and a battery of 3 pieces of cannon forms the fourth. The churches are built of canes interwoven, and covered with clay, or painted white. Here are 5 monafteries, and an hofpital. The houfes are in general built of flight materials; the fingular circumftance of its never raining in this country, renders ftone houfes unneceffary; and befides, thefe are more apt to fuffer from earthquakes, which are frequent here. The moft remarkable happened in the year 1746, which laid $\frac{3}{4}$ths of Lima level with the ground, and entirely demolifhed Callao; where the deftruction was fo entire that only one man, of 3000 inhabitants, was left to record this dreadful calamity. S. lat. 12. 1. W. long. 77.—*Morse.*

CALOS, a bay on the W. coaft of the peninfula of E. Florida, where are excellent fifhing banks and grounds. Not far from this is a confiderable town of Seminole Indians. The Spaniards from Cuba take great quantities of fifh here, and barter with the Indians and traders for fkins, furs, &c. and return with their cargoes to Cuba.—*ib.*

CAMBRIDGE, a townfhip in Grafton co. New-Hampfhire, E. of Androfcoggin, and S. of Umbagog Lake.—*ib.*

CAMBRIDGE, a townfhip in Wafhington co. New-York. By the cenfus of 1790, it contained 4996 inhabitants, including 41 flaves. By the ftate cenfus of 1796, it appears there are 623 electors.—*ib.*

CAMBRIDGE, the half fhire town of Middlefex co. Maffachufetts, Maſſachuſetts, is one of the largeſt and moſt reſpectable townſhips of the county. Its 3 pariſhes, Cambridge, Little Cambridge, and Menotomy, contain 3 Congregational meeting houſes, one for Baptiſts, and another for Epiſcopalians; a number of very pleaſant ſeats, and 2115 inhabitants. The elegant bridge which connects this town with Boſton has been deſcribed under the head of Boſton. The compact part of Cambridge is pleaſantly ſituated 3½ miles weſtward of Boſton, on the N. bank of Charles river, over which is a bridge leading to Little Cambridge. It contains about 100 dwelling houſes. Its public buildings, beſides the edifices which belong to Harvard univerſity, are the Epiſcopal and Congregational meeting-houſes, and a handſome court-houſe. The college buildings are 4 in number, and are of brick, named Harvard, Hollis, and Maſſachuſetts Halls, and Holden Chapel. They ſtand on a beautiful green which ſpreads to the N. W. and exhibit a pleaſing view. This univerſity, as to its library, philoſophical apparatus and profeſſorſhips, is at preſent the firſt literary inſtitution on this continent. It takes its date from the year 1638, 7 years after the firſt ſettlement in the townſhip, then called *Newtown*. Since its eſtabliſhment, to July 1794, 3399 ſtudents have received honorary degrees from its ſucceſſive officers. It has generally from 140 to 200 ſtudents. The library contains upwards of 12000 volumes. The cabinet of minerals, in the muſeum, contains the more uſeful productions of nature; and excepting what are called the *precious ſtones*, there are very few ſubſtances yet diſcovered in the mineral kingdom, but what may be found here. The univerſity owes this noble collection of minerals, and ſeveral other natural curioſities, to the munificence of Dr. Lettſom, of London, and to that of the republic of France. N. lat. 42. 23. 28. W. long. from Greenwich 71. 7. 30. —*ib.*

Cambridge, a poſt town of Ninety-Six diſtrict, in the upper country of S. Carolina, where the circuit courts are held. It contains about 60 houſes, a court-houſe and a brick gaol. The college by law inſtituted here is no better than a grammar ſchool. It is 80 miles N. N. W. of Columbia; 50 N by W. of Auguſta, in Georgia, 140 N. W. of Charleſton, and 762 S. W. of Philadelphia. N. lat. 34. 9.—*ib.*

Cambridge, the chief town of Dorcheſter co. Maryland, is ſituated on the S. ſide of Choptank River, about 13 miles E. S. E. from Cook's point at its mouth; 9 W. S. W. from Newmarket, and 57 S. E. from Baltimore. Its ſituation is healthy, and it contains about 50 houſes and a church. N. lat. 38. 34.—*ib.*

Cambridge, in Franklin co. Vermont, is ſituated on both ſides of La Moille River, about 20 miles W. of Lake Champlain and has 359 inhabitants.—*ib.*

CAMDEN *Co.* in Edenton diſtrict, N. Carolina, is in the N. E. corner of the ſtate. It has 4033 inhabitants, including 1038 ſlaves. Joneſborough is the chief town.—*ib.*

Camden, *Diſtrict*, in the upper country of S. Carolina, has Cheraws diſtrict on the N. E. Georgetown diſtrict on the S. E. and the ſtate of N. Carolina on the N.; and is divided into the following counties, Fairfield, Richland, Clarendon, Claremont, Kerſhaw, Salem and Lancaſter. It is 82 miles from N. to S. and 60 from E. to W. and contain 38,265 inhabitants, including 8865 ſlaves. This diſtrict is watered by the Wateree, or Catabaw River and its branches; the upper part is variegated with hills, generally fertile and well watered. It produces Indian corn, wheat, rye, barley, tobacco, and cotton. The Catabaw Indians, the only tribe which reſide in the ſtate, live in the N. part of this diſtrict.—*ib.*

Camden, a poſt town, and chief of Camden diſtrict, S. Carolina, in Kerſhaw co. ſtands on the E. ſide of Wateree River; 35 miles N. E. of Columbia; 55 S. W. of Cheraw; 120 N. by W. of Charleſton, and 643 S. W. of Philadelphia. It is regularly laid out, and contains about 120 houſes, an Epiſcopal church, a court-houſe and gaol. The navigable river on which the town ſtands, enables the inhabitants to carry on a lively trade with the back country. N. lat. 34. 12. W. long. 80. 54.

This town, or near it, was the ſcene of two battles in the late war. On the 16th of Auguſt, 1780, between Gen. Gates and Lord Cornwallis, in which the American general was defeated. The other was a briſk action between Lord Rawdon and Gen. Green, on the 25th of April, 1781. Lord Rawdon ſallied out of the town with 800 men, and attacked the American camp, which was within a mile of the town. The Americans had 126 men killed, and 100 taken priſoners, and the Britiſh had about 100 killed. The town was evacuated the 9th of May, in the ſame year, after Lord Rawdon had burned the gaol, mills, many private houſes, and part of his own baggage.—*ib.*

Camden *Co.* in the lower diſtrict of Georgia, at the S. E. corner of the ſtate, on St Mary's River, contains 305 inhabitants, including 70 ſlaves. Chief town St Patricks.—*ib.*

Camden, a ſmall poſt town on the weſtern ſide of Penobſcot bay, diſtrict of Maine, and the S. eaſternmoſt townſhip of Lincoln co. having Thomaſtown on the S. W.; 35 miles N. N. E. from Pownalborough, and 228 miles N. E. from Boſton.—*ib.*

Camden, a village in Kent co. ſtate of Delaware; about 4 miles S. W. from Dover, and 5 N. weſterly from Frederica.—*ib.*

CAMEL, in navigation, is a machine which has been deſcribed with ſufficient accuracy in the Encyclopædia; but the following account of its invention, given by Profeſſor Beckmann, is perhaps not unworthy of a place in this Supplement.

"In the Zuyder-Zee, oppoſite to the mouth of the river Y, about ſix miles from the city of Amſterdam, there are two ſand banks, between which is a paſſage called the *Pampus*, which is ſufficiently deep for ſmall ſhips, but not for ſuch as are large or heavy laden. In 1672 the Dutch contrived, however, to carry their numerous fleet through this paſſage, by means of large empty cheſts faſtened to the bottom of each ſhip; and this contrivance gave riſe to the invention of the *camel*." In the Encyclopædia its invention is given to the famous De Wit; in the German Cyclopædia to Meyer a Dutch engineer of very conſiderable eminence; but the Dutch writers, almoſt unanimouſly, aſcribe the invention of the camel to a citizen of Amſterdam, who calls himſelf Meeuves Meindertſon Bakker. "Some make the year of the invention to have been 1688, and others 1690. Much has been ſaid of the utility of this invention; but however beneficial it may be, we have reaſon to ſuppoſe that ſuch heavy veſſels as ſhips of war cannot

cannot be raised up, in so violent a manner, without sustaining injury. A sure proof of this is the well known circumstance mentioned by Muschenbroek (*Introductio ad Philosoph. Natur.*), that the ports of a ship which had been raised by the camel could not afterwards be shut closely."

CAMELEON, one of the constellations of the southern hemisphere, near the south pole, and invisible in our latitude. There are 10 stars marked in this constellation in Sharp's catalogue.

CAMELOPARDALUS, a new constellation of the northern hemisphere, formed by Hevelius, consisting of 32 stars, first observed by him. It is situated between Cepheus, Cassiopeia, Perseus, the Two Bears, and Draco; and it contains 58 stars in the British catalogue.

CAMELLIA, in botany (see *Encycl.*), is a plant which the Chinese call *Cha wha*, or flower of tea, on account of the resemblance of the one to the other, and because its petals are sometimes mixed among the teas to increase their fragrance. Sir George Staunton, who calls it *Camellia Sesanqua*, saw it flourishing on the sides and very high tops of mountains, where the soil consisted of little more than fragments of stone, crumbled into a sort of coarse earth by the joint action of the sun and rain. It yields, he says, a nut, from which is expressed an esculent oil, equal to the best which comes from Florence. On this account, it is cultivated in vast abundance; and is particularly valuable from the facility of its culture in situations fit for little else.

CAMPBELL (George, D. D.), so justly admired for his metaphysical acuteness and various erudition, was, in 1719, born at Aberdeen, where his father, the reverend Colin Campbell, was one of the ministers of the established church. He was educated in his native city; and, after passing through the usual course of academical learning, he studied divinity under the Rev. J. Chalmers, professor of divinity in Marischal College.—He was, in 1749, an unsuccessful candidate for the church of Fordown, though his competitor Mr Forbes was a man of very slender abilities, and supposed to be attached to the constitution and liturgy of the church of England. It might indeed be that attachment which contributed principally to procure him the living in preference to Mr Campbell.

The living of Fordown is in the gift of the crown; and it has generally been a rule with his majesty's ministers, to give such livings, when they become vacant, to those candidates who are favoured by the majority of land-owners in the parish. At the era of 1749, the land-owners in some of the northern and middle counties of Scotland were more generally attached to the constitution of the church of England than to that of their own establishment; and such was certainly the case in the parish of Fordown.

But whatever was the cause of Mr Campbell's failure, he failed by a very small number, and was not long without an establishment. In 1750, he was presented, by Sir Thomas Burnett, of Leys, to the living of Banchary Ternan, on the Dee, about twenty miles west from Aberdeen. From this he was translated, or, as the Scotch ecclesiastical phrase is, *transported* to Aberdeen in 1756, and nominated one of the city ministers, in the room of Mr John Bisset deceased, a puritan of the old school, whose strictness and peculiarities are yet remembered by many in that place.

In 1759, on the decease of principal Pollock, he was chosen principal of the Marischal college, and succeeded to the divinity chair in 1771, on Dr Alexander Gerard being translated to the professorship of divinity in King's-college. Before his settling in Aberdeen, he married Miss Grace Farquharson, daughter of Mr Farquharson of Whitehouse, by whom he had no issue. This amiable woman died about a year before him. They were an eminent pattern of conjugal affection.

From this time he enjoyed a remarkable share of good health and spirits. He had, all his life, a rooted aversion to medicine. He got the better of every ailment by a total and rigorous abstinence from all kind of sustenance whatever; and it was not till he was attacked by an alarming illness, about two years before his death, that he was persuaded by his friends to call in medical aid. What nature could do, she had all along performed well; but her day was over, and something of art became necessary. Then, for the first time, he owned the utility of medical men, and declared his recantation of the very mean opinion he had formerly entained of them and their art. A few months before his death, he resigned his offices of principal, professor of divinity, and one of the city ministers, and was in all succeeded by Dr W. L. Brown, late of Utrecht, a man of distinguished abilities. Dr Campbell retained all his faculties entire to the last, and died on the 6th of April 1796, in the 77th year of his age. His character has been so justly drawn by his successor, that we shall give it to our readers in his words, adding only a circumstance or two, which we have reason to think will contribute to endear his memory to every liberal and enlightened mind.

"Dr Campbell, as a public teacher, was long admired for the clearness and copiousness with which he illustrated the great doctrines and precepts of religion, and the strength and energy with which he enforced them. Intimately persuaded of the truth and infinite consequence of what revelation teaches, he was strongly desirous of carrying the same conviction to the minds of his hearers, and delivered his discourses with that zeal which flows from strong impressions, and that power of persuasion which is the result of sincerity of heart, combined with clearness of understanding. He was satisfied, that the more the pure dictates of the gospel were studied, the more they would approve themselves to the mind, and bring forth, in the affections and conduct, all the peaceable fruits of righteousness. The unadulterated dictates of Christianity, he was, therefore, only studious to recommend and inculcate, and knew perfectly to discriminate them from the inventions and traditions of men. His chief study ever was, to direct belief to the great objects of practice; and, without these, he viewed the most orthodox profession as "a sounding brass, and a tinkling cymbal." But, besides the character of a preacher of righteousness, he had also that of a teacher of the science of divinity to sustain. How admirably he discharged this duty, and with what effect he conveyed the soundest and most profitable instruction to the minds of his scholars, let those declare who are now in various congregations of this country, communicating to their fellow

Campbell.

Chriſtians the fruits of their ſtudies under ſo able and judicious a teacher. Diſcarding all attachment to human ſyſtems, merely conſidered as ſuch, he tied his faith to the Word of God alone, poſſeſſed the happieſt talent in inveſtigating its meaning, and communicated to his hearers the reſult of his own inquiries, with a preciſion and perſpicuity which brought light out of obſcurity, and rendered clear and ſimple what appeared intricate and perplexed. He expoſed, without reſerve, the corruptions which ignorance, craft, and hypocriſy, had introduced into religion, and applied his talent for ridicule to the beſt of all purpoſes, to hold up to contempt the abſurdities with which the pureſt and ſublimeſt truths had been loaded.

"Placed at the head of a public ſeminary of learning, he felt all the importance of ſuch a ſituation, and uniformly directed his influence to public utility. His enlarged and enlightened mind, juſtly appreciated the extenſive conſequence of the education of youth. He anticipated all the effects reſulting to the great community of mankind, from numbers of young men iſſuing, in regular ſucceſſion, from the univerſity over which he preſided, and occupying the different departments of ſocial life.

"His benevolent heart delighted to repreſent to itſelf the ſtudents under his direction uſefully and honourably diſcharging the reſpective duties of their diſferent profeſſions; and ſome of them, perhaps, filling the moſt diſtinguiſhed ſtations of civil ſociety. With theſe proſpects before him, he conſtantly directed his public conduct to their attainment. He never ſuffered his judgment to be warped by prejudice or partiality, or his heart to be ſeduced by paſſion or private intereſt. Thoſe mean and ignoble motives by which many are actuated in the diſcharge of important truſts, approached not his mind. A certain honourable pride, if pride it may be called, diffuſed an uniform dignity over the whole of his behaviour. He felt the man degraded by the perverſion of public character. His underſtanding alſo clearly ſhewed him even perſonal advantage attached to ſuch principles and practice, as he adopted from a ſenſe of obligation, and thoſe elevated conceptions of real worth which were ſo congenial to his ſoul. He ſaw, he experienced, eſteem, reſpect, and influence, following in the train of integrity and beneficence; but contempt, diſgrace, averſion, and complete inſignificance, cloſely linked to corruption and ſelfiſhneſs. Little minds are ſeduced and overpowered by ſelfiſh conſiderations, becauſe they have not the capacity to look beyond the preſent advantage, and to extend to the miſery that ſtands on the other ſide of it. The ſame circumſtance that betrays the perverſity of their hearts, alſo evinces the weakneſs of their judgments.

"His reputation as a writer, is as extenſive as the preſent intercourſe of letters; not confined to his own country, but ſpread through every civilized nation. In his literary purſuits, he aimed not, as is very often the caſe, with men of diſtinguiſhed literary abilities, merely at eſtabliſhing his own celebrity, or increaſing his fortune; but had chiefly at heart the defence of the great cauſe of Religion, or the elucidation of her dictates.

"At an early period he entered the liſts as a champion for Chriſtianity againſt one of its acuteſt opponents. He not only triumphantly refuted his arguments, but even conciliated his reſpect by the handſome and dexterous manner in which his defence was conducted. While he refuted the infidel, he ſpared the man, and exhibited the uncommon ſpectacle of a polemical writer poſſeſſing all the moderation of a Chriſtian. But while he defended Chriſtianity againſt its enemies, he was deſirous of contributing his endeavours to increaſe, among its profeſſors, the knowledge of the ſacred writings. Accordingly, in the latter part of his life, he favoured the world with a work, the fruit of copious erudition, of unwearied application, for almoſt thirty years, and of a clear and comprehenſive judgment. We have only to regret, that the other writings of the New Teſtament have not been elucidated by the ſame pen that tranſlated the Goſpels. Nor were his literary merits confined to theology, and the ſtudies more immediately connected with it. Philoſophy, and the fine arts, are alſo indebted to his genius and labours; and in him the polite ſcholar was eminently joined to the deep and liberal divine.

"Political principles will always be much affected by general character. This was alſo the caſe with Dr Campbell. In politics, he maintained that moderation which is the ſureſt criterion of truth and rectitude, and was equally diſtant from thoſe extremes into which men are ſo apt to run on great political queſtions. He cheriſhed that patriotiſm which conſiſts in wiſhing, and endeavouring to promote, the greateſt happineſs of his country, and is always ſubordinate to univerſal benevolence. Firmly attached to the Britiſh conſtitution, he was animated with that genuine love of liberty which it inſpires and invigorates. He was equally averſe to deſpotiſm and to popular anarchy; the two evils into which political parties are ſo frequently hurried, to the deſtruction of all that is valuable in government. Party-ſpirit, of whatever deſcription, he conſidered as having an unhappy tendency to pervert, to the moſt pernicious purpoſes, the beſt principles of the human mind, and to clothe the moſt iniquitous actions with the moſt ſpecious appearances. Although tenacious of thoſe ſentiments, whether in religion or politics, which he was convinced to be rational and juſt, he never ſuffered mere difference of opinion to impair his good will, to obſtruct his good offices, or to cloud the cheerfulneſs of converſation. His own converſation was enlivened by a vein of the moſt agreeable pleaſantry."

So far was he from being influenced by jealouſy, or any portion of that corporation ſpirit which ſometimes incites men of undoubted abilities to detract from the merit of every writer who fills not a ſtation as conſpicuous as their own, that he was loud in his praiſes of thoſe, whom men of meaner minds would have looked upon with diſguſt, as upon preſumptuous rivals. This generoſity was fully experienced by the writer of the article Miracle, in the Encyclopædia, who, though he had preſumed to treat the ſubject differently from Dr Campbell, received from him ſuch a teſtimony of approbation of what he had done, as he will hardly look for from any other man in ſimilar circumſtances.

Among his other qualities, which ſo much endeared him to all who had the honour of his acquaintance, Dr Campbell poſſeſſed an uncommon facility of paſſing from the graveſt to the moſt airy ſubjects, and from the livelieſt to the graveſt, without degrading the one or diminiſhing the pleaſure of the other. The infirmities of age abated not the cheerfulneſs of his temper, nor did even

even the perfuafion of approaching diffolution impair his ferenity.

We cannot conclude this fhort fketch better than with a lift of his works, in the order in which they were publifhed. In 1752, he publifhed a Sermon, preached before the Synod of Aberdeen.

1761. A Differtation on Miracles, againft Mr Hume. This treatife is well known to the learned world. He obtained, and defervedly obtained, a very high reputation, not only from the able manner in which he handled the fubject, but from the liberal ftyle in which he addreffed his antagonift. It was fpeedily tranflated into French, German, and Dutch.

1771. A Sermon before the Society for Propagating Chriftian Knowledge, Edinburgh.

———— before the Synod of Aberdeen.

1776. The Philofophy of Rhetoric, 2 vols 8vo. A work which difcovers a clearnefs of difcernment, and accuracy of obfervation, which juftly intitled him to be ranked among the moft judicious critics. He entered on this inquiry as early as 1750, when a part of the work was compofed. The laws of elegant compofition and criticifm are laid down with great perfpicuity: but the moft valuable part of the work is undoubtedly the *theory of evidence*, to which we know nothing fuperior, perhaps nothing equal, on the fubject, in our own or any other language. His philofophy, in general, is the philofophy of Dr Reid; and where he differs from that acute reafoner refpecting *abftraction*, and fome other objects of metaphyfical difquifition, we think it impoffible to refufe him the pre-eminence in every thing but ftyle.

1777. A Sermon on the King's Faft-day, on Allegiance, firft printed in 4to, and afterwards, at the expence of government, fix thoufand copies were printed in 12mo, enlarged with notes, and fent to America, when the unhappy ftruggle had, however, put on appearances which prevented the effect hoped for from this fermon.

1780. An Addrefs to the People of Scotland on the Alarms which have been raifed by what is called the Popifh Bill. This is a powerful diffuafive from bigotry, and every fpecies of religious perfecution.

1793. His *Magnum Opus*. The tranflation of the Gofpels, with Preliminary Differtations, 2 vols 4to.

CAMPBELL *Co.* in Virginia, lies E. of Bedford co. on Staunton River. It is 45 miles long, and 30 broad, and contains 7,685 inhabitants, including 2,488 flaves.—*Morfe.*

CAMPBELLTOWN, a village in Dauphin co. Pennfylvania, which ftands near a water of Quitipihilla Creek; 13 miles E. of Harrifburgh, and 96 N. W. of Philadelphia.—*ib.*

CAMPBELLTOWN, in N. Carolina, is a large and flourifhing town on a branch of Cape Fear River 100 miles above Wilmington; having, according to Bartram, "above 100 houfes, many wealthy merchants, refpectable public buildings, a vaft refort of inhabitants and travellers, and continual brifk commerce by waggons, from the back fettlements, with large trading boats."—*ib.*

CAMPBELL's *Fort*, in the ftate of Tenneffee, ftands near the junction of Holfton River with the Tenneffee; diftant 135 miles from Abingdon, in Wafhington co. Virginia, and 445 W. of Richmond in Virginia.—*ib.*

CAMPBELL's *Salines*, in North Holfton, in the ftate of Tenneffee, are the only ones that have yet been difcovered on the upper branches of the Tenneffee, though great fearch has been made for them. Large bones, like thofe found at Big Bone Lick, have been dug up here; and other circumftances render the tract which contains the falines a great natural curiofity. Capt. Charles Campbell, one of the firft explorers of the weftern country, made the difcovery of this tract in 1745. In 1753, he obtained a patent for it from the governor of Virginia. His fon the late Gen. William Campbell, the fame who behaved fo gallantly in the years 1780, and 1781, became owner of it on his death. But it was not till the time of his death, when falt was very fcarce and dear, that falt-water was difcovered, and falt made by a poor man. Since that time it has been improved to a confiderable extent, and many thoufands of people are now fupplied from it, with falt of a fuperior quality, and at a low price. The tract confifts of about 300 acres of falt marfh land, of as rich a foil as can be imagined. In this flat, pits are funk, in order to obtain the falt water. The beft is found from 30 to 40 feet deep; after paffing through the rich foil or mud, from 6 to 10 feet, you come to a very brittle lime-ftone rock, with cracks or chafms, through which the falt water iffues into the pits, whence it is drawn by buckets and put into the boilers, which are placed in furnaces adjoining the pits. The hills that furround this flat are covered with fine timber; and a coal mine has been difcovered not far from it. —*ib.*

CAMPEACHY, a town in the audience of Old-Mexico, or New-Spain, and province of Yucatan, fituated on the bay of Campeachy, near the W. fhore. Its houfes are well built of ftone; when taken by the Spaniards it was a large town of 3000 houfes, and had confiderable monuments of Indian art and induftry. There is a good dock and fort, with a governor and garrifon, which commands both the town and harbor. It has been often ftormed and taken, both by the Englifh and French buccaniers, in 1659, 1678, and laft in 1685, when thefe freebooters united, and plundered every place within 15 leagues round it, for the fpace of two months; they afterwards fet fire to the fort and town, which the governor, who kept the field with his men, would not ranfom; and to complete the pillage by a fingular piece of folly, the French buccaniers celebrated the feaft of their king, the day of St Louis, by burning to the value of £.50,000 fterling of Campeachy wood, which was a part of their fhare of the plunder. The port is large but fhallow. It was a ftated market for logwood, of which great quantities grew in the neighbourhood, before the Englifh landed there, and cut it at the ifthmus, which they entered at Triefta Ifland, near the bottom of the bay, 40 leagues S. W. from Campeachy. The chief manufacture here is cotton cloth. Lat. 15. 40. long. 91. 30.—*ib.*

CAMPHOR, or CAMPHIRE (fee *Encycl.*), is, in China, obtained by boiling the branches, twigs, and leaves, of the *Laurus-Camphora* in water, upon the furface of which it is found fwimming in the form of an oil, or adhering, in a glutinous form, to a wooden rod, with which the boiling matter is conftantly ftirred. The glutinous mafs is then mixed with clay and lime, and put into an earthen veffel, with another of the fame fize properly luted over it; the lower veffel being placed over a flow fire, the camphor gradually fublimes through the clay and lime, and adheres to the fides of the upper veffel, forming a cake of a fhape correfponding to the cavity which received it. It is, however, lefs pure and much weaker than what is difcovered in a folid ftate among the fibres of the trunk, as turpentine is found in different forts of pines. In the great, but ill-peopled, ifland of Borneo, and alfo in Japan, the camphor tree is felled for the fole purpofe of finding this coftly drug in fubftance among the fplinters of the trunk, in the fame manner as other trees are felled in Louifiana merely for collecting the fruit they bear upon their fummits. The Borneo, or Japan camphor, is pure, and fo very ftrong, as readily to communicate much of its odour and its virtues to other infpiffated oils, which thus pafs for real camphor; and this adulterated drug is fold by Chinefe artifts at a vaftly lower price than they gave themfelves for the genuine fubftance from Borneo or Japan.

Sir George Staunton, from whom we have this account, does not inform us whether the camphor-tree of China, if felled and torn into fplinters, would not produce as large quantities of the drug, and equally pure, as the trees of Borneo and Japan; but he affures us, that in China it is never fo torn, being there a large and valuable timber-tree. "It is ufed (fays he) in the beft buildings of every kind, as well as for mafts of veffels, and bears too high a price to allow of any part, except the branches, being cut up for the fake of the drug."

CAMPO BELLO, a long and narrow ifland, on the E. coaft of Wafhington co. diftrict of Maine, and the N. eafternmoft of all the iflands of the diftrict. It lies at the mouth of a large bay into which Cobfcook river empties, and has communication with Paffamaquoddy bay on the N. by two channels; the one between the W. fide of Deer Ifland and the continent; the other into the mouth of Paffamaquoddy Bay between Deer Ifland and the N. end of Campo Bello Ifland which lies in about N. lat. 44. 48. The S. end is 5 miles N. wefterly from Grand Mannan Ifland.—*Morse.*

CANABAC, an ifland lying contiguous to Bulam on the weftern coaft of Africa, and inhabited by a fierce people, governed by two kings or chiefs. It would appear that the Canabacs had been very troublefome to their neighbours, fince the inhabitants of fome other iflands in that clufter rejoiced at the fettlement of the Englifh in Bulam, hoping to find in them a defence againft the ufurpations of the Canabacs.

CANADA *Creeks.* There are three creeks which bear this name; one a water of Wood creek, which it meets 4 or 5 miles N. N. W. of Fort Stanwix or New Fort Schuyler. The other two are northern branches of Mohawk River; the *upper* one mingles its waters with the Mohawk in the townfhip of Herkemer, on the German flats, 16 miles below Old Fort Schuyler; over the mouth of it is a fightly and ingenioufly conftructed bridge. The other empties into the Mohawk 13 miles below. Both thefe are long, rapid and unnavigable ftreams, and bring a confiderable acceffion of water to the Mohawk. The lands on thefe creeks are exceedingly rich and valuable, and faft fettling.—*Morse.*

CANADA SAGA, or *Seneca Lake,* a handfome piece of water from 35 to 40 miles long, and about 2 miles broad, in New-York. At the N. W. corner of the Lake ftands the town of Geneva, and on the E. fide between it and Cayuga, are the towns of Romulus, Ovid, Hector and Ulyffes, in Onondago co. New-York. Its outlet is Scayace River which alfo receives the waters of Cayuga Lake 9 miles N. E. from the mouth of Canada Saga, 18 miles below Geneva, on the fame fide of the lake ftands the Friend's fettlement, founded by Jemima Wilkinfon; there are 80 families in it, each has a fine farm, and are quiet, induftrious people.—*ib.*

CANAJOHARY, a poft town in Montgomery co. New-York, fituated on the S. fide of Mohawk River comprehending a very large diftrict of fine country, 40 miles W. of Schenectady, and 56 miles from Albany. In the ftate cenfus of 1796, 730 of the inhabitants appear to be electors. A creek named Canajohary enters the Mohawk in this town. In this townfhip, on the bank of the Mohawk, about 50 miles from Schenectady, is *Indian Caftle,* fo called, the feat of old king Hendrick, who was killed in Sept. 1755, at Lake George, fighting for the Britifh and Americans againft the French. Here are now the remains of a Britifh fort, built during that war, about 60 paces fquare. A gold coin of the value of about 7 dollars was found in thefe ruins in 1793. About a mile and half W. of this fort ftands a church, which is called Brant's church, which the noted chief of that name is faid to have left with great reluctance. This was the principal feat of the Mohawk nation of Indians, and abounds with apple trees of their planting, from which is made cider of an excellent quality.—*ib.*

CANALS of Communication may be of fuch advantage in a commercial or agricultural country, that every attempt to render them more convenient, and lefs expenfive in the conftruction, is intitled to public notice. In the Encyclopædia, an account, fufficiently perfpicuous, is given of the common canals with locks; but in many cafes it is very difficult to provide a fufficient quantity of water for the confumption of a canal where many boats are to pafs. Different attempts have therefore been made, by ingenious men, to fave water in the paffing of boats or lighters from one lock of a canal to another; and, among thefe, perhaps none is more deferving of public favour than the following, by the late Mr James Playfair of Ruffel-ftreet, architect. We fhall ftate his invention in his own words.

"The nature and principle of this manner of faving water confift in letting the water which has ferved to raife or fall a boat or barge from the lock, pafs into refervoirs or cifterns, whofe apertures of communication with the lock are upon different levels, and which may be placed or conftructed at the fide or fides of the lock with which they communicate, or in any other contiguous fituation that circumftances may render eligible; which apertures may be opened or fhut at pleafure, fo that the water may pafs from the lock to each refervoir of the canal, or from each refervoir to the lock, in the following manner: The water which fills the lock, when a boat is to afcend or defcend, inftead of being paffed immediately into the lower part of the canal, is let pafs into thefe cifterns or refervoirs, upon different levels; then, their communications with the lock being fhut, they remain full until another veffel is wanted to pafs; then, again, the cifterns are emptied into the lock, which is thereby nearly filled, fo that only the remainder which is not filled is fupplied from the higher part of the canal. Each of thefe cifterns muft have a furface not lefs than that of the lock, and muft contain half as much water as is meant to be expended for the paffing of each veffel. The ciftern the moft elevated is placed twice its own depth (meafuring by the aperture, or communicating opening of the cifterns) under the level of the water in the higher part of the canal. The fecond ciftern is placed once its own depth under the firft, and fo on are the others, to the loweft; which laft is placed once its own depth above the level of the water in the lower part of the canal. The apertures of the intermediate cifterns, whatever their number may be, muft all be equally divided into different levels; the furface of the water in the one being always on the level of the bottom of the aperture of the ciftern which is immediately above. As an example of the manner and rule for conftructing thefe cifterns, fuppofe that a lock is to be conftructed twelve feet deep, that is, that the veffel may afcend or defcend twelve feet in paffing. Suppofe the lock fixty feet long and fix feet wide, the quantity of water required to fill the lock, and to pafs a boat, is 4320 cubic feet; and fuppofe that, in calculating the quantity of water that can be procured for fupplying the canal, after allowing for wafte, it is found (according to the number of boats that may be expected to pafs) that there will not be above 800 cubic feet for each; then it will be neceffary to fave five-fixths of the whole quantity that in the common cafe would be neceffary: to do which ten cifterns muft be made (the mode of placing which is expreffed in the drawing, fig. 1. Plate VII.), each of which muft be one foot deep, or deeper at pleafure, and each muft have a furface of 360 feet fquare, equal to the furface of the lock. The bottom of the aperture of the loweft ciftern muft be placed one foot above the level of the water in the lower part of the canal, or eleven feet under the level of the high water; the fecond ciftern muft be two feet above the level of the low water; the third three feet, and fo on of the others; the bottom of the tenth, or uppermoft ciftern, being ten feet above the low water, and two feet lower than the high water; and, as each ciftern muft be twelve inches in depth, the furface of the water in the higher ciftern will be one foot under the level of the water in the upper part of the canal. The cifterns being thus conftructed, when the lock is full, and the boat to be let down, the communications between the lock and the cifterns, which until then have all been fhut, are to be opened in the following manner: firft, the communication with the higher ciftern is opened, which, being at bottom two feet under the level of the water in the lock, is filled to the depth of one foot, the water in the lock defcending one foot alfo at the fame time; that communication is then fhut, and the communication between the lock and the fecond ciftern is opened; one foot more of the water then paffes into that ciftern from the lock, and fills it; the opening is then fhut: the fame is done with the third, fourth, fifth, fixth, feventh, eighth, ninth, and tenth, cifterns, one by one, until they are all filled; and, when the tenth, or lowermoft ciftern, is filled, there remains but two feet depth of water in the lock. The communication between the lock and the lower part of the canal is then opened, and the laft two feet depth of water is emptied into the lower part of the canal. By this means, it is evident, that, inftead of twelve feet depth of water being let defcend into the lower part of the canal, there is only two feet depth that defcends, or one-fixth of the whole; therefore, inftead of 4320 cubic feet being ufed, there are only 720 cubic feet ufed: the remainder of the water in the cifterns being ufed as follows. When another boat is to mount, the fluices being then fhut, and the boat in the lock, the tenth or lowermoft ciftern is emptied into the lock, which it fills one foot; the communication being then fhut, the next loweft ciftern, or the ninth, is emptied into the lock, which is thereby filled another foot; and fo, in like manner, all the other cifterns are emptied one after another, until the higher ciftern being emptied, which fills the tenth foot of water in the lock, there remains but two feet of water to fill, which is done from the upper part of the canal, by opening the higher fluice to pafs the boat; by that means, the fame quantity of water defcends from the upper part of the canal into the lock, that in the other cafe defcended from the lock into the lower part of the canal; fo that, in both cafes, the fame quantity of water is faved, that is, five-fixths of what would be neceffary were there no cifterns. Suppofe again that, upon the fame canal, and immediately after the twelve feet lock, it would be advantageous to conftruct one of eighteen feet; then, in order not to ufe any greater quantity of water, it will be neceffary to have fixteen cifterns, upon different levels, communicating with the lock in the fame manner. Should, again, a lock of only fix feet be wanted, after that of eighteen, then it will only be neceffary to have four cifterns on different levels, and fo of any other height of lock. The rule is this: for finding the number and fize of the cifterns, each ciftern being the fame in fuperficies with the lock, its depth muft be fuch as to contain one half the quantity of water meant to be ufed in the paffing of one boat. The depth of the lock, divided by the depth neceffary for fuch a ciftern, will give, in all cafes, the whole number of cifterns, and two more: deduct the number two, therefore, from the number which you find by dividing the depth of the lock by the depth of one ciftern, and you have always the number of cifterns required; which are to be placed upon different levels, according to the rule already given. The above is the principle and manner of ufing the lock, for faving water in canals, and for enabling engineers to conftruct locks of different depths upon the fame canal, without ufing more water for the deep locks than for the fhallow ones. With regard to the manner of difpofing the cifterns, the circumftances of the ground, the declivity, &c. will be the beft guide for the engineer."

But fuppofing a fufficiency of water, or admitting that this method of Mr Playfair's of faving it, where defective, is adequate to his fondeft expectations, ftill, in paffing numerous locks, where the rife is confiderable, the interruption is fo great, that it has often been wifhed that an eligible method of lowering and elevating boats could be devifed, without the affiftance of water-locks. Though this is evidently at firft view practicable, and feveral different modes of doing it have been fuggefted, fome of which have actually been carried into effect, yet all of them have been found to be attended with fuch inconvenience as to render an improvement in this refpect ftill neceffary.

In China, where water-carriage is more generally practiſed than in any kingdom of Europe, boats are raiſed and lowered from one canal into another by ſliding them along an inclined plane: but the contrivances for effecting that purpoſe are ſo awkward, and ſuch a number of hands are required, that it has in general been deemed inexpedient to reſort to that mode of practice in Europe. Several devices that diſcover conſiderable ingenuity, however, have been publiſhed, with a view to facilitate this operation; either by rendering the motion up the inclined plane more equable, or producing a power ſufficient to move theſe great weights. But none of them have yet been ſo ſimple in their conſtruction as could be wiſhed, nor have they afforded ſatisfaction in practice. For the greater part of them, likewiſe, patents have been granted; ſo that whatever be their value, no engineer could avail himſelf of them without previouſly purchaſing a licence from the patentee.

The following contrivance for this purpoſe is the invention of James Anderſon, LL. D. whoſe knowledge of economics is well known, and of whoſe public ſpirit there cannot be a doubt. Inſtead of applying for a patent, to ſecure to himſelf the fruits of his ingenuity, he publiſhed, for the good of his countrymen in general, his device, in the View of the Agriculture of the County of Aberdeen, which he drew up for the conſideration of the board of agriculture. He introduces it to public notice with juſtly obſerving, that it poſſeſſes at leaſt the merit of ſimplicity, in as high a degree, perhaps, as could be wiſhed; and, "in the opinion (ſays he) of very good judges of matters of this ſort, to whom the plan has been ſhewn, it has been deemed fully adequate to the purpoſe of raiſing and lowering boats of a moderate ſize, that is of 20 tons, or downwards; and it is the opinion of moſt men with whom I have converſed, who are beſt acquainted with the inland navigations, that a boat of from 10 to 15 tons is better than thoſe of a larger ſize. When ſeveral are wanted to be ſent at once, they may be affixed to one another, as many as the towing-horſe can conveniently draw. Were boats of this ſize adopted, and were all the boats on one canal to be of the ſame dimenſions, it would prove a great convenience to a country in a ſtate of beginning improvements; becauſe the expence of ſuch a boat would be ſo trifling, that every farmer could have one for himſelf, and might of courſe make uſe of it when he pleaſed, by the aid of his own horſe, without being obliged to have any dependence on the time that might ſuit the convenience of his neighbour; and if two or more boats were going from the ſame neighbourhood, one horſe could ſerve the whole.

"You are to ſuppoſe that fig. 2. (Plate VII.) repreſents a bird's eye view of this ſimple apparatus, as ſeen from above. A is ſuppoſed to be the upper reach of the canal, and B the lower reach, with the apparatus between the two. This conſiſts of three diviſions; the middle one, extending from C to D, is a ſolid piece of maſonry, raiſed from a firm foundation below the level of the bottom of the ſecond reach; this is again divided into five parts, viz. *d d d*, where the wall riſes only to the height of the water in the upper reach, and *e e*, two pillars, raiſed high enough to ſupport the pivots of a wheel or pulley *g*, placed in the poſition there marked.

"The ſecond diviſion *h* conſiſts of a wooden coffer, of the ſame depth nearly as the water in the upper reach, and of a ſize exactly fitted to contain one of the boats. This communicates directly with the upper reach, and being upon the ſame plane with it, and ſo connected with it as to be water-tight, it is evident from inſpection, that nothing can be more eaſy than to float a boat into this coffer from the upper reach; the part of the wheel that projects over it being at a ſufficient height above it, ſo as to occaſion no ſort of interruption.

"Third diviſion. At *i* is repreſented another coffer, preciſely of the ſame dimenſions with the firſt. But here two ſluices, which were open in the former, and only repreſented by dotted lines, are ſuppoſed to be ſhut, ſo as to cut off all communication between the water in the canal and that in the coffer. As it was impoſſible to repreſent this part of the apparatus on ſo ſmall a ſcale, for the ſake of illuſtration it is repreſented more at large in fig. 5. where A, as before, repreſents the upper reach of the canal, and *h* one of the coffers. The ſluice *k* goes into two cheeks of wood, joined to the maſonry of the dam of the canal, ſo as to fit perfectly cloſe; and the ſluice *f* fits, equally cloſe, into cheeks made in the ſide of the coffer for that purpoſe; between theſe two ſluices is a ſmall ſpace *o*. The coffer, and this diviſion *o*, are to be ſuppoſed full of water, and it will be eaſy to ſee that theſe ſluices may be let down, or drawn up at pleaſure, with much facility.

"Fig. 6. repreſents a perpendicular ſection of theſe parts in the ſame direction as in fig. 5. and in which the ſame letters repreſent the ſame parts.

"Things being thus arranged, you are to ſuppoſe the coffer *h* to be ſuſpended, by means of a chain paſſed over the pulley, and balanced by a weight that is ſufficient to counterpoiſe it, ſuſpended at the oppoſite end of the chain. Suppoſe, then, that the counterpoiſe be made ſomewhat lighter than the coffer with its contents, and that the line *m n* (fig. 6.) repreſents a diviſion between the ſolid ſides of the dam of ſeparation, which terminates the upper reach, and the wooden coffer, which had been cloſed only by the preſſure of its own weight (being puſhed a very little from A towards B, beyond its preciſe perpendicular ſwing), and that the joining all round is covered with liſts of cloth put upon it for that purpoſe; it is evident that, ſo long as the coffer is ſuſpended to this height, the joining muſt be water-tight; but no ſooner is it lowered down a little than this joining opens, the water in the ſmall diviſion *o* is allowed to run out, and an entire ſeparation is made between the fixed dam and this moveable coffer, which may be lowered down at pleaſure without loſing any part of the water it contained.

"Suppoſe the coffer now perfectly detached, turn to fig. 3. which repreſents a perpendicular ſection of this apparatus, in the direction of the dotted line *p p* (fig. 2.). In fig. 3. *h* repreſents an end view of the coffer, indicated by the ſame letter as in fig. 2. ſuſpended by its chain, and now perfectly detached from all other objects, and balanced by a counterpoiſe *i*, which is another coffer exactly of the ſame ſize, as low down as the level of the lower reach. From inſpection only it is evident, that, in proportion as the one of theſe weights riſes, the other muſt deſcend. For the preſent, then, ſuppoſe that the coffer *h* is by ſome means rendered

Canals.

rendered more weighty than *i*, it is plain it will defcend while the other rifes; and they will thus continue till *h* comes down to the level of the lower reach, and *i* rifes to the level of the higher one.

"Fig. 4. reprefents a fection in the direction A B (fig. 2.), in which the coffer *i* (feen in both fituations) is fuppofed to have been gradually raifed from the level of the lower reach B, to that of the higher A, where it now remains ftationary; while the coffer *h* (which is concealed behind the mafonry) has defcended in the mean time to the level of the lower reach, where it clofes by means of the juncture *r s*, fig. 6. (which juncture is covered with lifts of cloth, as before explained at *m n*, and is of courfe become water-tight,) when, by lifting the fluice *t*, and the correfponding fluice at the end of the canal, a perfect communication by water is eftablifhed between them. If, then, inftead of water only, this coffer had contained a boat, floated into it from the upper reach, and then lowered down, it is very plain, that when thefe fluices were removed, after it had reached the level of the lower reach, that boat might have been floated out of the coffer with as much facility as it was let into it above. Here then we have a boat taken from the higher into the lower canal; and, by reverfing this movement, it is very obvious that it might be, with equal eafe, raifed from the lower into the higher one. It now only remains that I fhould explain by what means the equilibrium between thefe counter-balancing weights can be deftroyed at pleafure, and the motion of courfe produced.

"It is very evident, that if the two correfponding coffers be precifely of the fame dimenfions, their weight will be exactly the fame when they are both filled to the fame depth of water. It is equally plain, that fhould a boat be floated into either or both of them, whatever its dimenfions or weight may be, fo that it can be contained afloat in the coffer, the weight of the coffer and its contents will continue precifely the fame as when it was filled with water only: hence, then, fuppofing one boat is to be lowered, or one to be raifed at a time, or fuppofing one to be raifed and another lowered at the fame time—they remain perfectly in equilibrium in either place, till it is your pleafure to deftroy that equilibrium. Suppofe then, for the prefent, that both coffers are loaded with a boat in each, the double fluices both above and below clofed; and fuppofe alfo that a ftop-cock *u*, in the under edge of the fide of the lower coffer (fig. 4. and 6.), is opened, fome of the water which ferved to float the boat in the coffer will flow out of it, and confequently that coffer will become lighter than the higher one; the upper coffer will of courfe defcend, while the other mounts upwards. When a gentle motion has been thus communicated, it may be prevented from accelerating, merely by turning the ftop cock fo as to prevent the lofs of more water, and thus one coffer will continue to afcend, and the other to defcend, till they have affumed their ftations refpectively; when, in confequence of a ftop below, and another above, they are rendered ftationary at the level of the refpective canals (A).

"Precifely the fame effect will be produced when the coffers are filled entirely with water.

"It is unneceffary to add more to this explanation, except to obferve, that the fpace for the coffer to defcend into muft be deeper than the bottom of the lower canal, in order to allow a free defcent for the coffer to the requifite depth; and of courfe it will be neceffary to have a fmall conduit to allow the water to get out of it. Two or three inches free, below the bottom of the canal, is all that would be neceffary.

"Where the height is inconfiderable, there will be no occafion for providing any counterpoife for the chain, as that will give only a fmall addition to the weight of the undermoft coffer, fo as to make it preponderate, in circumftances where the two coffers would otherwife be in perfect equilibrium: but, where the height is confiderable, there will be a neceffity for providing fuch a counterpoife; as, without it, the chain by becoming more weighty every foot it defcended, would tend to deftroy the equilibrium too much, and accelerate the motion to an inconvenient degree. To guard againft this inconvenience, let a chain of the fame weight, per foot, be appended at the bottom of each coffer, of fuch a length as to reach within a few yards of the ground where the coffer is at its greateft height (fee fig. 3.); it will act with its whole weight upon the higheft coffer while in this pofition; but, as that gradually defcended, the chain would reach the ground, and, being there fupported, its weight would be diminifhed in proportion to its defcent; while the weight of the chain on the oppofite fide would be augmented in the fame proportion, fo as to counterpoife each other exactly, in every fituation, until the uppermoft chain was raifed from the ground. After which it would increafe its weight no more; and, of courfe, would then give the under coffer that preponderance which is neceffary for preferving the machine fteady. The under coffer, when it reached its loweft pofition, would touch the bottom on its edges, which would then fupport it, and keep every thing in the fame pofition, till it was made lighter for the purpofe of afcending.

"What conftitutes one particular excellence of the apparatus here propofed is, that it is not only unlimited as to the extent of the rife or depreffion of which it is fufceptible (for it would not require the expenditure of one drop more water to lower it one hundred feet than one foot); but it would alfo be eafy fo to augment the number of pulleys at any one place as to admit of two, three, four, or any greater number of boats being lowered or elevated at the fame time; fo that let the fucceffion of boats on fuch a canal be nearly as rapid as that of carriages upon a highway, none of them need be delayed one moment to wait an opportunity of paffing; a thing that is totally impracticable where water-locks are employed; for the intercourfe, on every canal conftructed with water-locks, is neceffarily limited to a certain degree, beyond which it is impoffible to force it.

"For example; fuppofe a hundred boats are following each other, in fuch a rapid fucceffion as to be only half

(A) "It does not feem neceffary to adopt any other contrivance than the above for regulating the motions; but if it fhould be found neceffary, it would be eafy to put a ratch-wheel on the fame axle.

half a minute behind each other: By the apparatus here propofed, they would all be elevated precifely as they came; in the other, let it be fuppofed that the lock is fo well conftructed as that it takes no more than five minutes to clofe and open it; that is, ten minutes in the whole to each boat (for the lock, being once filled, muft be again emptied before it can receive another in the fame direction): at this rate, fix boats only could be paffed in an hour, and of courfe it would take fixteen hours and forty minutes to pafs the whole hundred; and as the laft boat would reach the lock in the fpace of fifty minutes after the firft, it would be detained fifteen hours and fifty minutes before its turn would come to be raifed. This is an immenfe detention; but if a fucceffion of boats, at the fame rate, were to follow continually, they never could pafs at all. In fhort, in a canal conftructed with water-locks, not more than fix boats, on an average, can be paffed in an hour, fo that beyond that extent all commerce muft be ftopped; but, of the plan here propofed, fixty, or fix hundred, might be paffed in an hour if neceffary, fo as to occafion no fort of interruption whatever. Thefe are advantages of a very important nature, and ought not to be overlooked in a commercial country.

"This apparatus might be employed for innumerable other ufes as a moving power, which it would be foreign to our prefent purpofe here to fpecify. Nor does its power admit of any limitation, but that of the ftrength of the chain, and of the coffers which are to fupport the weights. All the other parts admit of being made fo immoveably firm as to be capable of fupporting almoft any affignable weight.

"I will not enlarge on the benefits that may be derived from this very fimple apparatus: its cheapnefs, when compared with any other mode of raifing and lowering veffels that has ever yet been practifed, is very obvious; the wafte of water it would occafion is next to nothing; and when it is confidered that a boat might be raifed or lowered fifty feet nearly with the fame eafe as five, it is evident that the interruptions which arife from frequent locks would be avoided, and an immenfe faving be made in the original expence of the canal, and in the annual repairs.

"It is alfo evident, that an apparatus, on the fame principle might be eafily applied for raifing coals or metals from a great depth in mines, wherever a very fmall ftream of water could be commanded, and where the mine was level-free."

CANANDAQUA, a poft town, lake, and creek, in Ontario co. New-York. It is the fhire town of the co. fituated on the N. end of the lake of the fame name, at its outlet into Canandaqua creek. The lake is about 20 miles long and 3 broad, and fends its waters in a N. eaftward and eaftward courfe 35 miles to Seneca River. This is the fcite of an ancient Indian town of the fame name, and ftands on the road from Albany to Niagara, 22 miles E. from Hartford in Geneffee River; 16 miles W. of Geneva, and 235 miles N. W. from New-York city, meafuring in a ftraight line, and 340 by Albany road. This fettlement was begun by Meffrs. Gorham and Phelps, and is now in a flourifhing ftate. There are about 30 or 40 houfes, fituated on a pleafant flope from the lake; and the adjoining farms are under good cultivation. By the ftate cenfus of 1796, it appears there are 291 electors in this townfhip.—*Morse.*

CANARY-BIRD, of which a defcription is given in the Encyclopædia, was not known in Europe till towards the end of the 15th century. Even in 1555, Bellon, who about that time defcribed all the birds then known, does not fo much as mention it. When it was firft brought from the Canary Iflands, it was fo dear that it could be purchafed only by people of fortune, who were often impofed upon. It was called the *fugar-bird*, becaufe it was faid to be fond of the fugar-cane, and could eat fugar in great abundance. This is rather a fingular circumftance, fugar being to many fowls a poifon. Experiments have fhewn, that a pigeon, to which four drams of fugar was given, died in four hours; and that a duck, which had fwallowed five drams, did not live feven hours.

In the middle of the laft century canary-birds began to be bred in Europe; and to this the following circumftance, related by Olina, feems to have given occafion: "A veffel which, among other commodities, was carrying a number of canary birds to Leghorn, was wrecked on the coaft of Italy; and thefe birds being thus fet at liberty, flew to the neareft land, which was the ifland of Elba, where they found the climate fo favourable, that they multiplied, and perhaps would have become domefticated, had they not been caught in fnares; for it appears that the breed of them there has been long deftroyed. Olina fays, that the breed foon degenerated; but it is probable, that by much the greater part of thefe canary-birds were males, which coupling with birds of the ifland, produced mules, fuch as are defcribed by Gefner and other naturalifts."

"Various treatifes have been publifhed in different languages on the manner of breeding thefe birds, and many people have made it a trade, by which they have acquired confiderable gain. It does no difcredit to the induftry of the Tyrolians, that they have carried it to the greateft extent. At Ymft there is a company, who, after the breeding feafon is over, fend out perfons to different parts of Germany and Switzerland to purchafe birds from thofe who breed them. Each perfon brings with him commonly from three to four hundred, which are afterwards carried for fale, not only through every part of Germany, but alfo to England, Ruffia, and even Conftantinople. About fixteen hundred are brought every year to England; where the dealers in them, notwithftanding the confiderable expence they are at, and after carrying them about on their backs, perhaps a hundred miles, fell them for five fhillings a piece. This trade, hitherto neglected, is now carried on in Schwarzwalde; and at prefent there is a citizen at Gottingen who takes with him every year to England feveral canary-birds and bulfinches *(loxia pyrrhula)*, with the produce of which he purchafes fuch fmall wares as he has occafion for."—*Profeffor Beckmann's Hiftory of Inventions and Difcoveries.*

Canary-Seed. See Phalaris, *Encycl.*—Profeffor Beckmann doubts whether the plant which bears the canary-feed be the *phalaris* of the ancients, becaufe that name feems to have been given by Pliny to more than one fpecies of grafs. He thinks it very probable, however, that the plant which the modern botanifts call *phalaris* was firft brought from the Canary Iflands to Spain, Candle.

Spain, where it began to be cultivated, as well as in the fouth of France, as foon as canary-birds came into general efteem. At prefent it is cultivated in various places, and forms no inconfiderable branch of trade, particularly in the ifland of Sicily, where it is called *Scagliuola* or *Scaghiola*. Were it not that the grains are not eafily freed from the hufks, this plant might be cultivated for the food of man, for its feeds yield a good kind of meal. The phalaris has by feveral writers been confounded with *argol* or the *lichen rocolla* of Linnæus; but they are very different plants. See LICHEN *Rocolla* in this Supplement.

CANDLE, a thing fo univerfally known as to need no particular defcription. Its ufe, however, is fo great, that every information tending to its improvement muft, we fhould think, be acceptable to our readers. Of the common method of making candles, whether of wax or of tallow, a fufficient account has been given in the Encyclopædia; but candles of every kind are far from being yet brought to that degree of perfection of which they feem fufceptible. Thus, for example, the light of a candle, which is fo exceedingly brilliant when firft fnuffed, is very fpeedily diminifhed to one-half, and is ufually not more than one-fifth or one-fixth, before the uneafinefs of the eye induces us to fnuff it. Hence it follows, that if candles could be made fo as not to require fnuffing, the average quantity of light afforded by the fame quantity of combuftible matter would be more than doubled. It may likewife be worthy of inquiry, fince the coft and duration of candles are eafily afcertainable, whether more or lefs light is obtained at the fame expence during a given time, by burning a number of fmall candles inftead of one of greater thicknefs.

To determine this laft point, a method muft be found of meafuring the comparative intenfities of light, for which fee PHOTOMETER in this Supplement. With refpect to the defideratum firft mentioned, we have fome very ingenious obfervations and well-contrived experiments by Mr Nicholfon, in the fecond number of his valuable Journal, which we fhall here infert nearly in the words of their author.

In every procefs of combuftion the free accefs of air is of the utmoft confequence. When a candle has a very flender wick, the flame is fmall and of a brilliant white colour; if the wick be large, the combuftion is lefs perfect, and the flame brown; and a wick ftill larger, not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatilized matter, which does not become ignited till it has afcended towards the point. When the wick is either very large or very long, part of this matter efcapes combuftion, and fhews itfelf in the form of coal or fmoke. The fame things take place in the burning of a lamp; but when the wick of a lamp is once adjufted as to its length, the flame continues nearly in the fame ftate for a much longer time than the flame of a candle.

"Upon comparing a candle with a lamp (fays Mr Nicholfon), two very remarkable particulars are immediately feen. In the firft place, the tallow itfelf, which remains in the unfufed ftate, affords a cup or cavity to hold that portion of melted tallow which is ready to flow into the lighted part of the wick. In the fecond place, the combuftion, inftead of being confined, as in the lamp, to a certain determinate portion of the fibrous matter, is carried, by a flow fucceffion, through the whole length. Hence arifes the greater neceffity for frequent fnuffing the candle; and hence alfo the ftation of the freezing point of the fat oil becomes of great confequence. For it has been fhewn, that the brilliancy of the flame depends very much on the diameter of the wick being as fmall as poffible; and this requifite will be moft attainable in candles formed of a material that requires a higher degree of heat to fufe it. The wick of a tallow candle muft be made thicker in proportion to the greater fufibility of the material, which would otherwife melt the fides of the cup, and run over in ftreams. The flame will therefore be yellow, fmoky, and obfcure, excepting for a fhort time immediately after fnuffing. Tallow melts at the 92d degree of Fahrenheit's thermometer; fpermaceti at the 133d degree; the fatty matter formed of flefh, after long immerfion in water, melts at 127 degrees; the *pela* of the Chinefe at 145 degrees; bees-wax at 142 degrees; and bleached wax at 155 degrees. Two of thefe materials are well known in the fabrication of candles. Wax in particular does not afford fo brilliant a flame as tallow; but, on account of its lefs fufibility, the wick can be made fmaller, which not only affords the advantage of a clear perfect flame, but from its flexibility it is difpofed to turn on one fide, and come in contact with the external air, which completely burns the extremity of the wick to white afhes, and thus performs the office of fnuffing. We fee therefore that the important object to fociety of rendering tallow candles equal to thofe of wax, does not at all depend on the combuftibility of the refpective materials, but upon a mechanical advantage in the cup, which is afforded by the inferior degree of fufibility in the wax; and that, to obtain this valuable object, one of the following effects muft be produced: Either the tallow muft be burned in a lamp, to avoid the gradual progreffion of the flame along the wick; or fome means muft be devifed to enable the candle to fnuff itfelf, as the wax candle does; or, laftly, the tallow itfelf muft be rendered lefs fufible by fome chemical procefs. I have no great reafon to boaft of fuccefs in the endeavour to effect thefe; but my hope is, that the facts and obfervations here reprefented may confiderably abridge the labour of others in the fame purfuit.

"The makers of thermometers and other fmall articles with the blow-pipe and lamp, give the preference to tallow inftead of oil, becaufe its combuftion is more complete, and does not blacken the glafs. In this operation the heat of the lamp melts the tallow which is occafionally brought into its vicinity by the workman. But for the ufual purpofes of illumination, it cannot be fuppofed that a perfon can attend to fupply the combuftible matter. Confiderable difficulties arife in the project for affording this gradual fupply as it may be wanted. A cylindrical piece of tallow was inferted into a metallic tube, the upper aperture of which was partly clofed by a ring, and the central part occupied by a metallic piece nearly refembling that part of the common lamp which carries the wick. In this apparatus the piece laft defcribed was intended to anfwer the fame purpofe, and was provided with a fhort wick. The cylinder of tallow was fupported beneath in fuch a manner that the metallic tube and other part of this lamp

Candle. lamp were left to reſt with their whole weight upon the tallow at the ring or contraction of the upper aperture. In this ſituation the lamp was lighted. It burned for ſome time with a very bright clear flame, which, when compared with that of a candle, poſſeſſed the advantage of uniform intenſity, and was much ſuperior to the ordinary flame of a lamp in its colour, and the perfect abſence of ſmell. After ſome minutes it began to decay, and very ſoon afterwards went out. Upon examination, it was found that the metallic piece which carried the wick had fuſed a ſufficient quantity of tallow for the ſupply during the combuſtion; that part of this tallow had flowed beneath the ring, and to other remote parts of the apparatus, beyond the influence of the flame; in conſequence of which, the tube and the cylinder of tallow were faſtened together, and the expected progreſſion of ſupply prevented. It ſeems probable, that in every lamp for burning conſiſtent oils, the material ought to be ſo diſpoſed that it may deſcend to the flame upon the principle of the fountain reſervoir. I ſhall not here ſtate the obſtacles which preſent themſelves in the proſpect of this conſtruction, but ſhall diſmiſs the ſubject by remarking, that a contrivance of this nature would be of the greateſt public utility.

"The wick of a candle being ſurrounded by the flame, is nearly in the ſituation of a body expoſed to deſtructive diſtillation in a cloſe veſſel. After loſing its volatile products, the carbonaceous reſidue retains its figure, until, by the deſcent of the flame, the external air can have acceſs to its upper extremity. But, in this caſe, the requiſite combuſtion, which might ſnuff it, is not effected: for the portion of oil emitted by the long wick is not only too large to be perfectly burned, but alſo carries off much of the heat of the flame while it aſſumes the elaſtic ſtate. By this diminiſhed combuſtion and increaſed efflux of half-decompoſed oil, a portion of coal or ſoot is depoſited on the upper part of the wick, which gradually accumulates, and at length aſſumes the appearance of a fungus. The candle does not then give more than one-tenth of the light emitted in its beſt ſtate. Hence it is that a candle of tallow cannot ſpontaneouſly ſnuff itſelf. It was not probable that the addition of a ſubſtance containing vital air or oxygene would ſupply that principle at the preciſe period of time required; but as experiment is the teſt of every probability of this nature, I ſoaked a wick of cotton in a ſolution of nitre, then dried it, and made a candle. When this came to be lighted, nothing remarkable happened for a ſhort time; at the expiration of which a decrepitation followed at the lower extremity of the flame, which completely divided the wick where the blackened part commences. The whole of the matter in combuſtion therefore fell off, and the candle was of courſe inſtantly extinguiſhed. Whether this would have happened in all proportions of the ſalt or conſtructions of the candle I did not try, becauſe the ſmell of azote was ſufficiently ſtrong and unpleaſant to forbid the uſe of nitre in the purſuit. From various conſiderations I am diſpoſed to think that the ſpontaneous ſnuffing of candles made of tallow, or other fuſible materials, will ſcarcely be effected but by the diſcovery of ſome material for the wick which ſhall be voluminous enough to abſorb the tallow, and at the ſame time ſufficiently flexible to bend on one ſide.

"The moſt promiſing ſpeculation reſpecting this moſt uſeful article, ſeems to direct itſelf to the cup which Candle. contains the melted tallow. The imperfection of this part has already been noticed, namely, that it breaks down by fuſion, and ſuffers its fluid contents to eſcape. The Chineſe have a kind of candle about half an inch in diameter, which, in the harbour of Canton, is called a *lobchock*; but whether the name be Chineſe, or the corruption of ſome European word, I am ignorant. The wick is of cotton, wrapped round a ſmall ſtick or match of the bamboo cane. The body of the candle is white tallow; but the external part, to the thickneſs of perhaps one-thirtieth of an inch, conſiſts of a waxy matter coloured red. This covering gives a conſiderable degree of ſolidity to the candle, and prevents its guttering, becauſe leſs fuſible than the tallow itſelf. I did not obſerve that the ſtick in the middle was either advantageous or the contrary; and as I now write from the recollection of this object at ſo remote a period as 25 years ago, I can only conjecture that it might be of advantage in throwing up a leſs quantity of oil into the flame than would have been conveyed by a wick of cotton ſufficiently ſtout to have occupied its place unſupported in the axis of the candle.

"Many years ago I made a candle in imitation of the lobchock. The expedient to which I had recourſe conſiſted in adapting the wick in the uſual pewter mould: wax was then poured in, and immediately afterwards poured out: the film of wax which adhered to the inner ſurface of the mould ſoon became cool, and the candle was completed by filling the mould with tallow. When it was drawn out it was found to be cracked longitudinally on its ſurface, which I attributed to the contraction of the wax, by cooling, being greater than that of the tallow. At preſent I think it equally probable that the cracking might have been occaſioned by too ſudden cooling of the wax before the tallow was poured in; but other avocations prevented the experiments from being varied and repeated. It is probable that the Chineſe external coating may not be formed of pure hard bleached wax.

"But the moſt deciſive remedy for the imperfection of this cheapeſt, and in other reſpects beſt material, for candles, would undoubtedly be to diminiſh its fuſibility. Various ſubſtances may be combined with tallow, either in the direct or indirect method. In the latter way, by the decompoſition of ſoap, a number of experiments were made by Berthollet, of which an account is inſerted in the Memoirs of the Academy at Paris for the year 1780, and copied into the 26th volume of the *Journal de Phyſique.* None of theſe point directly to the preſent object; beſides which, it is probable that the ſoap made uſe of by that eminent chemiſt was formed not of tallow, but oil. I am not aware of any regular ſeries of experiments concerning the mutual action of fat oils and other chemical agents, more eſpecially ſuch as may be directed to this important object of diminiſhing its ſolubility; for which reaſon I ſhall mention a few experiments made with this view.

1. Tallow was melted in a ſmall ſilver veſſel. Solid tallow ſinks in the fluid, and diſſolves without any remarkable appearance. 2. Gum ſandarach in tears was not diſſolved, but emitted bubbles, ſwelled up, became brown, emitted fumes, and became criſp or friable. No ſolution nor improvement of the tallow. 3. Shell-lac ſwelled up with bubbles, and was more perfectly fuſed than

than the gum fandarach in the former experiment. When the tallow was poured off, it was thought to congeal rather more fpeedily. The lac did not appear to be altered. 4. Benzoin bubbled without much fwelling, was fufed, and emitted fumes of an agreeable fmell, though not refembling the flowers of benzoin. A flight or partial folution feemed to take place. The benzoin was fofter and of a darker colour than before, and the tallow lefs confiftent. 5. Common refin unites very readily with melted tallow, and forms a more fufible compound than the tallow itfelf. 6. Camphor melts eafily in tallow, without altering its appearance. When the tallow is near boiling, camphoric fumes fly off. The compound appeared more fufible than tallow. 7. The acid or flowers of benzoin diffolves in great quantities without any ebullition or commotion. Much fmoke arifes from the compound, which does not fmell like the acid of benzoin. Tallow alone does not fume at a low heat, though it emits a fmell fomething like that of oil olive. When the proportion of the acid was confiderable, fmall needled cryftals appeared as the temperature diminifhed. The appearances of feparation are different according to the quantity of acid. The compound has the hardnefs and confiftence of firm foap, and is partially tranfparent. 8. Vitriolated tartar, nitre, white fugar, cream of tartar, cryftallized borax, and the falt fold in the markets under the name of falt of lemons, but which is fuppofed to be the effential falt of forrel, or vegetable alkali fuperfaturated with acid of fugar, were refpectively tried without any obvious mutual action or change of properties in the tallow. 9. Calcined magnefia rendered tallow opaque and turbid, but did not feem to diffolve. Its effect refembled that of lime.

" It is propofed to try the oxygenated acetous acid, or radical vinegar; the acid of ants, of fugar, of borax, of galls, the tanning principle, the ferous and gelatinous animal matter, the fecula of vegetables, vegetable gluten, bird-lime, and other principles, either by direct or indirect application. The object, in a commercial point of view, is entitled to an extenfive and affiduous inveftigation. Chemifts in general fuppofe the hardnefs or lefs fufibility of wax to arife from oxygen; and to this object it may perhaps be advantageous to direct a certain portion of the inquiry. The metallic falts and calces are the combinations from which this principle is moft commonly obtained; but the combinations of thefe with fat oils have hitherto afforded little promife of the improvement here fought. The fubject is, however, fo little known, that experiments of the loofeft and moft conjectural kind are by no means to be defpifed."

Thus far Mr Nicholfon: but it is probable that many of the advantages which he propofes by thefe mixtures might be obtained merely by purifying the tallow, and keeping it in that ftate for a long time expofed to the air before it be formed into candles. It is certain that tallow is rendered more difficult of fufion by age; and this is the fole reafon that old candles are lefs apt to run, and therefore more valuable than fuch as have been lately made.

CANIADERAGO, a lake in Otfego co. New-York, nearly as large as Otfego lake, and 6 miles W. of it. A ftream called Oaks Creek iffues from it, and falls into Sufquehanna River about 5 miles below Otfego. The beft cheefe in the ftate is faid to be made on this creek.—*Morse.*

CANNARES, Indians of the province of Quito, in Peru. They are very well made, and very active; they wear their hair long, which they weave and bind about their heads, in form of a crown. Their clothes are made of wool or cotton, and they wear fine fafhioned boots. Their women are handfome, and fond of the Spaniards; they generally till and manure the ground, whilft their hufbands at home, card, fpin, and weave wool and cotton. Their country had many rich gold mines, now drained by the Spaniards. The land bears good wheat and barley, and has fine vineyards. The magnificent palace of *Theomabamba* was in the country of the Cannares.—*ib.*

CANNAVERAL, CAPE, the extreme point of rocks on the E. fide of the peninfula of E. Florida. It has Mofquitos Inlet N. by W. and a large fhoal S. by E. This was the bounds of Carolina by charter from Charles II. N. lat. 28. 35. W. long. 81. 9.—*ib.*

CANONGOES, in Bengal, are the regifters of land and hereditary expounders of the ufages of the country. They have their officers and deputies everywhere; they are not liable to removal; and all papers attefted by them are received as authentic and decifive, in all difputes relative to lands and their boundaries. See *Sir Charles Roufe Boughton's Differtation on the Landed Property of Bengal.*

CANONNICUT *Ifland*, in Newport co. Rhode-Ifland, lies about 3 miles W. of Newport, the S. end of which, (called Beaver Tail, on which ftands the light-houfe) extends about as far S. as the S. end of Rhode Ifland. It extends N. about 7 miles, its average breadth being about one mile; the E. fhore forming the W. part of Newport-harbor, and the W. fhore being about 3 miles from the Narraganfet fhore. On this point is Jameftown. It was purchafed of the Indians in 1657, and in 1678, was incorporated by the name of Jameftown. The foil is luxuriant, producing grain and grafs in abundance.—Jameftown contains 507 inhabitants, including 16 flaves.—*Morse.*

CANONSBURG, a town in Wafhington co. Pennfylvania, on the N. fide of the W. branch of Chartiers Creek, which runs N. by E. into Ohio River about 5 miles below Pittfburg. In its environs are feveral valuable mills. Here are about 50 houfes and an academy; 7 miles N. E. by E. of Wafhington, and 15 S. W. of Pittfburg.—*ib.*

CANTERBURY, a townfhip in Rockingham co. New-Hampfhire, fituated on the eaftern bank of Merrimack River; 14 miles N. by W. of Concord, 45 N. W. of Exeter, and 48 from Portfmouth. It contains 1038 inhabitants.—*ib.*

Canterbury, a townfhip in Windham co. Connecticut, on the W. fide of Quinnabaug River which feparates it from Plainfield. It is 7 miles E. by S. of Windham, and about 10 or 12 N. of Norwich.—*ib.*

CANTON, a new townfhip in Norfolk co. Maffachufetts, incorporated in 1797, it being formerly the northerly part of Stoughton.—*ib.*

CAOUTCHOUC, Elastic Gum, or *Indian Rubber*, is a fubftance of which a pretty full account has been given in the Encyclopædia. It has there been likewife obferved how ufeful it might be, if we could form

Caoutchouc.

form it into catheters and other flexible instruments, by dissolving it in a menstruum less expensive, or at least more easily attained, than ether. Since that article was published, we have seen an account of such a menstruum in the *Annales de Chimie*, by M. Grossart (Chirly); and of the expence of that menstruum, or the difficulty of procuring it, no complaint will be made, when it is known to be nothing more than very hot water.

The author was led to this discovery by some experiments made with ether on caoutchouc; of which he gives the following account:

"It appeared, even in my first experiments, that I was attempting too much, and giving myself useless trouble, in searching for a manner of completely dissolving the elastic gum, so that it might be again made up in new forms. I then thought that it would be easier to find out a method, as it were, of soldering it, and of not acting upon it more than might be necessary to cause its softened parts to reunite. Experience has shewn me, that a strong pressure made upon two pieces of caoutchouc (when brought to that state of softness,) and continued until they are entirely dry, caused them to contract so strong an adhesion, that the piece, being pulled out till it broke, often broke, not at the united part, but by the side of it.

"By means of ether I immediately succeeded in making these tubes. The method which appears to me to succeed the best is, to cut a bottle circularly in a spiral slip of a few lines in breadth. It is very easy to cut a bottle in such a manner as to form a single long slip, and thus unnecessary joinings are avoided.

"The whole slip is to be plunged into ether, until it is sufficiently softened, which comes to pass sooner or later according to the quality of the vitriolic ether that is employed. Half an hour frequently suffices; but I have already observed, that there is a great diversity in the manner in which different sorts of vitriolic ether act, and of which the cause is not yet, so far as I know, determined.

"The slip being taken out, one of the extremities is to be taken hold of and rolled, first upon itself at the bottom of the tube, pressing it; then the rolling is to be continued, mounting spirally along the mould, and taking care to lay over and compress with the hand every edge, one against the other, so that there may not be any vacant space, and that all the edges may join exactly. The whole then is to be bound hard with a tape of an inch in width, taking care to turn it the same way with the slip of elastic gum. The tape is to be tied up with packthread, so that, by every turn of the packthread joining another, an equal pressure is given to every part: it is then left to dry, and the tube is made.

"The bandage is to be taken off with great care, that none of the outward surfaces, which may have been lodged within the hollows of the tape (of which the caoutchouc takes the exact impression), may be pulled away. I advise the application of a tape before packthread, because, especially in the thinner tubes, we should run the risk of cutting the caoutchouc, if the packthread were applied immediately upon it.

"It is easy to take off the tube of elastic gum which has been formed upon a solid mould of one piece; if the mould be made rather conic, it may be made to slide off by the smaller end; at the worst, it is easily accomplished by plunging it into hot water; for it is softened by the heat, and is distended; without this precaution it would be sometimes difficult to draw it off when dry, because, having been applied upon the mould whilst it had its volume augmented by the interposition of the ether, the parts of the caoutchouc are drawn nearer each other, by the evaporation of the interposed bodies.

"The great affinity between these two bodies is seen by the length of time that the odour of the ether remains, notwithstanding the great volatility of the latter, and that the apparent dryness of the tube seems to shew that there is none remaining; nevertheless, after a certain time, the odour disappears entirely. One of those tubes, which was made with ether after the method here described, does not retain the least trace of the solvent. It is needless to say, that it is easy to make tubes as thin or as thick as may be judged proper.

"Although the process that I am now describing is but very little expensive, yet I have tried to employ other solvents in lieu of ether, because it is not to be had in every place, and requires particular care in its preservation. I have employed, with some success, the essential oils of lavender and of turpentine: both of them speedily dilate the caoutchouc, and are of no great price. The disagreeable smell of the oil of turpentine becomes, perhaps, in process of time, less disagreeable than that of lavender. This last is dearer; but the difference is not so great as it appears at first: for we may make some advantage of the oil of lavender that is employed by the following operation: Upon plunging into alcohol the elastic tube prepared with the oil of lavender, the alcohol charges itself with the oil, and forms a very good lavender-water; the same as would be made by an immediate mixture of oil of lavender with spirit of wine. Immersion in this liquor also serves to hasten the drying of the caoutchouc instruments thus made by means of essential oils. I have made tubes with the oils of turpentine and of lavender; both are much slower in evaporating than ether. The oil of turpentine particularly appeared to me always to have a kind of stickiness, and I know not as yet that we have any means whereby to get speedily rid of its smell.

"Nevertheless there is a solvent which has not that inconvenience; it is cheaper, and may easily be procured by every one: this solvent is *water*. I conceive it will appear strange to mention water as a solvent of elastic gum, that liquid having been always supposed to have no action upon it. I myself resisted the idea; but reflecting that ether, by being saturated with water, is the better enabled to act on caoutchouc, and that this gum when plunged into boiling water becomes more transparent at the edges, I presumed that this effect was not due simply to the dilation of its volume by the heat. I thought that, at that temperature, some action might take place, and that a long-continued ebullition might produce more sensible effects. I was not disappointed in my expectations, and one of those tubes was prepared without any other solvent than water and heat. I proceeded in the same manner as with ether: the elastic gum dilates but very little in boiling water; it becomes whitish, but recovers its colour again by drying it in the air and light. It is sufficiently prepared for use when it has been a quarter of an hour in boiling water:

water: by this time its edges are sometimes transparent. It is to be turned spirally round the mould, in the manner we described before, and replunged frequently into the boiling water, during the time that is employed in forming the tube, to the end that the edges may be disposed to unite together. When the whole is bound with packthread, it is to be kept some hours in boiling water; after which it is to be dried, still keeping on the binding.

"If we wish to be more certain that the connection is perfect, the spiral may be doubled; but we must always avoid placing the exterior surfaces of the slips one upon the other, as these surfaces are the parts which most resist the action of solvents. This precaution is less necessary when ether is employed, on account of its great action upon the caoutchouc.

"It might be feared that the action of water upon caoutchouc would deprive us of the advantages which might otherwise be expected; but these fears will be removed, if we consider that the affinities differ according to the temperatures; that it is only at a very high temperature that water exercises any sensible action upon caoutchouc. I can affirm, that at 120° of Reaumur's thermometer (302° of Fahrenheit) this affinity is not such as that the water can give a liquid form to caoutchouc; and it does not appear that we have any thing to fear in practice from a combination between these two bodies, which, though it really is a true solution, does not take place in any sensible degree but at a high temperature. It is therefore at present easy to make of caoutchouc whatever instruments it may be advantageous to have of a flexible, supple, and elastic substance, which is impermeable to water at the temperature of our atmosphere, and resists the action of acids as well as that of most other solvents. As to the durability of these instruments, few substances promise more than this, because it may be soldered afresh in a damaged part. Any woven substance may be covered with it; it is only required that the substance should be of a nature not to be acted upon during the preparation, either by ether or by boiling water; for these two agents are those which appear to me to merit the preference. Artists will frequently find an advantage in employing ether, as it requires less time; so that a person may make, in a single day, any tube he may have occasion for. The expence of ether is very little, since it is needful only to dispose the caoutchouc to adhere; and being brought into that state, the caoutchouc may be kept in a vessel perfectly well closed. It would also diminish the expence of the ether if, instead of washing it with a large quantity of water, there should be added to it only as much water as it can take up."

CAP and BUTTON, are two small islands, or rather rocks, lying in longitude 105° 48′ 30″ east; and in latitude, the former 5° 58′ 30″: the latter 5° 49′ south. They were visited by some of the persons attending Lord Macartney on his embassy to China; and are thus described by Sir George Staunton.

"At a little distance they might be mistaken for the remains of old castles, mouldering into heaps of ruins, with tall trees already growing upon the tops; but at a nearer view, they betrayed evident marks of a volcanic origin. Explosions from subterraneous fires, produce, for the most part, hills of a regular shape, and terminating in truncated cones; but when from a subaqueous volcano eruptions are thrown up above the surface of the sea, the materials, falling back into the water, are more irregularly dispersed, and generally leave the sides of the new creation naked and misshapen, as in the instance of AMSTERDAM, and of those smaller spots called, from some resemblance in shape, the Cap and Button.

"In the Cap were found two caverns, running horizontally into the side of the rock; and in these were a number of those birds nests so much prized by the Chinese epicures. They seemed to be composed of fine filaments cemented together by a transparent viscous matter, not unlike what is left by the foam of the sea upon stones alternately covered by the tide, or those gelatinous animal substances found floating on every coast. The nests adhere to each other, and to the sides of the cavern, mostly in rows, without any break or interruption. The birds that build these nests are small grey swallows, with bellies of a dirty white. They were flying about in considerable numbers: but they were so small, and their flight so quick, that they escaped the shot fired at them. The same nests are said also to be found in deep caverns, at the foot of the highest mountains in the middle of Java, and at a distance from the sea, from which the birds, it is thought, derive no materials, either for their food or the construction of their nests; as it does not appear probable they should fly, in search of either, over the intermediate mountains, which are very high, or against the boisterous winds prevailing thereabouts. They feed on insects, which they find hovering over stagnated pools between the mountains, and for catching which their wide opening beaks are particularly adapted. They prepare their nests from the best remnants of their food. Their greatest enemy is the kite, who often intercepts them in their passage to and from the caverns, which are generally surrounded with rocks of grey limestone or white marble. The nests are placed in horizontal rows at different depths, from 50 to 500 feet. The colour and value of the nests depend on the quantity and quality of the insects caught, and perhaps also on the situation where they are built. Their value is chiefly determined by the uniform fineness and delicacy of their texture; those that are white and transparent being most esteemed, and fetching often in China their weight in silver. These nests are a considerable object of traffic among the Javanese, and many are employed in it from their infancy. The birds having spent near two months in preparing their nests, lay each two eggs, which are hatched in about fifteen days. When the young birds become fledged, it is thought time to seize upon their nests, which is done regularly thrice a year, and is effected by means of ladders of bamboo and reeds, by which the people descend into the cavern; but when it is very deep, rope ladders are preferred. This operation is attended with much danger; and several break their necks in the attempt. The inhabitants of the mountains generally employed in it begin always by sacrificing a buffalo; which custom is constantly observed by the Javanese on the eve of every extraordinary enterprise. They also pronounce some prayers, anoint themselves with sweet-scented oil, and smoke the entrance of the cavern with gum-benjamin. Near some of those caverns a tutelar goddess is worshipped, whose priest burns incense, and lays his protecting hands on every person preparing to descend into the cavern. A flambeau is carefully prepared at the same time, with a gum which exudes from a tree growing in the vicinity, and is not easily extinguished by fixed air or subterraneous vapours. The swallow, which builds those nests, is described as not having its tail feathers marked with white spots, which is a character attributed to it by Linnæus; and it is possible that there are two species or varieties of the swallow, whose nests are alike valuable." See *Birds-Nests*, Encycl.

CAPE of Good Hope. See *Good Hope*, both in *Encycl.* and this *Supplement*.

CAPE ST. ANDREWS, on the coast of Paraguay, or La Plata, S. America. S. lat. 38. 50. W. long. 59. 46.—*Morse.*

Cape St. Antonio, or *Anthonio*, is the point of land on the southern side of La Plata River in S. America, which, with Cape St Mary on the northward, forms the mouth of that river. S. lat. 36. 32. W. long. 56. 34.—*ib.*

Cape St. Augustine, on the coast of Brazil, S. America, lies southward of Pernambuco. S. lat. 10. 15. W. long. 35. 13.—*ib.*

Cape Blow-me-down, which is the southern side of the entrance from the bay of Fundy into the Basin of Minas, is the easternmost termination of a range of mountains, extending about 80 or 90 miles to the gut of Annapolis; bounded N. by the shores of the bay of Fundy, and S. by the shores of Annapolis river.—*ib.*

Cape Cod, anciently called *Mallebarre*, by the French, is the S. eastward point of the bay of Massachusetts, opposite Cape Ann. N. lat. 42. 4. W. long. from Greenwich, 70. 14.—*ib.*

Cape Elizabeth, a head-land and township in Cumberland co. district of Maine. The cape lies in N. lat. 43. 33. E. by S. from the centre of the town 9 miles; about 20 S. westerly of Cape Small Point, and 12 N. E. from the mouth of Saco River. The town has Portland on the N. E. and Scarborough S. W. and contains 1355 inhabitants. It was incorporated in 1765, and lies 126 miles N. E. of Boston.—*ib.*

Cape Fear, is the southern point of Smith's Island which forms the mouth of Cape Fear River into two channels, on the coast of N. Carolina; S. W. of Cape Look-Out, and remarkable for a dangerous shoal called the Frying Pan, from its form. Near this cape is Johnson's Fort, in Brunswick co. and district of Wilmington. N. lat. 33. 32. W. long. 78. 25.

Cape Fear *River* more properly Clarendon, affords the best navigation in N. Carolina. It opens to the Atlantic ocean by two channels. The S. western and largest channel between the S. W. end of Smith's Island at Bald Head, where the light-house stands, and the E. end of Oakes Island, S. W. from Fort Johnston. The new inlet is between the sea-coast and the N. E. end of Smith's Island. It will admit vessels drawing 10 or 11 feet, and is about 3 miles wide at its entrance, having 18 feet water at full tides over the bar. It continues its breadth to the flats, and is navigable for large vessels 21 miles from its mouth, and 14 from Wilmington; to which town vessels drawing 10 or 12 feet can reach without any risk. As you ascend this river you leave Brunswick on the left, and Wilmington on the right. A little above Wilmington, the river divides into N. E. and N. W. branches. The former is broader than the latter, but is neither so deep nor so long. The N. W. branch rises within a few miles of the Virginia line, and is formed by the junction of Haw and Deep rivers. Its general course is S. easterly. Sea vessels can go 25 miles above Wilmington, and large boats 90 miles, to Fayetteville. The N. E. branch joins the N. W. branch a little above Wilmington, and is navigable by sea vessels 20 miles above that town, and by large boats to South Washington, 40 miles further, and by rafts to Sarecto, which is nearly 70 miles. The whole length of Cape Fear river is about 200 miles.—*ib.*

Cape May, is the S. westernmost point of the state of New-Jersey, and of the county to which it gives name. N. lat. 39. W. long. 75. 2. It lies 20 miles N. E. from Cape Henlopen, which forms the S. W. point of the mouth of Delaware bay, as Cape May does the N. E.—*ib.*

Cape May *Co.* spreads northward, around the cape of its name, is a healthy, sandy tract of country, of sufficient fertility to give support to 2571 industrious and peaceable inhabitants. The county is divided into Upper, Middle, and Lower precincts.—*ib.*

CAPITAL of a Bastion, is an imaginary line dividing any work into two equal and similar parts; or a line drawn from the angle of the polygon to the point of the bastion, or from the point of the bastion to the middle of the gorge.

CAPRA, or the She-goat, a name given to the star Capella, on the left shoulder of Auriga, and sometimes to the constellation Capricorn. Some again represent Capra as a constellation in the northern hemisphere, consisting of three stars, comprised between the 45th and 55th degree of latitude.—The poets fable her to be Amalthea's goat, which suckled Jupiter in his infancy.

CAPUT Draconis, or *Dragon's Head*, a name given by some to a fixed star of the first magnitude, in the head of the constellation Draco.

CARACCAS, a province of Terra Firma, S. America, lying on the southern coast of the Caribbean Sea. This coast is bordered in its greatest length by a chain of mountains, running E. and W. and divided into many fruitful vallies, whose direction and opening are towards the N. It has maritime fortified towns, Puerto Cabelo, and La Guayra. The Dutch carry thither to the Spaniards all sorts of European goods, especially linen, making vast returns of silver and cocoa. The cocoa tree grows here in abundance. There are from 500 to 2000 trees in a walk, or plantation. These nuts are passed for money, and are used as such in the bay of Campeachy. N. lat. 10. 12. W. long. 67. 10.—*Morse.*

CARANGAS, a province and jurisdiction under the bishop of Plata, and 70 leagues W. of that city, in Peru, very barren in corn and grain, &c. but abounding in cattle. Here are a great number of silver mines constantly worked, among which that called Tureo, and by the miners Machacado, is very remarkable. The fibres of the silver forming an admirable intermixture with the stone; such mines are generally the richest. There are other masses of silver in this province equally remarkable, being found in the barren sandy desarts, where they find, by digging only, detached

lumps

Carbon ‖ Carlisle.

lumps of silver, unmixed with any ore or stone. These lumps are called *papas*, because taken out of the ground as that root is, and have the appearance of melted silver; which proves that they are thus formed by fusion. Some of these papas have weighed from 50 to 150 marks, being a Paris foot in length.—*ib.*

CARBON. See CHEMISTRY in this *Supplement*, Part I. Chap. II. Sect. iii.

CARLISLE, the chief town of Cumberland co. Pennsylvania, on the post road from Philadelphia to Pittsburgh; is 125 miles W. by N. from the former, and 178 E. from the latter, and 18 S. W. from Harrisburgh. Its situation is pleasant and healthy, on a plain near the southern bank of Conedogwinet creek, a water of the Susquehanna. The town contains about 400 houses, chiefly of stone and brick, and about 1500 inhabitants. The streets intersect each other at right angles, and the public buildings are a college, court-house and gaol, and 4 edifices for public worship. Of these the Presbyterians, Germans, Episcopalians, and Roman Catholics, have each one. Dickinson College, named after the celebrated John Dickinson, Esq. author of several valuable tracts, has a principal, 3 professors, a philosophical apparatus, and a library containing near 3000 volumes. Its revenue arises from £.4000 in funded certificates, and 10,000 acres of land. In 1787 there were 80 students, and its reputation is daily increasing. About 40 years ago this spot was inhabited by Indians, and wild beasts.—*Morse.*

Carlisle ‖ Carp.

CARLISLE, a bay on the W. side of the island of Barbadoes, in the West-Indies, situated between James and Charles Forts, on which stands Bridgetown, the capital of the island, in N. lat. 13. 9. W. long. 60. 3. —*ib.*

CARMEL, a township in Dutchess co. New-York. By the state census of 1796, 237 of its inhabitants were electors.—*ib.*

CAROLINE *Co.* in Virginia, is on the S. side of Rappahannock River, which separates it from King George's co. It is about 40 miles square, and contains 17,489 inhabitants, including 10,292 slaves.—*ib.*

CAROLINE *Co.* on the eastern shore in Maryland, borders on Delaware state to the E. and contains 9506 inhabitants, including 2057 slaves. Its chief town Danton —*ib.*

CARP. See CYPRINUS, both in the *Encycl.* and in this *Supplement.*

CARPENTRY,

1 Definition.

THE art of framing timber for the purposes of architecture, machinery, and, in general, for all considerable structures.

It is not intended in this article to give a full account of carpentry as a *mechanical* art, or to describe the various ways of executing its different works, suited to the variety of materials employed, the processes which must be followed for fashioning and framing them for our purposes, and the tools which must be used, and the manner in which they must be handled: This would be an occupation for volumes; and though of great importance, must be entirely omitted here. Our only aim at present will be to deduce, from the principles and laws of mechanics, and the knowledge which experience and judicious inferences from it have given us concerning the strength of timber, in relation to the strain laid on it, such maxims of construction as will unite economy with strength and efficacy.

This object is to be attained by a knowledge, 1st, of the strength of our materials, and of the absolute strain that is to be laid on them; 2dly, of the modifications of this strain, by the place and direction in which it is exerted, and the changes that can be made by a proper disposition of the parts of our structure; and, 3dly, having disposed every piece in such a manner as to derive the utmost advantage from its relative strength, we must know how to form the joints and other connections in such a manner as to secure the advantages derived from this disposition.

2 An important branch of mechanical science.

This is, evidently, a branch of mechanical science, which makes carpentry a *liberal* art, constitutes part of the learning of the ENGINEER, and distinguishes him from the workman. Its importance in all times and states of civil society is manifest and great. In the present condition of these kingdoms, raised, by the active ingenuity and energy of our countrymen, to a pitch of prosperity and influence unequalled in the history of the world, a condition which consists chiefly in the superiority of our manufactures, attained by prodigious multiplication of engines of every description, and for every species of labour, the SCIENCE (so to term it) of carpentry is of immense consequence. We regret therefore exceedingly, that none of our celebrated artists have done honour to themselves and their country, by digesting into a body of consecutive doctrines the results of their great experience, so as to form a system from which their pupils might derive the first principles of their education. The many volumes called COMPLETE INSTRUCTORS, MANUALS, JEWELS, &c. take a much humbler flight, and content themselves with instructing the mere workman, or sometimes give the master builder a few approved forms of roofs and other framings, with the rules for drawing them on paper; and from thence forming the working draughts which must guide the saw and the chissel of the workman. Hardly any of them offer any thing that can be called a principle, applicable to many particular cases, with the rules for this adaptation. We are indebted for the greatest part of our knowledge of this subject to the labours of literary men, chiefly foreigners, who have published in the memoirs of the learned academies dissertations on different parts of what may be termed the *science of carpentry*. It is singular, that the members of the Royal Society of London, and even of that established and supported by the patriotism of these days for the encouragement of the arts, have contributed so little to the public instruction in this respect. We observe of late some beginnings of this kind, such as the last part of Nicholson's CARPENTERS AND JOINERS ASSISTANT, published by J. Taylor, Holburn, 1797. And it

3 Principally indebted to foreigners for a knowledge of this subject.

it is with pleasure that we can say, that we were told by the editor, that this work was prompted in a great measure by what has been delivered in the *Encyclopædia* in the articles ROOF and *STRENGTH of Materials*. It abounds more in important and new observations than any book of the kind that we are acquainted with. We again call on such as have given a scientific attention to this subject, and pray that they would render a meritorious service to their country by imparting the result of their researches. The very limited nature of this work does not allow us to treat the subject in detail; and we must confine our observations to the fundamental and leading propositions.

4 Theory, founded on what.

The theory (so to term it) of carpentry is founded on two distinct portions of mechanical science, namely, a knowledge of the strains to which framings of timber are exposed, and a knowledge of their *relative* strength.

We shall therefore attempt to bring into one point of view the propositions of mechanical science that are more immediately applicable to the art of carpentry, and are to be found in various articles of our work, particularly ROOF and *STRENGTH of Materials*. From these propositions we hope to deduce such principles as shall enable an attentive reader to comprehend distinctly what is to be aimed at in framing timber, and how to attain this object with certainty: and we shall illustrate and confirm our principles by examples of pieces of carpentry which are acknowledged to be excellent in their kind.

5 Composition and resolution of forces

The most important proposition of general mechanics to the carpenter is that which exhibits the composition and resolution of forces; and we beg our practical readers to endeavour to form very distinct conceptions of it, and to make it very familiar to their mind. When accommodated to their chief purposes, it may be thus expressed:

Plate VIII.

1. If a body, or any part of a body, be at once pressed in the two directions AB, AC (fig. 1.), and if the intensity or force of those pressures be in the proportion of these two lines, the body is affected in the same manner as if it were pressed by a single force acting in the direction AD, which is the diagonal of the parallelogram ABDC formed by the two lines, and whose intensity has the same proportion to the intensity of each of the other two that AD has to AB or AC.

Such of our readers as have *studied* the laws of motion, know that this is fully demonstrated. We refer them to the article MECHANICS, n° 5, &c. where it is treated at some length. Such as wish for a very accurate view of this proposition, will do well to read the demonstration given by D. Bernoulli, in the first volume of the *Comment. Petropol.* and the improvement of this demonstration by D'Alembert in his *Opuscles*, and in the *Comment. Taurinens.* The practitioner in carpentry will get more useful confidence in the doctrine, if he will shut his book, and verify the theoretical demonstrations by actual experiments. They are remarkably easy and convincing. Therefore it is our request that the artist, who is not so habitually acquainted with the subject, do not proceed further till he has made it quite familiar to his thoughts. Nothing is so conducive to this as the actual experiment; and since this only requires the trifling expence of two small pulleys and a few yards of whipcord, we hope that none of our practical readers will omit it: They will thank us for this injunction.

6 Illustrated by experiment.

2. Let the threads A*d*, AF*b*, and AE*c* (fig. 2), have the weights *d*, *b*, and *c*, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus the knot A will be drawn in the directions AB, AC, and AK. If the sum of the weights *b* and *c* be greater than the single weight *d*, the assemblage will of itself settle in a certain determined form; if you pull the knot A out of its place, it will always return to it again, and will rest in no other position. For example, if the three weights are equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle opposite to the thread stretched by five pounds will always be square, &c. When the knot A is thus in equilibrio, we must infer, that the action of the weight *d*, in the direction A*d*, is in direct opposition to the combined action of *b*, in the direction AB, and of *c*, in the direction AC. Therefore, if we produce *d*A to any point D, and take AD to represent the magnitude of the force, or pressure exerted by the weight *d*, the pressures exerted on A by the weights *b* and *c*, in the directions AB, AC, are in fact equivalent to a pressure acting in the direction AD, whose intensity we have represented by AD. If we now measure off by a scale on AF and AE the lines AB and AC, having the same proportions to AD that the weights *b* and *c* have to the weight *d*, and if we draw DB and DC, we shall find DC to be equal and parallel to AB, and DB equal and parallel to AC; so that AD is the diagonal of a parallelogram ABDC. We shall find this always to be the case, whatever are the weights made use of; only we must take care that the weight which we cause to act without the intervention of a pulley be less than the sum of the other two: if any one of the weights exceeds the sum of the other two, it will prevail, and drag them along with it.

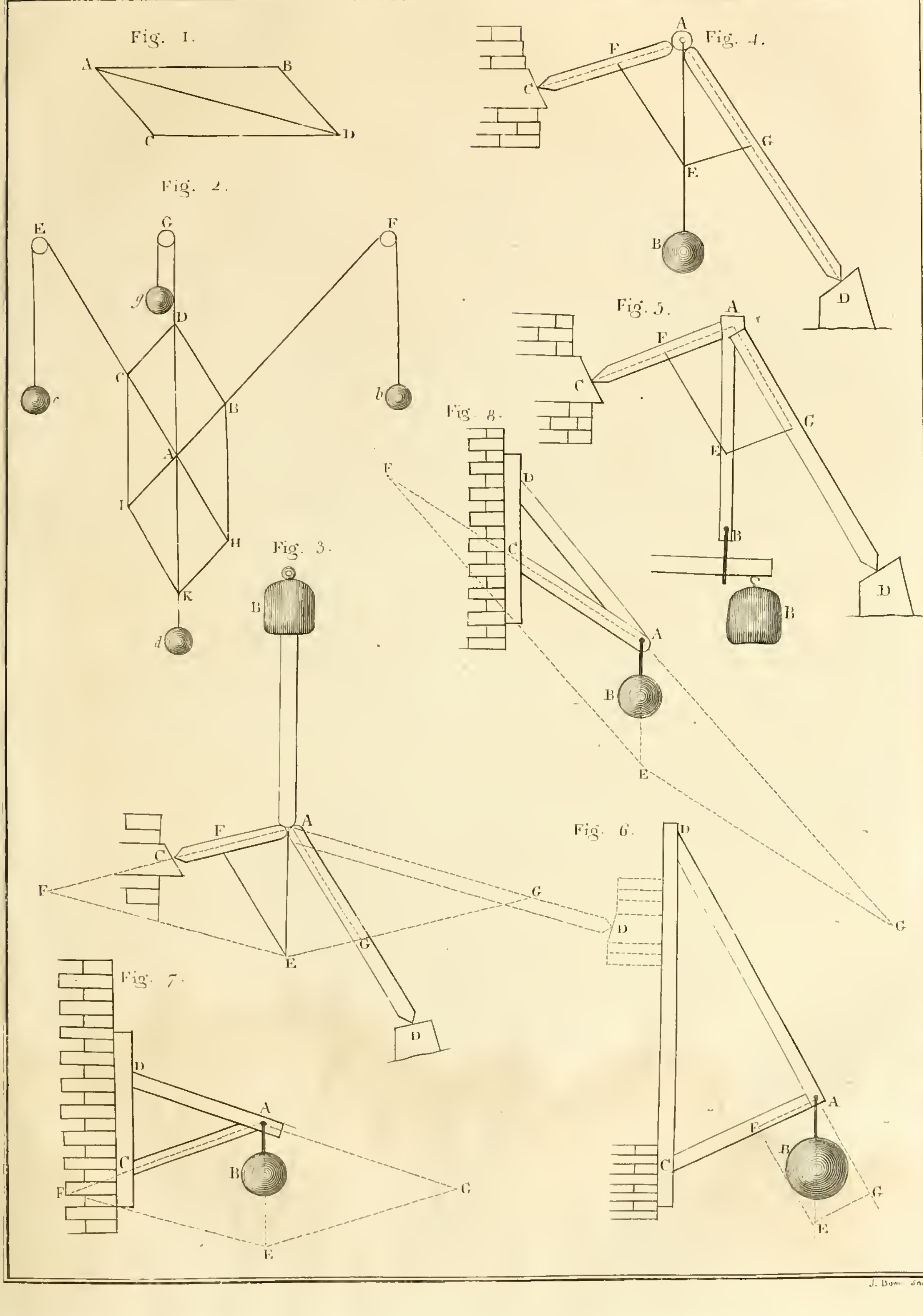
Now since we know that the weight *d* would just balance an equal weight *g* pulling directly upwards by the intervention of the pulley G; and since we see that it just balances the weights *b* and *c* acting in the directions AB, AC, we must infer, that the knot A is affected in the same manner by those two weights, or by the single weight *g*; and therefore, that *two pressures, acting in the directions, and with the intensities,* AB, AC, *are equivalent to a single pressure having the direction and proportion of* AD. In like manner, the pressures AB, AK, are equivalent to AH, which is equal and opposite to AC. Also AK and AC are equivalent to AI, which is equal and opposite to AB.

We shall consider this combination of pressures a little more particularly. 7 Considered more particularly.

Suppose an upright beam BA (fig. 3.) pushed in the direction of its length by a load B, and abutting on the ends of two beams, AC, AD, which are firmly resisted at their extreme points C and D, which rest on two blocks, but are nowise joined to them: these two beams can resist no way but in the directions CA, DA; and therefore the pressures which they sustain from the beam BA are in the directions AC, AD. We wish to know how much each sustains? Produce BA to E, taking AE from a scale of equal parts, to represent the number of tons or pounds by which BA is pressed.

Draw

CARPENTRY PLATE VIII.



Draw EF and EG parallel to AD and AC; then AF, measured on the same scale, will give us the number of pounds by which AC is strained or crushed, and AG will give the strain on AD.

It deserves particular remark here, that the length of AC or AD has no influence on the strain, arising from the thrust of BA, while the directions remain the same. The effects, however, of this strain are modified by the length of the piece on which it is exerted. This strain compresses the beam, and will therefore compress a beam of double length twice as much. This may change the form of the assemblage. If AC, for example, be very much shorter than AD, it will be much less compressed: The line CA will turn about the centre C, while DA will hardly change its position; and the angle CAD will grow more open, the point A sinking down. The artist will find it of great consequence to pay a very minute attention to this circumstance, and to be able to see clearly the change of shape which necessarily results from these mutual strains. He will see in this the cause of failure in many very great works.—By thus changing shape, strains are often produced in places where there were none before, and frequently of the very worst kind, tending to break the beams across.

The dotted lines of this figure shew another position of the beam AD′. This makes a prodigious change, not only in the strain on AD′, but also in that on AC. Both of them are much increased; AG is almost doubled, and AF is four times greater than before. This addition was made to the figure, to shew what enormous strains may be produced by a very moderate force AE, when it is exerted on a very obtuse angle.

The 4th and 5th figures will assist the most uninstructed reader in conceiving how the very same strains AF, AG, are laid on these beams, by a weight simply hanging from a billet resting on A, pressing hard on AD, and also leaning a little on AC; or by an upright piece AE, joggled on the two beams AC, AD, and performing the office of an ordinary king-post. The reader will thus learn to call off his attention from the means by which the strains are produced, and learn to consider them abstractedly, merely as strains, in whatever situation he finds them, and from whatever cause they arise.

We presume that every reader will perceive, that the proportions of these strains will be precisely the same if every thing be inverted, and each beam be drawn or pulled in the opposite direction. In the same way that we have substituted a rope and weight in fig. 4. or a king-post in fig. 5. for the loaded beam BA of fig. 3. we might have substituted the framing of fig. 6. which is a very usual practice. In this framing, the batten DA is stretched by a force AG, and the piece AC is compressed by a force AF. It is evident, that we may employ a rope, or an iron rod hooked on at D, in place of the batten DA, and the strains will be the same as before.

This seemingly simple matter is still full of instruction; and we hope that the well-informed reader will pardon us, though we dwell a little longer on it for the sake of the young artist.

By changing the form of this framing, as in fig. 7. we produce the same strains as in the disposition represented by the dotted lines in fig. 3. The strains on both the battens AD, AC, are now greatly increased.

The same consequences result from an improper change of the position of AC. If it is placed as in fig. 8. the strains on both are vastly increased. In short, the rule is general; that the more open we make the angle against which the push is exerted, the greater are the strains which are brought on the struts or ties which form the sides of the angle.

The reader may not readily conceive the piece AC of fig. 8. as sustaining a compression; for the weight B appears to hang from AC as much as from AD. But his doubts will be removed by considering whether he could employ a rope in place of AC. He cannot: But AD may be exchanged for a rope. AC is therefore a strut, and not a tie.

In fig. 9. AD is again a strut, butting on the block D, and AC is a tie: and the batten AC may be replaced by a rope. While AD is compressed by the force AG, AC is stretched by the force AF.

If we give AC the position represented by the dotted lines, the compression of AD is now AG′, and the force stretching AC′ is now AF′; both much greater than they were before. This disposition is analogous to fig. 8. and to the dotted lines in fig. 3. Nor will the young artist have any doubts of AC′ being on the stretch, if he consider whether AD can be replaced by a rope. It cannot, but AC′ may; and it is therefore not compressed, but stretched.

In fig. 10. all the three pieces, AC, AD, and AB, are ties, on the stretch. This is the complete inversion of fig. 3.; and the dotted position of AC′ induces the same changes in the forces AF′, AG′, as in fig. 3.

Thus have we gone over all the varieties which can happen in the bearings of three pieces on one point. All calculations about the strength of carpentry are reduced to this case: for when more ties or braces meet in a point (a thing that rarely happens), we reduce them to three, by substituting for any two the force which results from their combination, and then combining this with another; and so on.

The young artist must be particularly careful not to mistake the kind of strain that is exerted on any piece of the framing, and suppose a piece to be a brace which is really a tie. It is very easy to avoid all mistakes in this matter by the following rule, which has no exception.

8
Rule for distinguishing the cases of compression and extension.

Take notice of the direction in which the piece acts from which the strain proceeds. Draw a line in that direction *from* the point on which the strain is exerted; and let its length (measured on some scale of equal parts) express the magnitude of this action in pounds, hundreds, or tons. From its *remote* extremity draw lines parallel to the pieces on which the strain is exerted. The line parallel to one piece will necessarily cut the other, or its direction produced: If it cut the piece itself, that piece is compressed by the strain, and it is performing the office of a strut or brace: if it cut its direction produced, the piece is stretched, and it is a tie. In short, the strains on the pieces AC, AD, are to be estimated in the direction of the points F and G *from* the strained point A. Thus, in fig. 3. the upright piece BA, loaded with the weight B, presses the point A in the direction AE: so does the rope AB in the other figures, or the batten AB in fig. 5.

In general, if the straining piece is within the angle formed

formed by the pieces which are ſtrained, the ſtrains which they ſuſtain are of the oppoſite kind to that which it exerts. If it be puſhing, they are drawing; but if it be within the angle formed by their directions produced, the ſtrains which they ſuſtain are of the ſame kind. All the three are either drawing or preſſing. If the ſtraining piece lie within the angle formed by one piece and the produced direction of the other, its own ſtrain, whether compreſſion or extenſion, is of the ſame kind with that of the moſt remote of the other two, and oppoſite to that of the neareſt. Thus, in fig. 9. where AB is drawing, the remote piece AC is alſo drawing, while AD is puſhing or reſiſting compreſſion.

In all that has been ſaid on this ſubject, we have not ſpoken of any joints. In the calculations with which we are occupied at preſent, the reſiſtance of joints has no ſhare; and we muſt not ſuppoſe that they exert any force which tends to prevent the angles from changing. The joints are ſuppoſed perfectly flexible, or to be like compaſs joints; the pin of which only keeps the pieces together when one or more of the pieces draws or pulls. The carpenter muſt always ſuppoſe them all compaſs joints when he calculates the thruſts and draughts of the different pieces of his frames. The ſtrains on joints, and their power to produce or balance them, are of a different kind, and require a very different examination.

9
General expreſſion of the magnitude of the ſtrain.

Seeing that the angles which the pieces make with each other are of ſuch importance to the magnitude and the proportion of the excited ſtrains, it is proper to find out ſome way of readily and compendiouſly conceiving and expreſſing this analogy.

In general, the ſtrain on any piece is proportional to the ſtraining force. This is evident.

Secondly, the ſtrain on any piece AC is proportional to the ſine of the angle which the ſtraining force makes with the other piece directly, and to the ſine of the angle which the pieces make with each other inverſely.

For it is plain, that the three preſſures AE, AF, and AG, which are exerted at the point A, are in the proportion of the lines AE, AF, and FE (becauſe FE is equal to AG). But becauſe the ſides of a triangle are proportional to the ſines of the oppoſite angles, the ſtrains are proportional to the ſines of the angles AFE, AEF, and FAE. But the ſine of AFE is the ſame with the ſine of the angle CAD, which the two pieces AC and AD make with each other; and the ſine of AFE is the ſame with the ſine of EAD, which the ſtraining piece BA makes with the piece AC. Therefore we have this analogy, Sin. CAD : Sin. EAD = AE : AF, and $AF = AE \times \frac{\text{Sin. EAD}}{\text{Sin. CAD}}$.—Now the ſine of angles are moſt conveniently conceived as decimal fractions of the radius, which is conſidered as unity. Thus, *Sin.* 30° is the ſame thing with 0,5, or $\frac{1}{2}$; and ſo of others. Therefore, to have the ſtrain on AC, ariſing from any load AE acting in the direction AE, multiply AE by the ſine of EAD, and divide the product by the ſine of CAD.

This rule ſhews how great the ſtrains muſt be when the angle CAD becomes very open, approaching to 180 degrees. But when the angle CAD becomes very ſmall, its ſine (which is our diviſor) is alſo very ſmall; and we ſhould expect a very great quotient in this caſe alſo. But we muſt obſerve, that in this caſe the ſine of EAD is alſo very ſmall; and this is our multiplier. In ſuch a caſe, the quotient cannot exceed unity.

But it is unneceſſary to conſider the calculation by the tables of ſines more particularly. The angles are ſeldom known any otherwiſe but by drawing the figure of the frame of carpentry. In this caſe, we can always obtain the meaſures of the ſtrains from the ſame ſcale, with equal accuracy, by drawing the parallelogram AFCG.

10
Strains propagated to the points of ſupport.

Hitherto we have conſidered the ſtrains excited at A only as they affect the pieces on which they are exerted. But the pieces, in order to ſuſtain, or be ſubject to, any ſtrain, muſt be ſupported at their ends C and D; and we may conſider them as mere intermediums, by which theſe ſtrains are made to act on thoſe points of ſupport: Therefore AF and AG are alſo meaſures of the forces which preſs or pull at C and D. Thus we learn the ſupports which muſt be found for theſe points. Theſe may be infinitely various. We ſhall attend only to ſuch as ſomehow depend on the framing itſelf.

11
Action of a ſtraining beam.

Such a ſtructure as fig. 11. very frequently occurs, where a beam BA is ſtrongly preſſed to the end of another beam AD, which is prevented from yielding, both becauſe it lies on another beam HD, and becauſe its end D is hindered from ſliding backwards. It is indifferent from what this preſſure ariſes: we have repreſented it as owing to a weight hung on at B, while B is withheld from yielding by a rod or rope hooked to the wall. The beam AD may be ſuppoſed at full liberty to exert all its preſſure on D, as if it were ſupported on rollers lodged in the beam HD; but the loaded beam BA preſſes both on the beam AD and on HD. We wiſh only to know what ſtrain is borne by AD?

All bodies act on each other in the direction perpendicular to their touching ſurfaces; therefore the ſupport given by HD is in a direction perpendicular to it. We may therefore ſupply its place at A by a beam AC, perpendicular to HD, and firmly ſupported at C. In this caſe, therefore, we may take AE, as before, to repreſent the preſſure exerted by the loaded beam, and draw EG perpendicular to AD, and EF parallel to it, meeting the perpendicular AC in F. Then AG is the ſtrain compreſſing AD, and AF is the preſſure on the beam HD.

12
The form of the abutting joint of no great importance.

It may be thought, that ſince we aſſume as a principle that the mutual preſſures of ſolid bodies are exerted perpendicular to their touching ſurfaces, this balance of preſſures, in framings of timbers, depends on the directions of their butting joints: but it does not, as will readily appear by conſidering the preſent caſe. Let the joint or abutment of the two pieces BA, AD be mitred, in the uſual manner, in the direction *f* A *f t*. Therefore, if A *e* be drawn perpendicular to A *f*, it will be the direction of the actual preſſure exerted by the loaded beam BA on the beam AD. But the reaction of AD, in the oppoſite direction A *t*, will not balance the preſſure of BA; becauſe it is not in the direction preciſely oppoſite. BA will therefore ſlide along the joint, and preſs on the beam HD. AE repreſents the load on the mitre joint A. Draw E *e* perpendicular to A *e*, and E *f* parallel to it. The preſſure AE will be balanced by the reactions *e* A and *f* A: or, the

the preffure AE produces the preffures A *e* and A *f*; of which A *f* muft be refifted by the beam HD, and A *e* by the beam AD. The preffure A *f* not being perpendicular to HD, cannot be fully refifled by it; becaufe (by our affumed principle) it reacts only in a direction perpendicular to its furface. Therefore draw *fp*, *fi* parallel to HD, and perpendicular to it. The preffure A *f* will be refifted by HD with the force *p* A; but there is required another force *i* A, to prevent the beam BA from flipping outwards. This muft be furnifhed by the reaction of the beam DA.—In like manner, the other force A *e* cannot be fully refifted by the beam AD, or rather by the prop D, acting by the intervention of the beam; for the action of that prop is exerted through the beam in the direction DA. The beam AD, therefore, is preffed to the beam HD by the force A *e*, as well as by A *f*. To find what this preffure on HD is, draw *eg* perpendicular to HD, and *eo* parallel to it, cutting EG in *r*. The forces *g* A and *o* A will refift, and balance A *e*.

Thus we fee, that the two forces A *e* and A *f*, which are equivalent to AE, are equivalent alfo to A *p*, A *i*, A *o*, and A *g*. But becaufe A *f* and *e* E are equal and parallel, and E *r* and *fi* are alfo parallel, as alfo *er* and *fp*, it is evident, that *if* is equal to *r* E, or to *o* F, and *i* A is equal to *re*, or to G *g*. Therefore the four forces A *g*, A *o*, A *p*, A *i*, are equal to AG and AF. Therefore AG is the compreffion of the beam AD, or the force preffing it on D, and A F is the force preffing it on the beam HD. The proportion of thefe preffures, therefore, is not affected by the form of the joint.

This remark is important; for many carpenters think the form and direction of the butting joint of great importance; and even the theorift, by not profecuting the general principle through *all* its confequences, may be led into an error. The form of the joint is of no importance, in as far as it affects the ftrains in the direction of the beams; but it is often of great confequence, in refpect to its own firmnefs, and the effect it may have in bruifing the piece on which it acts, or being crippled by it.

13 Origin of the ftrain on a tie-beam.

The fame compreffion of AB, and the fame thruft on the point D by the intervention of AD, will obtain, in whatever way the original preffure on the end A is produced. Thus fuppofing that a chord is made faft at A, and pulled in the direction AE, and with the fame force, the beam AD will be equally compreffed, and the prop D muft react with the fame force.

But it often happens that the obliquity of the preffure on AD, inftead of compreffing it, ftretches it; and we defire to know what tenfion it fuftains. Of this we have a familiar example in a common roof. Let the two rafters AC, AD (fig. 12.), prefs on the tie-beam DC. We may fuppofe the whole weight to prefs vertically on the ridge A, as if a weight B were hung on there. We may reprefent this weight by the portion A *b* of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing *bf* and *bg* parallel to AD and AC, A *g* and A *f* will reprefent the preffures on AC and AD. Produce AC till CH be equal to A *f*. The point C is forced out in this direction, and with a force reprefented by this line. As this force is not perpendicularly acrofs the beam, it evidently ftretches it; and this extending force muft be withftood by an equal force pulling it in the oppofite direction. This muft arife from a fimilar oblique thruft of the oppofite rafter on the other end D. We concern ourfelves only with this extenfion at prefent; but we fee that the cohefion of the beam does nothing but fupply the balance to the extending forces. It muft ftill be fupported externally, that it *may refift*, and, by refifting obliquely, be ftretched. The points C and D are fupported on the walls, which they prefs in the directions CK and DO, parallel to A *b*. If we draw HK parallel to DC, and HI parallel to CK (that is, to A *b*), meeting DC produced in I, it follows from the compofition of forces, that the point C would be fupported by the two forces KC and IC. In like manner, making DN = A *g*, and completing the parallelogram DMNO, the point D would be fupported by the forces OD and MD. If we draw *go* and *fk* parallel to DC, it is plain that they are equal to NO and CK, while A *o* and A *k* are equal to DO and CK, and A *b* is equal to the fum of DO and CK (becaufe it is equal to A *o* + A *k*). The weight of the roof is equal to its vertical preffure on the walls.

Thus we fee, that while a preffure on A, in the direction A *b*, produces the ftrains A *f* and A *g*, on the pieces AC and AD, it alfo excites a ftrain CI or DM in the piece DC. And this completes the mechanifm of a frame; for all derive their efficacy from the triangles of which they are compofed, as will appear more clearly as we proceed.

14 External action of a frame.

But there is more to be learned from this. The confideration of the ftrains on the two pieces AD and AC, by the action of a force at A, only fhewed them as the means of propagating the fame ftrains in their own direction to the points of fupport. But, by adding the ftrains exerted in DC, we fee that the frame becomes an intermedium, by which exertions may be made on other bodies, in certain directions and proportions; fo that this frame may become part of a more complicated one, and, as it were, an element of its conftitution. It is worth while to afcertain the proportion of the preffures CK and DO, which are thus exerted on the walls. The fimilarity of triangles gives the following analogies:

DO : DM = A *b* : *b* D
CI, or DM : CK = C *b* : A *b*
Therefore DO : CK = C *b* : *b* D.

Or, *the preffures on the points* C *and* D, *in the direction of the ftraining force* A *b*, *are reciprocally proportional to the portions of* DC *intercepted by* A *b*.

Alfo, fince A *b* is = DO + CK, we have
A *b* : CK = C *b* + *b* D (or CD) : *b* D, and
A *b* : DO = C D : *b* C.

In general, any two of the three parallel forces A *b*, DO, CK, are to each other in the reciprocal proportion of the parts of CD, intercepted between their directions and the direction of the third.

And this explains a ftill more important office of the frame ADC. If one of the points, fuch as D, be fupported, an external power acting at A, in the direction A *b*, and with an intenfity which may be meafured by A *b*, may be fet in equilibrio, with another acting at C, in the direction CL, oppofite to CK or A *b*, and with an intenfity reprefented by CK: for fince the preffure CH is partly withftood by the force IC, or the firmnefs of the beam DC fupported at D, the force KC will complete the balance. When we do not attend to the fupport

fupport at D, we conceive the force A b to be balanced by KC, or KC to be balanced by A b. And, in like manner, we may neglect the fupport or force acting at A, and confider the force DO as balanced by CK.

15 It becomes a lever.

Thus our frame becomes a lever, and we are able to trace the interior mechanical procedure which gives it its efficacy: it is by the intervention of the forces of cohefion, which connect the points to which the external forces are applied with the fupported point or fulcrum, and with each other.

Thefe ftrains or preffures A b, DO, and CK, not being in the directions of the beams, may be called *tranfverfe*. We fee that by their means a frame of carpentry may be confidered as a folid body: but the example which brought this to our view is too limited for explaining the efficacy which may be given to fuch conftructions. We fhall therefore give a general propofition, which will more diftinctly explain the procedure of nature, and enable us to trace the ftrains as they are propagated through all the parts of the moft complicated framing, finally producing the exertion of its moft diftant points.

16 General propofition.

We prefume that the reader is now pretty well habituated to the conception of the ftrains as they are propagated along the lines joining the points of a frame, and we fhall therefore employ a very fimple figure.

Let the ftrong lines ACBD (fig. 13.) reprefent a frame of carpentry. Suppofe that it is pulled at the point A by a force acting in the direction AE, but that it refts on a fixed point C, and that the other extreme point B is held back by a power which refifts in the direction BF: It is required to determine the proportion of the ftrains excited in its different parts, the proportion of the external preffures at A and B, and the preffure which is produced on the obftacle or fulcrum C?

It is evident that each of the external forces at A and B tend one way, or to one fide of the frame, and that each would caufe it to turn round C if the other did not prevent it; and that if, notwithftanding their action, it is turned neither way, the forces in actual exertion are in equilibrio by the intervention of the frame. It is no lefs evident that thefe forces concur in preffing the frame on the prop C. Therefore, if the piece CD were away, and if the joints C and D be perfectly flexible, the pieces CA, CB would be turned round the prop C, and the pieces AD, DB would alfo turn with them, and the whole frame change its form. This fhews, by the way, and we defire it to be carefully kept in mind, that the firmnefs or ftiffnefs of framing depends entirely on the triangles bounded by beams which are contained in it. An open quadrilateral may always change its fhape, the fides revolving round the angles. A quadrilateral may have an infinity of forms, without any change of its fides, by merely pufhing two oppofite angles towards each other, or drawing them afunder. But when the three fides of a triangle are determined, its fhape is alfo invariably determined; and if two angles be held faft, the third cannot be moved. It is thus that, by inferting the bar CD, the figure becomes unchangeable; and any attempt to change it by applying a force to an angle A, immediately excites forces of attraction or repulfion between the particles of the ftuff which form its fides. Thus it happens, in the prefent inftance, that a change of fhape is prevented by the bar CD. The power at A preffes its end againft the prop; and in doing this it puts the bar AD on the ftretch, and alfo the bar DB. Their places might therefore be fupplied by cords or metal wires. Hence it is evident that DC is compreffed, as is alfo AC: and, for the fame reafon, CB is alfo in a ftate of compreffion; for either A or B may be confidered as the point that is impelled or withheld. Therefore DA and DB are ftretched, and are refifting with attractive forces. DC and CB are compreffed, and are refifting with repulfive forces. DB is alfo acting with repulfive forces, being compreffed in like manner: and thus the fupport of the prop, combined with the firmnefs of DC, puts the frame ADBC into the condition of the two frames in fig. 8. and fig. 9. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction AD, and a repulfive force acting in the direction AK. And fince all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction DA. The condition of the point B is fimilar to that of A, and D is alfo drawn in the direction DB. Thus the point D, being urged by the forces in the directions DA and DB, preffes the beam DC on the prop, and the prop refifts in the oppofite direction. Therefore the line DC is the diagonal of the parallelogram, whofe fides have the proportion of the forces which connect D with A and B. This is the principle on which the reft of our inveftigation proceeds. We may take DC as the reprefentation and meafure of their joint effect. Therefore draw CH, CG, parallel to DA, DB. Draw HL, GO, parallel to CA, CB, cutting AE, BF in L and O, and cutting DA, DB in I and M. Complete the parallelograms ILKA, MONB. Then DG and AI are the equal and oppofite forces which connect A and D: for GD = CH, = AI. In like manner DH and BM are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces, connecting A with D and with C. AI is one of them: Therefore AK is the other; and AL is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and oppofite to AL. In like manner, the external force at B is equal and oppofite to BO; and AL is to BO as the external force at A to the external force at B. The prop C refifts with forces equal to thofe which are propagated to it from the points D, A, and C. Therefore it refifts with forces CH, CG, equal and oppofite to DG, DH; and it refifts the compreffions KA, NB, with equal and oppofite forces C k, C n. Draw $k\,l$, $n\,o$ parallel to AD, BD, and draw C lQ, C o P: It is plain that lCHl is a parallelogram equal to KAIL, and that C l is equal to AL. In like manner C o is equal to BO. Now the forces C k, CH, exerted by the prop, compofe the force C l; and C n, CG compofe the force C o. Thefe two forces C l, C o are equal and parallel to AL and BO; and therefore they are equal and oppofite to the external forces acting at A and B. But they are (primitively) equal and oppofite to the preffures (or at leaft the compounds of the preffures) exerted on the prop, by the forces propagated to C from A, D, and B. Therefore the preffures exerted on the prop are the fame as if the external forces were applied there in the fame directions as they are applied to A and

Fig 9.

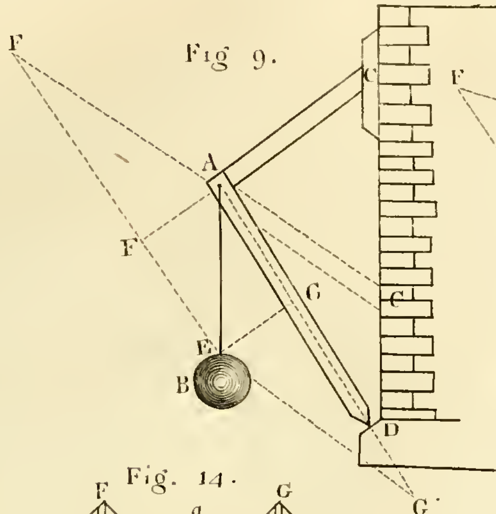


Fig. 10.

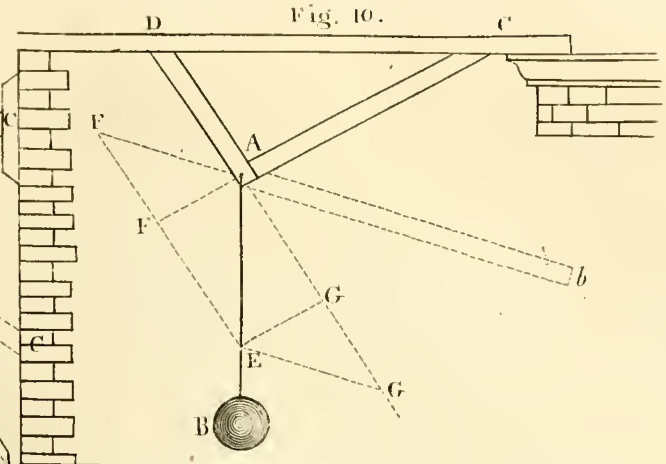


Fig. 14.

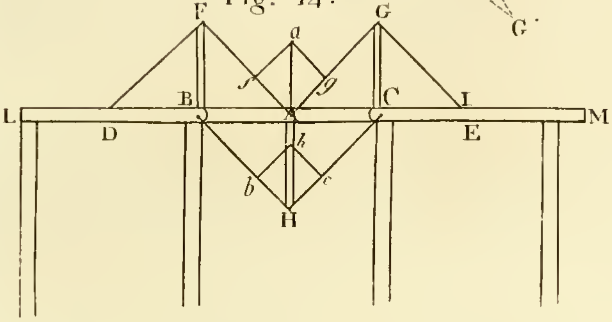


Fig. 15.

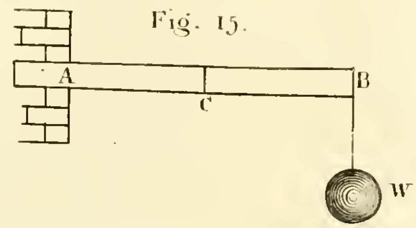


Fig. 11.

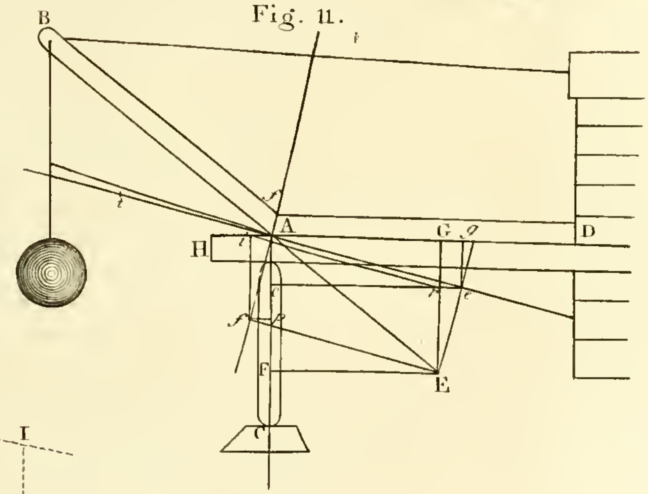


Fig. 12.

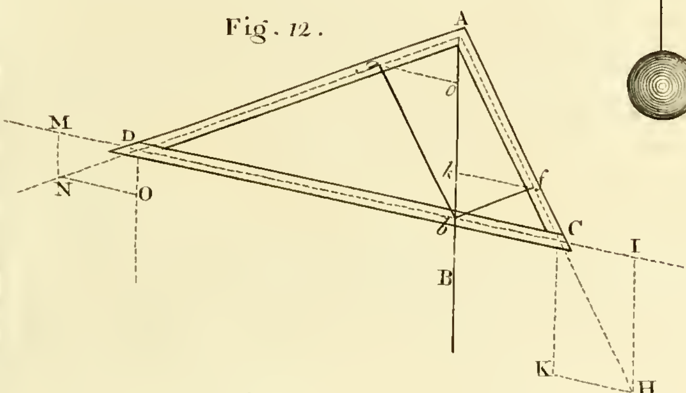


Fig. 16.

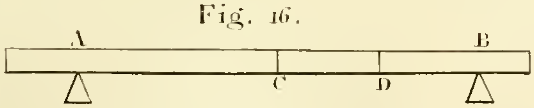
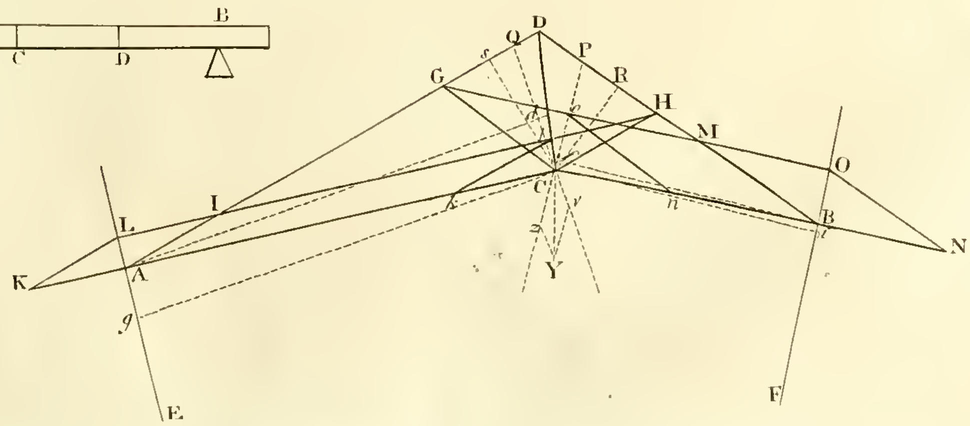


Fig. 13.



Bowes Sc.

and B. Now if we make CV, CZ equal to C *l* and C *o*, and complete the parallelogram CVYZ; it is plain that the force YC is in equilibrio with *l* C and *o* C. Therefore the preffures at A, C, and B, are fuch as would balance if applied to one point.

Laftly, in order to determine their proportions, draw CS and CR perpendicular to DA and DB. Alfo draw A *d*, B *f* perpendicular to CQ and CP; and draw C *g*, C *i* perpendicular to AE, BF.

The triangles CPR and BP *f* are fimilar, having a common angle P, and a right angle at R and *f*.

In like manner the triangles CQS and A Q *d* are fimilar. Alfo the triangles CHR, CGS are fimilar, by reafon of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

$$C o : CP = O n : PB, = CG : PB$$
$$CP : CR = PB : fB$$
$$CR : CS = CH : CG$$
$$CS : CQ = A d : AQ$$
$$CQ : C l = AQ : K l, = AQ : CH.$$

Therefore, by equality,

$$C o : C l = A d : f B$$
$$\text{or } BO : AL = C g : C i.$$

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction (A).

17 Extenfive confequences.

This propofition (fufficiently general for our purpofe) is fertile in confequences, and furnifhes many ufeful inftructions to the artift. The ftrains LA, OB, CY, that are excited, occur in many, we may fay in all, framings of carpentry, whether for edifices or engines, and are the fources of their efficacy. It is alfo evident, that the doctrine of the tranfverfe ftrength of timber is contained in this propofition; for every piece of timber may be confidered as an affemblage of parts, connected by forces which act in the direction of the lines which join the ftrained points on the matter which lies between thofe points, and alfo act on the reft of the matter, exciting thofe lateral forces which produce the inflexibility of the whole. See *Strength of Materials*, Encycl.

Thus it appears that this propofition contains the principles which direct the artift to frame the moft powerful levers; to fecure uprights by fhores or braces, or by ties and ropes; to fecure fcaffoldings for the erection of fpires, and many other moft delicate problems of his art. He alfo learns, from this propofition, how to afcertain the ftrains that are produced, without his intention, by pieces which he intended for other offices, and which, by their tranfverfe action, put his work in hazard. In fhort, this propofition is the key to the fcience of his art.

We would now counfel the artift, after he has made the tracing of the ftrains and thrufts through the various parts of a frame familiar to his mind, and even amufed himfelf with fome complicated fancy framings, to read over with care the articles *Strength of Materials* and Roof in the *Encyclopædia*. He will now conceive its doctrines much more clearly than when he was confidering them as abftract theories. The mutual action of the woody fibres will now be eafily comprehended, and his confidence in the refults will be greatly increafed.

18 Decifion of a difputed and very important queftion.

There is a propofition (n° 19. in the article Roof) which has been called in queftion by feveral very intelligent perfons; and they fay that Belidor has demonftrated, in his Science des Ingenieurs, that a beam firmly fixed at both ends is not twice as ftrong as when fimply lying on the props, and that its ftrength is increafed only in the proportion of 2 to 3; and they fupport this determination by a lift of experiments recited by Belidor, which agree *precifely* with it. Belidor alfo fays, that Pitot had the fame refult in his experiments. Thefe are refpectable authorities: but Belidor's reafoning is any thing but demonftration; and his experiments are defcribed in fuch an imperfect manner, that we cannot build much on them. It is not faid in what manner the battens were fecured at the ends, any farther than that it was by *chevalets*. If by this word is meant a trefsle, we cannot conceive how they were employed; but we fee it fometimes ufed for a wedge or key. If the battens were wedged in the holes, their refiftance to fracture may be made what we pleafe: they may be loofe, and therefore refift little more than when fimply laid on the props. They may be (and probably were) wedged very faft, and bruifed or crippled.

Our propofition mentioned diftinctly the fecurity given to the ends of the beams. They were mortifed into remote pofts. Our *precife* meaning was, that they were fimply kept from rifing by thefe mortifes, but at full liberty to bend up between E and I, and between G and K. Our affertion was not made from theory

 alone

(A) The learned reader will perceive, that this analogy is precifely the fame with that of forces which are in equilibrio by the intervention of a lever. In fact, this whole frame of carpentry is nothing elfe than a *built* or *framed lever* in equilibrio. It is acting in the fame manner as a folid, which occupies the whole figure compreffed in the frame, or as a body of any fize and fhape whatever that will admit the three points of application A, C, and B. It is always in equilibrio in the cafe firft ftated; becaufe the preffure *produced* at B by a force applied to A is always fuch as balances it. The reader may alfo perceive, in this propofition, the analyfis or tracing of thofe internal mechanical forces which are indifpenfably requifite for the functions of a lever. The mechanicians have been extremely puzzled to find a legitimate demonftration of the equilibrium of a lever ever fince the days of Archimedes. Mr Vince has the honour of firft demonftrating, moft ingenioufly, the principle affumed by Archimedes, but without fufficient ground for *his* demonftration: but Mr Vince's demonftration is only a putting the mind into that perplexed ftate which makes it acknowledge the propofition, but without a clear perception of its truth. The difficulty has proceeded from the abftract notion of a lever, conceiving it as a mathematical line—inflexible, without reflecting how it is inflexible—for the very fource of this indifpenfable quality furnifhes the mechanical connection between the remote preffures and the fulcrum; and this fupplies the demonftration (without the leaft difficulty) of the defperate cafe of a ftraight lever urged by parallel forces. See Rotation, n° 11. *Encycl.*

alone (although we think the reafoning incontrovertible), but was agreeable to numerous experiments made in thofe precife circumftances. Had we mortifed the beams firmly into two very ftout pofts, which could not be drawn nearer to each other by bending, the beam would have borne a *much* greater weight, as we have verified by experiment. We hope that the following mode of conceiving this cafe will remove all doubts.

Let LM be a long beam (fig. 14.) divided into fix equal parts, in the points D, B, A, C, E. Let it be firmly fupported at L, B, C, M. Let it be cut thro' at A, and have compafs joints at B and C. Let FB, GC be two equal uprights, refting on B and C, but without any connection. Let AH be a fimilar and equal piece, to be occafionally applied at the feam A. Now let a thread or wire AGE be extended over the piece GC, and made faft at A, G, and E. Let the fame thing be done on the other fide of A. If a weight be now laid on at A, the wires AFD, AGE will be ftrained, and may be broken. In the inftant of fracture we may fuppofe their ftrains to be reprefented by A *f* and A *g*. Complete the parallelogram, and A *a* is the magnitude of the weight. It is plain that nothing is concerned here but the cohefion of the wires; for the beam is fawed through at A, and its parts are perfectly moveable round B and C.

Inftead of this procefs apply the piece AH below A, and keep it there by ftraining the fame wire BHC over it. Now lay on a weight. It muft prefs down the ends of BA and CA, and caufe the piece AH to ftrain the wire BHC. In the inftant of fracture of *the fame* wire, its refiftances H *b* and H *c* muft be equal to A *f* and A *g*, and the weight *b* H which breaks them muft be equal to A *a*.

Laftly employ all the three pieces FB, AH, GC, with the fame wire attached as before. There can be no doubt but that the weight which breaks all the four wires muft be $= a\text{A} + b\text{H}$, or twice A *a*.

The reader cannot but fee that the wires perform the very fame office with the fibres of an entire beam LM held faft in the four holes D, B, C, and E, of fome upright pofts.

In the experiments for verifying this, by breaking flender bars of fine deal, we get complete demonftration, by meafuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam fimply laid on the props B and C: and there are many curious inferences to be made from thefe obfervations, but we have not room for them in this place.

19 The beft manner of framing purlins.

We may obferve, by the way, that we learn from this cafe, that purlins are able to carry twice the load when notched into the rafters that they carry when mortifed into them, which is the moft ufual manner of framing them. So would the binding joifts of floors; but this would double the thicknefs of the flooring. But this method fhould be followed in every poffible cafe, fuch as breaft fummers, lintels over feveral pillars, &c. Thefe fhould never be cut off and mortifed into the fides of every upright; numberlefs cafes will occur which fhew the importance of the maxim.

We muft here remark, that the proportion of the fpaces BC and CM, or BC and LB, has a very fenfible effect on the ftrength of the beam BC; but we have not yet fatisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the ferpentine form of the curve of the beam before fracture. This fhould be attended to in the conftruction of the fprings of carriages. Thefe are frequently fupported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the eafieft motion to the body of the carriage. We alfo think that it is connected with that deviation from the beft theory obfervable in Buffon's experiments on various lengths of the fame fcantling. The force of the beams diminifhed much more than in the inverfe proportion of their lengths.

20 Ties are in general better than ftruts.

We have feen that it depends entirely on the pofition of the pieces in refpect of their points of ultimate fupport, and of the direction of the external force which produces the ftrains, whether any particular piece is in a ftate of extenfion or of compreffion. The knowledge of this circumftance may greatly influence us in the choice of the conftruction. In many cafes we may fubftitute flender iron rods for maffive beams, when the piece is to act the part of a tie. But we muft not invert this difpofition; for when a piece of timber acts as a ftrut, and is in a ftate of compreffion, it is next to certain that it is not equally compreffible in its oppofite fides through the whole length of the piece, and that the compreffing force on the abutting joint is not acting in the moft equable manner all over the joint. A very trifling inequality in either of thefe circumftances (efpecially in the firft) will comprefs the beam more on one fide than on the other. This cannot be without the beam's bending, and becoming concave on that fide on which it is moft compreffed. When this happens, the frame is in danger of being crufhed, and foon going to ruin. It is therefore indifpenfably neceffary to make ufe of beams in all cafes where ftruts are required of confiderable length, rather than of metal rods of flender dimenfions, unlefs in fituations where we can effectually prevent their bending, as in truffing a girder internally, where a caft iron ftrut may be firmly cafed in it, fo as not to bend in the fmalleft degree. In cafes where the preffures are enormous, as in the very oblique ftruts of a centre or arch frame, we muft be particularly cautious to do nothing which can facilitate the compreffion of either fide. No mortifes fhould be cut near to one fide; no lateral preffures, even the flighteft, fhould be allowed to touch it. We have feen a pillar of fir 12 inches long and one inch in fection, when loaded with three tons, fnap in an inftant when preffed on one fide by 16 pounds, while another bore $4\frac{1}{2}$ tons without hurt, becaufe it was inclofed (loofely) in a ftout pipe of iron.

In fuch cafes of enormous compreffion, it is of great importance that the compreffing force bear equally on the whole abutting furface. The German carpenters are accuftomed to put a plate of lead over the joint. This prevents, in fome meafure, the penetration of the end fibres. Mr Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the ftrut. By this contrivance the unavoidable change of form of the triangle made no partial bearing of either angle of the abutment. This always has a tendency to fplinter off the heel of the beam where it preffes ftrongeft. It is a very judicious practice.

When circumftances allow it, we fhould rather employ

ploy ties than ſtruts for ſecuring a beam againſt lateral ſtrains. When an upright pillar, ſuch as a flag ſtaff, a maſt, or the uprights of a very tall ſcaffolding, are to be ſhoared up, the dependence is more certain on thoſe braces that are ſtretched by the ſtrain than on thoſe which are compreſſed. The ſcaffolding of the iron bridge near Sunderland had ſome ties very judiciouſly diſpoſed, and others with leſs judgment.

We ſhould proceed to conſider the tranſverſe ſtrains as they affect the various parts of a frame of carpentry; but we have very little to add to what has been ſaid already in the article *Strength of Materials* (Encycl.) and in the article Roof. What we ſhall add in this article will find a place in our occaſional remarks on different works. It may, however, be of uſe to recal to the reader's memory the following propoſitions.

21 General theorems concerning the relative ſtrength of beams.

1. When a beam AB (fig. 15.) is firmly fixed at the end A, and a ſtraining force acts perpendicularly to its length at any point B, the ſtrain occaſioned at any ſection C between B and A is proportional to CB, and may therefore be repreſented by the product W+CB; that is, by the product of the number of tons, pounds, &c. which meaſure the ſtraining force, and the number of feet, inches, &c. contained in CB. As the loads on a beam are eaſily conceived, we ſhall ſubſtitute this for any other ſtraining force.

2. If the ſtrain or load is uniformly diſtributed along any part of the beam lying beyond C (that is, further from A), the ſtrain at C is the ſame as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

3. The ſtrain on any ſection D of a beam AB (fig 16.) reſting freely on two props A and B, is $w \times \frac{AD \times DB}{AB}$ (ſee Roof, n° 19. and *Strength of Materials*, n° 92, &c. *Encycl*.). Therefore,

4. The ſtrain on the middle point, by a force applied there, is one-fourth of the ſtrain which the ſame force would produce, if applied to one end of a beam of the ſame length, having the other end fixed.

5. The ſtrain on any ſection C of a beam, reſting on two props A and B, occaſioned by a force applied perpendicularly to another point D, is proportional to the rectangle of the exterior ſegments, or is equal to $w \times \frac{AC \times DB}{AB}$. Therefore

The ſtrain at C occaſioned by the preſſure on D, is the ſame with the ſtrain at D occaſioned by the ſame preſſure on C.

6. The ſtrain on any ſection D, occaſioned by a load uniformly diffuſed over any part EF, is the ſame as if the two parts ED, DF of the load were collected at their middle points *e* and *f*. Therefore

The ſtrain on any part D, occaſioned by a load uniformly diſtributed over the whole beam, is one-half of the ſtrain that is produced when the ſame load is laid on at D; and

The ſtrain on the middle point C, occaſioned by a load uniformly diſtributed over the whole beam, is the ſame which half that load would produce if laid on at C.

7. A beam ſupported at both ends on two props B and C (fig. 14), will carry twice as much when the ends beyond the props are kept from riſing, as it will carry when it reſts looſely on the props.

8. Laſtly, the tranſverſe ſtrain on any ſection, occaſioned by a force applied obliquely, is diminiſhed in the proportion of the ſine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the ſtrain is one-half of the ſtrain occaſioned by the ſame force acting perpendicularly.

On the other hand, the relative strength of a beam, or its power in any particular ſection to reſiſt any tranſverſe ſtrain, is proportional to the abſolute coheſion of the ſection directly, to the diſtance of its centre of effort from the axis of fracture directly, and to the diſtance from the ſtrained point inverſely.

Thus in a rectangular ſection of the beam, of which b is the breadth, d the depth (that is, the dimenſion in the direction of the ſtraining force), meaſured in inches, and f the number of pounds which one ſquare inch will juſt ſupport without being torn aſunder, we muſt have $f \times b \times d^2$, proportional to $w \times CB$ (fig. 15.) Or, $f \times b \times d^2$, multiplied by ſome number m, depending on the nature of the timber, muſt be equal to $w \times CB$. Or, in the caſe of the ſection C of fig. 16. that is ſtrained by the force w applied at D, we muſt have $m \times f b d^2 = w \times \frac{AC \times DB}{AB}$. Thus if the beam is of ſound oak, m is very nearly $= \frac{1}{9}$ (ſee *Strength of Materials*, n° 116, Encycl.). Therefore we have $\frac{f b d^2}{9} = w \times \frac{AC \times CB}{AB}$.

Hence we can tell the preciſe force w which any ſection C can juſt reſiſt when that force is applied in any way whatever. For the above mentioned formula gives $w = \frac{f b d^2}{9 CB}$, for the caſe repreſented by fig. 15. But the caſe repreſented in fig. 16. having the ſtraining force applied at D, gives the ſtrain at C $(= w) = f \times \frac{b d^2 \times AB}{9 AC \times CB}$.

Example. Let an oak beam, four inches ſquare, reſt freely on the props A and B, ſeven feet apart, or 84 inches. What weight will it juſt ſupport at its middle point C, on the ſuppoſition that a ſquare inch rod will juſt carry 16,000 pounds, pulling it aſunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 42}$, or $w = \frac{86016000}{15876}$, $= 5418$ pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the ſtraining force acted on a point D, half way between C and B, the force ſufficient to break the beam at C would be $= \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} = 10836$ lbs.

Had the beam been found red fir, we muſt have taken $f = 10,000$ nearly, and m nearly 8; for although fir be leſs coheſive than oak in the proportion of 5 to 8 nearly, it is leſs compreſſible, and its axis of fracture is therefore nearer to the concave ſide.

22 Of joints.

Having conſidered at ſufficient length the ſtrains of of different kinds which arise from the form of the parts of a frame of carpentry, and the direction of the external forces which act on it, whether considered as impelling or as supporting its different parts, we must now proceed to consider the means by which this form is to be secured, and the connections by which those strains are excited and communicated.

The joinings practised in carpentry are almost infinitely various, and each has advantages which make it preferable in some circumstances. Many varieties are employed merely to please the eye. We do not concern ourselves with these: Nor shall we consider those which are only employed in connecting small works, and can never appear on a great scale; yet even in some of these, the skill of the carpenter may be discovered by his choice; for in all cases, it is wise to make every, even the smallest, part of his work as strong as the materials will admit. He will be particularly attentive to the changes which will necessarily happen by the shrinking of timber as it dries, and will consider what dimensions of his framings will be affected by this, and what will not; and will then dispose the pieces which are less essential to the strength of the whole, in such a manner that their tendency to shrink shall be in the same direction with the shrinking of the whole framing. If he do otherwise, the seams will widen, and parts will be split asunder. He will dispose his boardings in such a manner as to contribute to the stiffness of the whole, avoiding at the same time the giving them positions which will produce lateral strains on truss beams which bear great pressures; recollecting, that although a single board has little force, yet many united have a great deal, and may frequently perform the office of very powerful struts.

Our limits confine us to the joinings which are most essential for connecting the parts of a single piece of a frame when it cannot be formed of one beam, either for want of the necessary thickness or length; and the joints for connecting the different sides of a trussed frame.

23 Of building up beams. Much ingenuity and contrivance has been bestowed on the manner of building up a great beam of many thicknesses, and many singular methods are practised as great nostrums by different artists; but when we consider the manner in which the cohesion of the fibres performs its office, we will clearly see that the simplest are equally effectual with the most refined, and that they are less apt to lead us into false notions of the strength of the assemblage.

24 Building up a girder or lever. Thus, were it required to build up a beam for a great lever or a girder, so that it may act nearly as a beam of the same size of one log—it may either be done by plain joggling, as in fig. 17. A, or by scarfing as in fig. 17. B or C. If it is to act as a lever, having the gudgeon on the lower side at C, we believe that most artists will prefer the form B and C; at least this has been the case with nine-tenths of those to whom we have proposed the question. The best informed only hesitated; but the ordinary artists were all confident in its superiority; and we found their views of the matter very coincident. They considered the upper piece as grasping the lower in its hooks; and several imagined that, by driving the one very tight on the other, the beam would be stronger than an entire log: but if we attend carefully to the internal procedure in the loaded lever, we shall find the upper one clearly the strongest. If they are formed of equal logs, the upper one is thicker than the other by the depth of the joggling or scarfing, which we suppose to be the same in both; consequently, if the cohesion of the fibres in the intervals is able to bring the uppermost filaments into full action, the form A is stronger than B, in the proportion of the greater distance of the upper filaments from the axis of the fracture: this may be greater than the difference of the thickness, if the wood is very compressible. If the gudgeon be in the middle, the effect, both of the joggles and the scarfings, is considerably diminished; and if it is on the upper side, the scarfings act in a very different way. In this situation, if the loads on the arms are also applied to the upper side, the joggled beam is still more superior to the scarfed one. This will be best understood by resolving it in imagination into a trussed frame. But when a gudgeon is thus put on that side of the lever which grows convex by the strain, it is usual to connect it with the rest by a powerful strap, which embraces the beam, and causes the opposite point to become the resisting point. This greatly changes the internal actions of the filaments, and, in some measure, brings it into the same state as the first, with the gudgeon below. Were it possible to have the gudgeon on the upper side, and to bring the whole into action without a strap, it would be the strongest of all; because, in general, the resistance to compression is greater than to extension. In every situation the joggled beam has the advantage; and it is the easiest executed.

25 Joggling preferable to scarfing. We may frequently gain a considerable accession of strength by this building up of a beam; especially if the part which is stretched by the strain be of oak, and the other part be fir. Fir being so much superior to oak as a pillar (if Musschenbroek's experiments may be confided in), and oak so much preferable as a tie, this construction seems to unite both advantages. But we shall see much better methods of making powerful levers, girders, &c. by trussing.

Observe, that the efficacy of both methods depends entirely on the difficulty of causing the piece between the cross joints to slide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as soon as they are so deep that their ends have a force sufficient to push the slice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings are frequently made oblique, as in fig. 18. but we imagine that this is a bad practice. It begins to yield at the point, where the wood is crippled and splintered off, or at least bruised out a little: as the pressure increases, this part, by squeezing broader, causes the solid parts to rise a little upwards, and gives them some tendency, not only to push their antagonists along the base, but even to tear them up a little. For similar reasons, we disapprove of the favourite practice of many artists, to make the angles of their scarfings acute, as in fig. 19. This often causes the two pieces to tear each other up. The abutments should always be perpendicular to the directions of the pressures. Lest it should be forgotten in its proper place, we may extend this injunction also to the abutments of different pieces of a frame, and recommend it to the artist even

to

to attend to the ſhrinking of the timbers by drying. When two timbers abut obliquely, the joint ſhould be moſt full at the obtuſe angle of the end; becauſe, by drying that angle grows more obtuſe, and the beam would then be in danger of ſplintering off at the acute angle.

26 We muſt not wedge too hard.

It is evident, that the niceſt work is indiſpenſably neceſſary in building up a beam. The parts muſt abut on each other completely, and the ſmalleſt play or void takes away the whole efficacy. It is uſual to give the butting joints a ſmall taper to one ſide of the beam, ſo that they may require moderate blows of a maul to force them in, and the joints may be perfectly cloſe when the external ſurfaces are even on each ſide of the beam. But we muſt not exceed in the leaſt degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a ſtate of violent ſtrain, and the abutments are perhaps ready to ſplinter off by a ſmall addition of preſſure. This is like too ſevere a proof for artillery; which, though not ſufficient to burſt the pieces, has weakened them to ſuch a degree, that the ſtrain of ordinary ſervice is ſufficient to complete the fracture. The *workman* is tempted to exceed in this, becauſe it ſmooths off and conceals all uneven ſeams; but he muſt be watched. It is not unuſual to leave ſome abutments open enough to admit a thin wedge reaching through the beam. Nor is this a bad practice, if the wedge is of materials which is not compreſſed by the driving or the ſtrain of ſervice. Iron would be preferable for this purpoſe, and for the joggles, were it not that by its too great hardneſs it cripples the fibres of timber to ſome diſtance. In conſequence of this, it often happens that, in beams which are ſubjected to deſultory and ſudden ſtrains (as in the levers of reciprocating engines), the joggles or wedges widen the holes, and work themſelves looſe: Therefore ſkilful engineers never admit them, and indeed as few bolts as poſſible, for the ſame reaſon: but when reſiſting a ſteady or dead pull, they are not ſo improper, and are frequently uſed.

Beams are built up, not only to increaſe their dimenſions in the direction of the ſtrain (which we have hitherto called their depth), but alſo to increaſe their breadth or the dimenſions perpendicular to the ſtrain. We ſometimes double the breadth of a girder which is thought too weak for its load, and where we muſt not increaſe the thickneſs of the flooring. The maſt of a great ſhip of war muſt be made bigger athwartſhip, as well as fore and aft. This is one of the niceſt problems of the art; and profeſſional men are by no means agreed in their opinions about it. We do not preſume to decide; and ſhall content ourſelves with exhibiting the different methods.

27 Building of maſts.

The moſt obvious and natural method is that ſhewn in fig. 20. It is plain that (independent of the connection of croſs bolts, which are uſed in them all when the beams are ſquare) the piece C cannot bend in the direction of the plane of the figure without bending the piece D along with it. This method is much uſed in the French navy; but it is undoubtedly imperfect. Hardly any two great trees are of equal quality, and ſwell or ſhrink alike. If C ſhrinks more than D, the feather of C becomes looſe in the groove wrought in D to receive it; and when the beam bends, the p[illegible] can ſlide on each other like the plates of a co[illegible]; and if the bending is in the direction $e\ f$, there is nothing to hinder this ſliding but the bolts, which ſoon work themſelves looſe in the bolt-holes.

28 Method uſed in the French Navy.

29 Another method.

Fig. 21. exhibits another method. The two halves of the beam are tabled into each other in the ſame manner as in fig. 17. It is plain that this will not be affected by the unequal ſwelling or ſhrinking, becauſe this is inſenſible in the direction of the fibres; but when bent in the direction $a\ b$, the beam is weaker than fig. 20. bent in the direction $e\ f$. Each half of fig. 20. has, in every part of its length, a thickneſs greater than half the thickneſs of the beam. It is the contrary in the alternate portions of the halves of fig. 21. When one of them is bent in the direction AB, it is plain that it drags the other with it by means of the croſs butments of its tables, and there can be no longitudinal ſliding. But unleſs the work is accurately executed, and each hollow completely filled up by the table of the other piece, there will be a lateral ſlide along the croſs joints ſufficient to compenſate for the curvature: and this will hinder the one from compreſſing or ſtretching the other in conformity to this curvature.

30 Its imperfection.

The imperfection of this method is ſo obvious, that it has ſeldom been practiſed; but it has been combined with the other, as is repreſented in fig. 22. where the beams are divided along the middle, and the tables in each half are alternate, and alternate alſo with the tables of the other half. Thus 1, 3, 4, are prominent, and 5, 2, 6, are depreſſed. This conſtruction evidently puts a ſtop to both ſlides, and obliges every part of both pieces to move together. $a\ b$ and $c\ d$ ſhow ſections of the built-up beam correſponding to AB and CD.

No more is intended in this practice by any intelligent artiſt, than the cauſing the two pieces to act together in all their parts, although the ſtrains may be unequally diſtributed on them. Thus, in a built-up girder, the binding joiſts are frequently mortiſed into very different parts of the two ſides. But many ſeem to aim at making the beam ſtronger than if it were of one piece; and this inconſiderate project has given riſe to many whimſical modes of tabling and ſcarfing, which we need not regard.

31 Britiſh method;

The practice in the Britiſh dock-yards is ſomewhat different from any of theſe methods. The pieces are tabled as in fig. 22. but the tables are not thin parallelopipeds, but thin priſms. The two outward joints or viſible ſeams are ſtraight lines, and the table n° 1. riſes gradually to its greateſt thickneſs in the axis. In like manner the hollow 5 for receiving the oppoſite table, ſinks gradually from the edge to its greateſt depth in the axis. Fig. 23. repreſents a ſection of a round piece of timber built up in this way, where the full line EFGH is the ſection correſponding to AB of fig. 22. and the dotted line EGFH is the ſection correſponding to CD.

This conſtruction, by making the external ſeam ſtraight, leaves no lodgment for water, and looks much fairer to the eye: but it appears to us that it does not give ſuch firm hold when the maſt is bent in the direction EH. The exterior parts are moſt ſtretched and moſt compreſſed by this bending; but there is hardly any abutment in the exterior parts of theſe tables. In the very axis, where the abutment is the firmeſt, there is little or no difference of extenſion and compreſſion.

But

But this construction has an advantage, which we imagine much more than compensates for these imperfections, at least in the particular case of a round mast: it will draw together by hooping incomparably better than any of the others. If the cavity be made somewhat too shallow for the prominence of the tables, and if this be done uniformly along the whole length, it will make a somewhat open seam; and this opening can be regulated with the utmost exactness from end to end by the plane. The heart of those vast trunks is very sensibly softer than the exterior circles: Therefore, when the whole is hooped, and the hoops hard driven, and at considerable intervals between each spell—we are confident that all may be compressed till the seam disappears; and then the whole makes one piece, *much* stronger than if it were an original log of that size, because the middle has become, by compression, as solid as the crust, which was naturally firmer, and resisted farther compression. We verified this beyond a doubt, by hooping a built stick of a timber which has this inequality of firmness in a remarkable degree, and it was nearly twice as strong as another of the same size.

Our mastmakers are not without their fancies and whims; and the manner in which our masts and yards are generally built up, is not near so simple as fig. 22.: but it consists of the same essential parts, acting in the very same manner, and derives all its efficacy from the principles which are here employed.

32 Attended with peculiar advantages.

This construction is particularly suited to the situation and office of a ship's mast. It has no bolts; or, at least, none of any magnitude, or that make very important parts of its construction. The most violent strains perhaps that it is exposed to, is that of twisting, when the lower yards are close braced up by the force of many men acting by a long lever. This form resists a twist with peculiar energy: it is therefore an excellent method for building up a great shaft for a mill. The way in which they are usually built up is by reducing a central log to a polygonal prism, and then filling it up to the intended size by *planting* pieces of timber along its sides, either spiking them down, or cocking them into it by a feather, or joggling them by slips of hard wood sunk into the central log and into the slips. *N. B.* Joggles of elm are sometimes used in the middle of the large tables of masts; and when sunk into the firm wood near the surface, they must contribute much to the strength. But it is very necessary to employ wood not much harder than the pine; otherwise it will soon enlarge its bed, and become loose; for the timber of these large trunks is very soft.

The most general reason for piecing a beam is to increase its length. This is frequently necessary, in order to procure tie-beams for very wide roofs. Two pieces must be scarfed together.—Numberless are the modes of doing this; and almost every master carpenter has his favorite nostrum. Some of them are very ingenious: But here, as in other cases, the most simple are commonly the strongest. We do not imagine that any, the most ingenious, is equally strong with a tie consisting of two pieces of the same scantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artless and clumsy tie-beam; but we only say that it will be stronger than any that is more artificially made up of the same thickness of timber. This, we imagine, will appear sufficiently certain.

33 Various methods of scarfing.

The simplest and most obvious scarfing (after the one now mentioned) is that represented in fig. 24. n° 1. and 2. If considered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the strength of an entire piece, supposing that the bolts (which are the only connections) are fast in their holes. N° 2. requires a bolt in the middle of the scarf to give it that strength; and, in every other part, is weaker on one side or the other.

But the bolts are very apt to bend by the violent strain, and require to be strengthened by uniting their ends by iron plates; in which case it is no longer a wooden tie. The form of n° 1. is better adapted to the office of a pillar than n° 2.; especially if its ends be formed in the manner shewn in the elevation n° 3. By the sally given to the ends, the scarf resists an effort to bend it in that direction. Besides, the form of n° 2. is unsuitable for a post; because the pieces, by sliding on each other by the pressure, are apt to splinter off the tongue which confines their extremity.

Fig. 25. and 26. exhibit the most approved form of a scarf, whether for a tie or for a post. The key represented in the middle is not essentially necessary; the two pieces might simply meet square there. This form, without a key, needs no bolts (although they strengthen it greatly); but, if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightness. The same precaution must be observed that we mentioned on another occasion, not to produce a constant internal strain on the parts by overdriving the key. The form of fig. 25. is by far the best; because the triangle of 26. is much easier splintered off by the strain, or by the key, than the square wood of 25. It is far preferable for a post, for the reason given when speaking of fig. 24. n° 1. and n° 2. Both may be formed with a sally at the ends equal to the breadth of the key. In this shape fig. 25. is vastly well suited for joining the parts of the long corner posts of spires and other wooden towers. Fig. 25. n° 2. differs from n° 1. only by having three keys. The principle and the longitudinal strength are the same. The long scarf of n° 2. tightened by the three keys, enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third, it has less than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the simple form of fig. 24. n° 1. is stronger than those more ingenious scarfings. It may be strengthened against lateral bending by a little tongue, or by a sally; but it cannot have both.

The strongest of all methods of piecing a tie-beam would be to set the parts end to end, and grasp them between other pieces on each side, as in fig. 27. This is what the ship-carpenter calls *fishing* a beam; and is a frequent practice for occasional repairs. Mr Perronet used it for the tie-beams or stretchers, by which he connected

34 Fishing a beam.

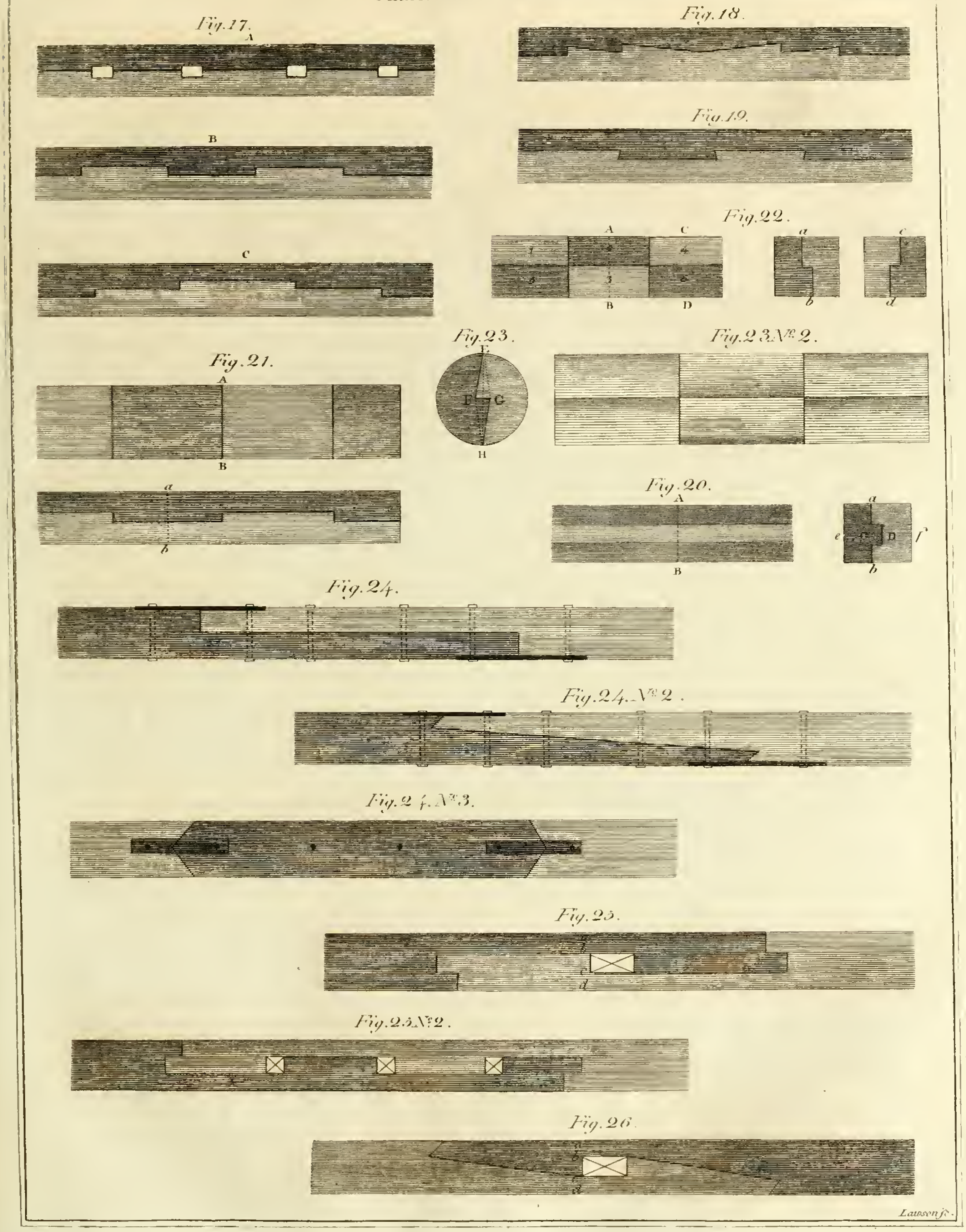


Fig. 17.
A
B
C
Fig. 18.
Fig. 19.
Fig. 22.
A
C
B
D
a
b
c
d
Fig. 23.
E
F
G
H
Fig. 23. No. 2.
Fig. 21.
A
B
a
b
Fig. 20.
A
B
a
b
e
f
C
D
Fig. 24.
Fig. 24. No. 2.
Fig. 24. No. 3.
Fig. 25.
a
b
c
d
Fig. 25. No. 2.
Fig. 26.
a
b
c
d
Lawson sc.

nected the oppofite feet of a centre, which was yielding to its load, and had pufhed afide one of the piers above four inches. Six of thefe not only withftood a ftrain of 1800 tons, but, by wedging behind them, he brought the feet of the trufs $2\frac{1}{2}$ inches nearer. The ftretchers were 14 inches by 11 of found oak, and could have withftood three times that ftrain. Mr Perronet, fearing that the great length of the bolts employed to connect the beams of thefe ftretchers would expofe them to the rifk of bending, fcarfed the two fide pieces into the middle piece. The fcarfing was of the triangular kind *(Trait de Jupiter)*, and only an inch deep, each face being two feet long, and the bolt paffed through clofe to the angle.

In piecing the pump rods, and other wooden ftretchers of great engines, no dependence is had on fcarfing; and the engineer connects every thing by iron ftraps. We doubt the propriety of this, at leaft in cafes where the bulk of the wooden connection is not inconvenient. Thefe obfervations muft fuffice for the methods employed for connecting the parts of a beam; and we now proceed to confider what are more ufually called the joints of a piece of carpentry.

35 Square joints. Where the beams ftand fquare with each other, and the ftrains are alfo fquare with the beams, and in the plane of the frame, the common mortife and tenon is the moft perfect junction. A pin is generally put through both, in order to keep the pieces united, in oppofition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, fo that it fhall draw the tenon tight into the mortife, and caufe the fhoulder to butt clofe, and make neat work; and he knows the rifk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may juft obferve, that fquare holes and pins are much preferable to round ones for this purpofe, bringing more of the wood into action, with lefs tendency to fplit it. The fhip carpenters have an ingenious method of making long wooden bolts, which do not pafs completely through, take a very faft hold, though not nicely fitted to their holes, which they muft not be, left they fhould be crippled in driving. They

36 Foxtail wedging. call it *foxtail wedging*. They ftick into the point of the bolt a very thin wedge of hard wood, fo as to project a proper diftance: when this reaches the bottom of the hole by driving the bolt, it fplits the end of it, and fqueezes it hard to the fide. This may be practifed with advantage in carpentry. If the ends of the mortife are widened inwards, and a thin wedge be put into the end of the tenon, it will have the fame effect, and make the joint equal to a dovetail. But this rifks the fplitting the piece beyond the fhoulder of the tenon, which would be unfightly. This may be avoided as follows: Let the tenon T, fig. 28. have two *very* thin wedges *a* and *c* ftuck in near its angles, projecting equally: at a very fmall diftance within thefe, put in two fhorter ones *b*, *d*, and more within thefe if neceffary. In driving this tenon, the wedges *a* and *c* will take firft, and fplit off a thin flice, which will eafily bend without breaking. The wedges *b*, *d*, will act next, and have a fimilar effect, and the others in fucceffion. The thicknefs of all the wedges taken together muft be equal to the enlargement of the mortife toward the bottom.

When the ftrain is tranfverfe to the plane of the two beams, the principles laid down in nº 85, 86, of the article *Strength of Materials*, will direct the artift in placing his mortife. Thus the mortife in a girder for receiving the tenon of a binding joift of a floor fhould be as near the upper fide as poffible, becaufe the girder becomes concave on that fide by the ftrain. But as this expofes the tenon of the binding-joift to the rifk of being torn off, we are obliged to mortife farther down. The form (fig. 29.) generally given to this joint is extremely judicious. The floping part *a b* gives a very firm fupport to the additional bearing *c d*, without much weakening of the girder. This form fhould be copied in every cafe where the ftrain has a fimilar direction.

The joint that moft of all demands the careful attention of the artift, is that which connects the ends of beams, one of which pufhes the other very obliquely, putting it into a ftate of extenfion. The moft familiar inftance of this is the foot of a rafter preffing on the tie-beam, and thereby *drawing* it away from the other wall. When the direction is very oblique (in which cafe the extending ftrain is the greateft), it is difficult to give the foot of the rafter fuch a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a fmall diftance beyond the foot of the rafter: but, indeed, the dimenfions which are given to tie-beams, for other reafons, are always fufficient to give enough of abutment when judicioufly employed. Unfortunately this joint is much expofed to failure by the effects of the weather. It is much expofed, and frequently perifhes by rot, or becomes fo foft and friable that a very fmall force is fufficient, either for pulling the filaments out of the tie-beam, or for crufhing them together. We are therefore obliged to fecure it with particular attention, and to avail ourfelves of every circumftance of conftruction. 37 Oblique mortife and tenon.

One is naturally difpofed to give the rafter a deep hold by a long tenon; but it has been frequently obferved in old roofs that fuch tenons break off. Frequently they are obferved to tear up the wood that is above them, and pufh their way through the end of the tie-beam. This in all probability arifes from the firft fagging of the roof, by the compreffion of the rafters and of the head of the king poft. The head of the rafter defcends, the angle with the tie-beam is diminifhed by the rafter revolving round its ftep in the tie-beam. By this motion the heel or inner angle of the rafter becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very fhort, and being ftill frefh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortife, and then pufhes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a fhape which abuts firmly, in the direction of the thruft, on the folid bottom of the mortife, which is well fupported on the under fide by the wall plate. This form has the farther advantage of having no tendency to tear up the end of the mortife. This form is reprefented in fig. 30. The tenon has a fmall portion *a b* cut perpendicular to the furface of the tie-beam, and the reft *b c* is perpendicular to the rafter.

But if the tenon is not fufficiently ftrong (and it is not

not so strong as the rafter, which is thought not to be stronger than is necessary), it will be crushed, and then the rafter will shade out along the surface of the beam. It is therefore necessary to call in the assistance of the whole rafter. It is in this distribution of the strain among the various abutting parts that the varieties of joints and their merits chiefly consists. It would be endless to describe every nostrum, and we shall only mention a few that are most generally approved of.

38 Most approved forms.

The aim in fig. 31. is to make the abutments exactly perpendicular to the thrusts. It does this very precisely; and the share which the tenon and the shoulder have of the whole may be what we please, by the portion of the beam that we notch down. If the wall plate lie duly before the heel of the rafter, there is no risk of straining the tie across or breaking it, because the thrust is made direct to that point where the beam is supported. The action is the same as against the joggle on the head or foot of a king post. We have no doubt but that this is a very effectual joint. It is not, however, much practised. It is said that the sloping seam at the shoulder lodges water; but the great reason seems to be a secret notion that it weakens the tie-beam. If we consider the direction in which it acts as a tie, we must acknowledge that this form takes the best method for bringing the whole of it into action.

Fig. 32. exhibits a form that is more general, but certainly worse. What part of the thrust that is not borne by the tenon acts obliquely on the point of the shoulder, and gives the whole a tendency to rise up and slide outward.

The shoulder joint is sometimes formed like the dotted line *a b c d e f g* of fig. 32. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals *b d* and *d f* are so short that the little wooden triangles *b c d*, *d e f*, will be easily pushed off their bases *b d*, *d f*.

Fig. 33. seems to have the most general approbation. It is the joint recommended by Price (page 7.), and copied into all books of carpentry as the *true joint* for a rafter foot. The visible shoulder-joint is flush with the upper surface of the tie-beam. The angle of the tenon at the tie nearly bisects the obtuse angle formed by the rafter and the beam, and is therefore somewhat oblique to the thrust. The inner shoulder *a c* is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally as at *e d*. Fig 34. is a section of the beam and rafter foot, shewing the different shoulders.

We do not perceive the peculiar merit of this joint. The effect of the three oblique abutments *a b*, *a c*, *e d*, is undoubtedly to make the whole bear on the outer end of the mortise, and there is no other part of the tie-beam that makes immediate resistance. Its only advantage over a tenon extending in the direction of the thrust is, that it will not tear up the wood above it. Had the inner shoulder had the form *e c i*, having its face *i c* perpendicular, it would certainly have acted more powerfully in stretching many filaments of the tie-beam, and would have had much less tendency to force out the end of the mortise. The little bit *c i* would have prevented the sliding upwards along *e c*. At any rate, the joint *a b* being flush with the beam, prevents any sensible abutment on the shoulder *a c*.

Fig. 33. N° 2. is a simpler, and in our opinion a preferable joint. We observe it practised by the most eminent carpenters for all oblique thrusts; but it surely employs less of the cohesion of the tie-beam than might be used without weakening it, at least when it is supported on the other side by the wall plate.

Fig. 33. N° 3. is also much practised by the first carpenters.

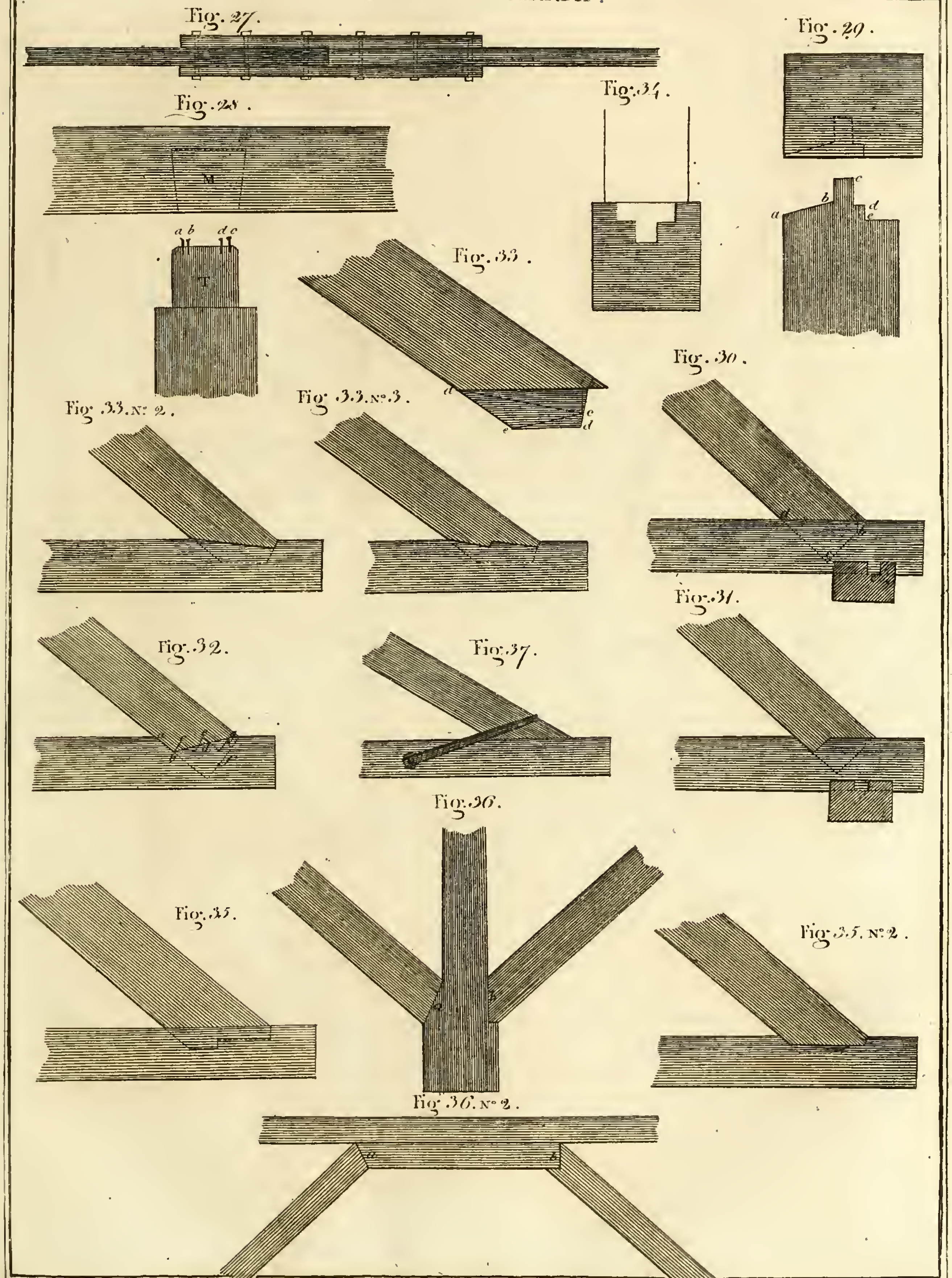
Fig. 35. is proposed by Mr Nicholson (page 65.) as preferable to fig. 33. n° 3. because the abutment of the inner part is better supported. This is certainly the case; but it supposes the whole rafter to go to the bottom of the socket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick; in which case they think that it requires a deeper socket than Nicholson has given it. Perhaps the advantages of Nicholson's construction may be had by a joint like fig. 35. n° 2.

Whatever is the form of these butting joints, great care should be taken that all parts bear alike, and the artist will attend to the magnitude of the different surfaces. In the general compression, the greater surfaces will be less compressed, and the smaller will therefore change most. When all has settled, every part should be *equally* close. Because great logs are moved with difficulty, it is very troublesome to try the joint frequently to see how the parts fit; therefore we must expect less accuracy in the interior parts. This should make us prefer those joints whose efficacy depends chiefly on the visible joint. 39 Circumstances to be attended to.

It appears from all that we have said on this subject, that a very small part of the cohesion of the tie-beam is sufficient for withstanding the horizontal thrust of a roof, even though very low pitched. If therefore no other use is made of the tie-beam, one much slenderer may be used, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king post. Although a tie-beam has commonly floors or ceilings to carry, and sometimes the workshops and store rooms of a theatre, and therefore requires a great scantling, yet there frequently occur in machines and engines very oblique stretchers, which have no other office, and are generally made of dimensions quite inadequate to their situation, often containing ten times the necessary quantity of timber. It is therefore of importance to ascertain the most perfect manner of executing such a joint. We have directed the attention to the principles that are really concerned in the effect. In all hazardous cases, the carpenter calls in the assistance of iron straps; and they are frequently necessary, even in roofs, notwithstanding this superabundant strength of the tie-beam. But this is generally owing to bad construction of the wooden joint, or to the failure of it by time. Straps will be considered in their place.

There needs but little to be said of the joints at a joggle worked out of solid timber; they are not near so difficult as the last. When the size of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a square shoulder; or, which is still better, an arch of a circle, having the other end of the brace for its centre. Indeed this in general will not sensibly differ from a straight line perpendicular to the brace. By this circular form, the settling of the roof makes no change in the abutment; but when there is not sufficient stuff for this,

CARPENTRY PLATE. XI.



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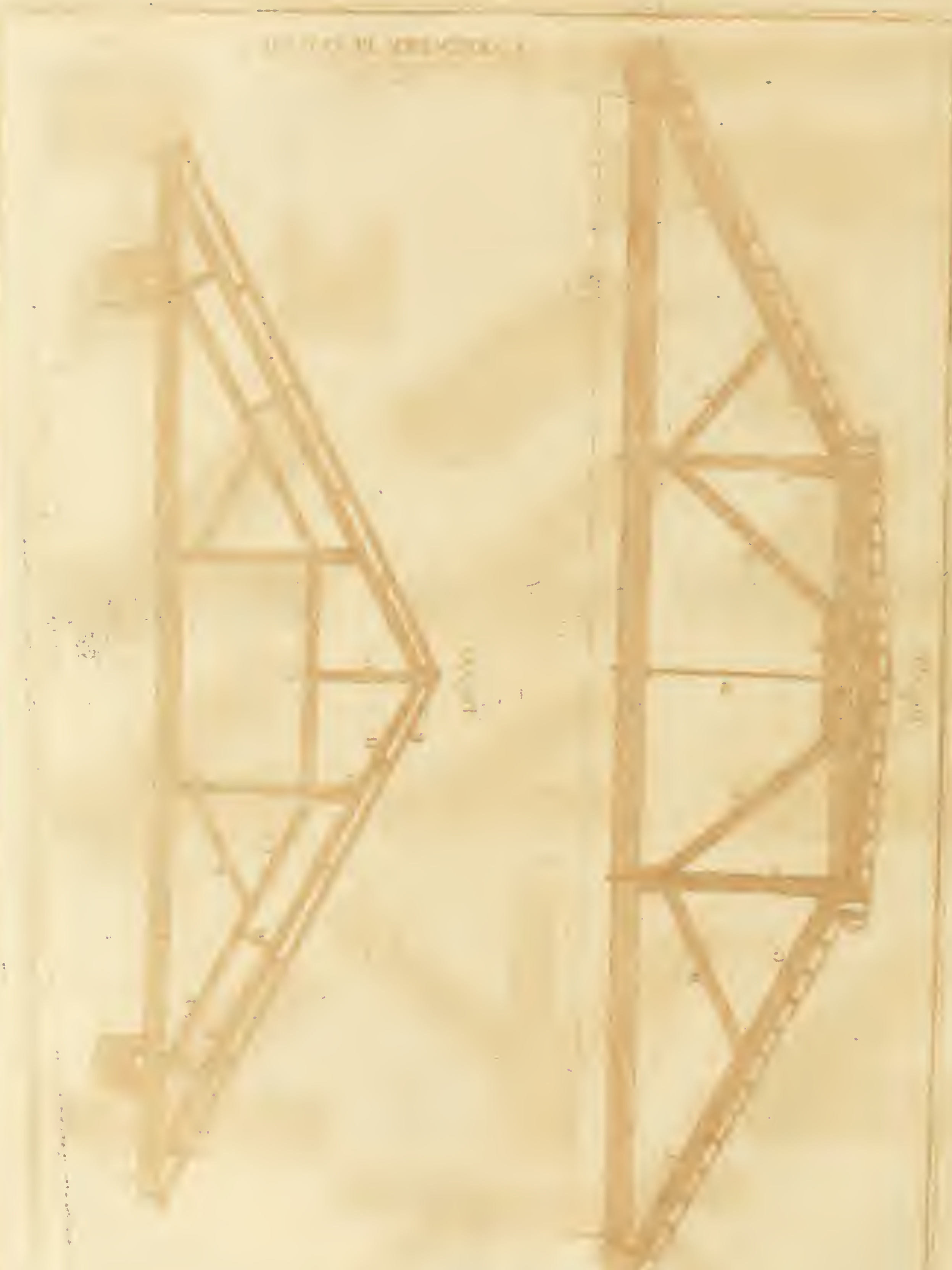


CARPENTRY PLATE XII.

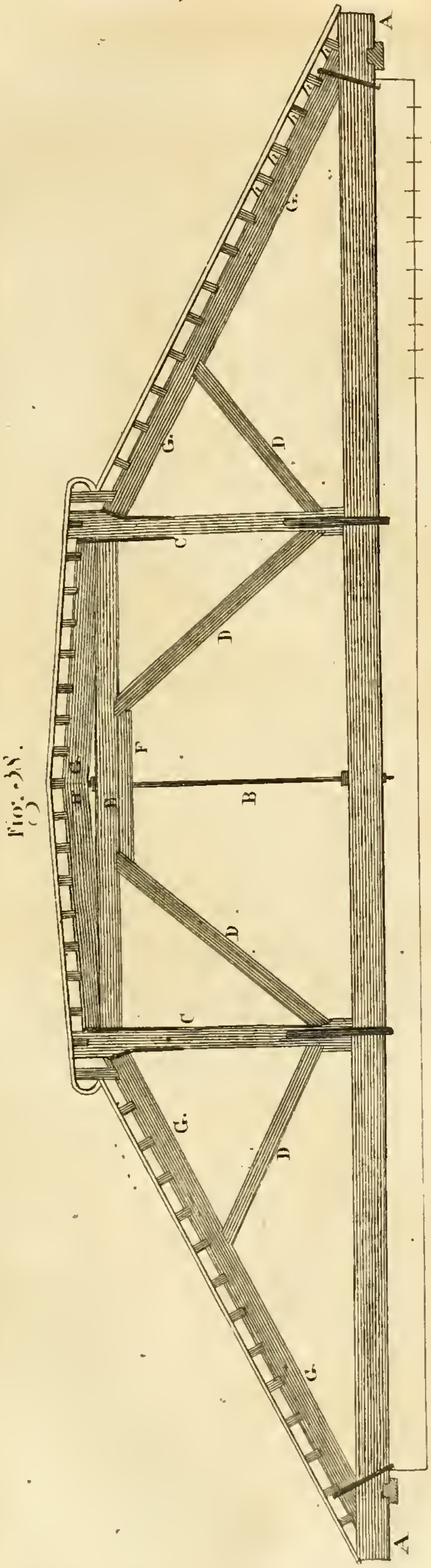


Fig. 38.

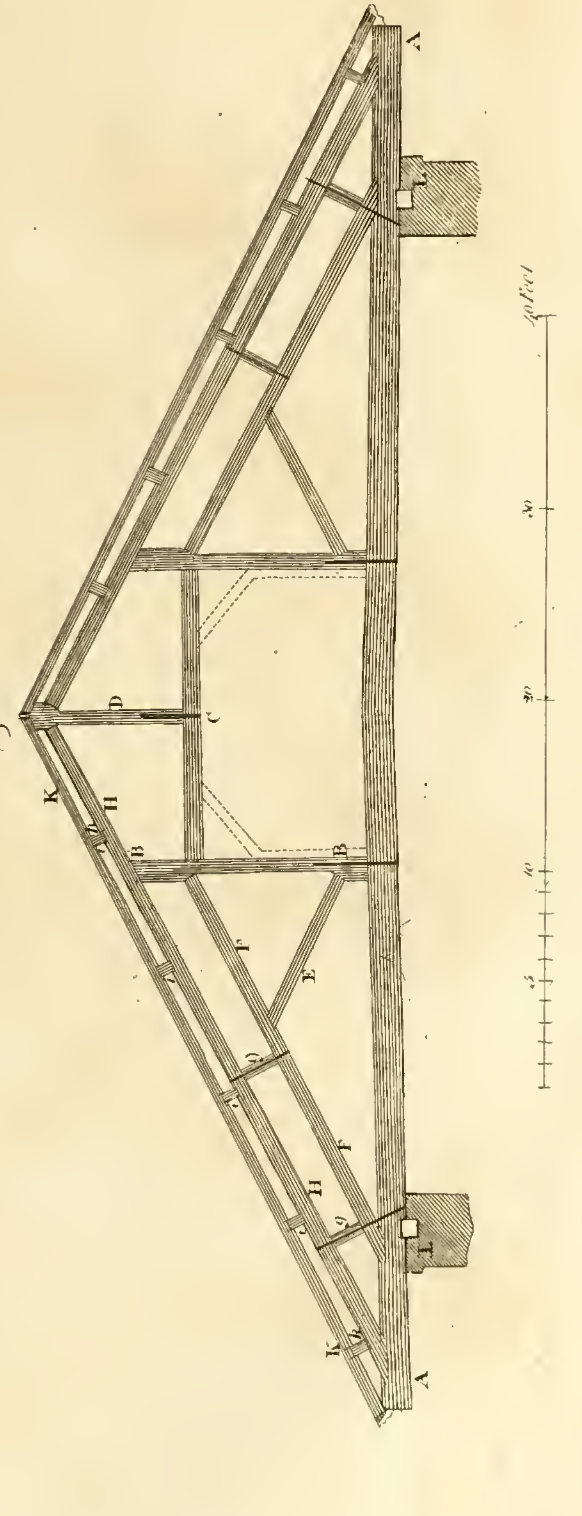


Fig. 39.

this, we muſt avoid bevel joints at the ſhoulders, becauſe theſe always tend to make the brace ſlide off. The brace in fig. 36. muſt not be joined as at *a*, but as at *b*, or ſome equivalent manner. Obſerve the joints at the head of the main poſts of Drury Lane theatre, fig. D.

40 Butting joints. When the very oblique action of one ſide of a frame of carpentry does not extend but compreſs the piece on which it abuts (as in fig. 11.), there is no difficulty in the joint. Indeed a joining is unneceſſary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual preſſure be equally borne by all parts, and that it do not produce lateral preſſures, which may cauſe one of the pieces to ſlide on the butting joint. A very ſlight mortiſe and tenon is ſufficient at the joggle of a king poſt with a rafter or ſtraining beam. It is beſt, in general, to make the butting plain, biſecting the angle formed by the ſides, or elſe perpendicular to one of the pieces. In fig. 36. n° 2. where the ſtraining beam *a b* cannot ſlip away from the preſſure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal preſſures on the different parts, by which ſome are crippled, others are ſplintered off, &c.

41 Directions for placing iron ſtraps. When it is neceſſary to employ iron ſtraps for ſtrengthening a joint, a conſiderable attention is neceſſary, that we may place them properly. The firſt thing to be determined is the direction of the ſtrain. This is learned by the obſervations in the beginning of this article. We muſt then reſolve this ſtrain into a ſtrain parallel to each piece, and another perpendicular to it. Then the ſtrap which is to be made faſt to any of the pieces muſt be ſo fixed, that it ſhall reſiſt in the direction parallel to the piece. Frequently this cannot be done; but we muſt come as near to it as we can. In ſuch caſes we muſt ſuppoſe that the aſſemblage yields a little to the preſſures which act on it. We muſt examine what change of ſhape a ſmall yielding will produce. We muſt now ſee how this will affect the iron ſtrap which we have already ſuppoſed attached to the joint in ſome manner that we thought ſuitable. This ſettling will perhaps draw the pieces away from it, leaving it looſe and unſerviceable (this frequently happens to the plates which are put to ſecure the obtuſe angles of butting timbers, when their bolts are at ſome diſtance from the angles, eſpecially when theſe plates are laid on the inſide of the angles); or it may cauſe it to compreſs the pieces harder than before; in which caſe it is anſwering our intention. But it may be producing croſs ſtrains, which may break them; or it may be crippling them. We can hardly give any general rules; but the reader will do well to read what is written in n° 36. and 41. of the article Roof, *Encycl.* In n° 36. he will ſee the nature of the ſtrap or ſtirrup, by which the king poſt carries the tie-beam. The ſtrap that we obſerve moſt generally ill-placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, but does not act againſt its horizontal thruſt. It ſhould be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It ſhould embrace the rafter almoſt horizontally near the foot, and ſhould be notched ſquare with the back of the rafter. Such a conſtruction is repreſented in fig. 37. By moving round the eye-bolt, it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that ſtraps which have eye-bolts in the very angles, and allow all motion round them, are of all the moſt perfect. A branched ſtrap, ſuch as may at once bind the king poſt and the two braces which butt on its foot, will be more ſerviceable if it have a joint. When a roof warps, thoſe branched ſtraps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artiſt will conſider how the beams will act on ſuch occaſions, and will avoid giving riſe to theſe great ſtrains by levers—A ſkilful carpenter never employs many ſtraps, conſidering them as auxiliaries foreign to his art, and ſubject to imperfections in workmanſhip which he cannot diſcern nor amend. We muſt refer the reader to Nicholſon's Carpenter and Joiner's Assistant for a more particular account of the various forms of ſtirrups, ſcrewed rods, and other iron work for carrying tie-beams, &c.

As for thoſe that are neceſſary for the turning joints of great engines conſtructed of timber, they make no part of the art of carpentry.

42 Examples of different pieces of carpentry. After having attempted to give a ſyſtematic view of the principles of framing carpentry, we ſhall conclude, by giving ſome examples which will illuſtrate and confirm the foregoing principles.

43 Roof of Greenwich chapel. Fig. 38. is the roof of the chapel of the Royal Hoſpital at Greenwich, conſtructed by Mr S. Wyatt.

	Inches Scantling.
AA, is the tie-beam, 57 feet long, ſpanning 51 feet clear	14 by 12
CC, Queen poſts	9 × 12
D, Braces	9 × 7
E, Truſs beam,	10 × 7
F, Straining piece	6 × 7
G, Principal rafters	10 × 7
H, A cambered beam for the platform	9.7
B, An iron ſtring, ſupporting the tie-beam	2 × 2

The truſſes are 7 feet apart, and the whole is covered with lead, the boarding being ſupported by horizontal ledgers *h*, *h*, of 6 by 4 inches.

This is a beautiful roof, and contains leſs timber than moſt of its dimenſions. The parts are all diſpoſed with great judgment. Perhaps the iron rod is unneceſſary; but it adds great ſtiffneſs to the whole.

The iron ſtraps at the rafter feet would have had more effect if not ſo oblique. Thoſe at the head of the poſts are very effective.

We may obſerve, however, that the joints between the ſtraining beam and its braces are not of the beſt kind, and tend to bruiſe both the ſtraining beam and the truſs beam above it.

44 St Pauls, Covent Garden. Fig. 39. the roof of St Paul's, Covent Garden, conſtructed by Mr Wapſhot in 1796.

AA, Tie-beam ſpanning 50 feet 2 inches	16.12
B, Queen poſt	9 × 8
C, Truſs beam	10 × 8
D, King poſt (14 at the joggle)	9 × 8
E, Brace	8 × 7½
FF, Principal brace (at bottom)	10 × 8½
HH, Principal rafter (at bottom)	10 × 8½
gg, Studs ſupporting the rafter	8 × 8

This roof far excels the original one put up by Inigo Jones. One of its truſſes contains 198 feet of timber.

One

One of the old roof had 273, but had many inactive timbers, and others ill difpofed (*N. B.* The figure which we gave of it in the article Roof, copied from Price, is very erroneous). The internal trufs FCF is admirably contrived for fupporting the exterior rafters, without any preffure on the far projecting ends of the tie-beam. The former roof had bent them greatly, fo as to appear ungraceful.

We think that the camber (fix inches) of the tie-beam is rather hurtful; becaufe by fettling, the beam lengthens; and this muft be accompanied by a *confiderable* finking of the roof. This will appear by calculation.

45 Birmingham theatre. Fig. 40. the roof of Birmingham theatre, conftructed by Mr Geo. Saunders. The fpan is 80 feet clear, and the truffes are 10 feet apart.

A, Is an oak corbel	9 × 5
B, Inner plate	9 × 9
C, Wall plate	8 × 5½
D, Pole plate	7 × 5
E, Beam	15 × 15
F, Straining beam	12 × 9
G, Oak king poft (in the fhaft)	9 × 9
H, Oak queen poft (in the fhaft)	7 × 9
I, Principal rafters	9 × 9½
K, Common ditto	4 × 2½
L, Principal braces	9 and 6 × 9
M, Common ditto	6 × 9
N, Purlins	7 × 5
Q, Straining fill	5½ × 9

This roof is a fine fpecimen of Britifh carpentry, and is one of the boldeft and lighteft roofs in Europe. The ftraining fill Q gives a firm abutment to the principal braces, and the fpace between the pofts is 19½ feet wide, affording roomy workfhops for the carpenters and other workmen connected with a theatre. The contrivance for taking double hold of the wall, which is very thin, is excellent. There is alfo added a beam (marked R), bolted down to the tie-beams. The intention of this was to prevent the total failure of fo bold a truffing, if any of the tie-beams fhould fail at the end by rot.

46 Drury Lane theatre. Akin to this roof is fig. 41. the roof of Drury Lane theatre, 80 feet 3 inches in the clear, and the truffes 15 feet apart, conftructed by Mr Edward Grey Saunders.

A, Beams	10 by 7
B, Rafters	7 × 7
C, King pofts	12 × 7
D, Struts	5 × 7
E, Purlins	9 × 5
G, Pole plates	5 × 5
I, Common rafters	5 × 4
K, Tie-beam to the main trufs	15 × 12
L, Pofts to ditto	15 × 12
M, Principal braces to ditto	14 and 12 × 12
N, Struts	8 × 12
P, Straining beams	12 × 12

The main beams are truffed in the middle fpace with oak truffes 5 inches fquare. This was neceffary for its width of 32 feet, occupied by the carpenters, painters, &c. The great fpace between the truffes afford good ftore-rooms, dreffing rooms, &c.

It is probable that this roof has not its equal in the world for lightnefs, ftiffnefs, and ftrength. The main trufs is fo judicioufly framed, that each of them will fafely bear a load of near 300 tons; fo it is not likely that they will ever be quarter loaded. The divifion of the whole into three parts makes the exterior roofings very light. The ftrains are admirably kept from the walls, and the walls are even firmly bound together by the roof. They alfo take off the dead weight from the main trufs one-third.

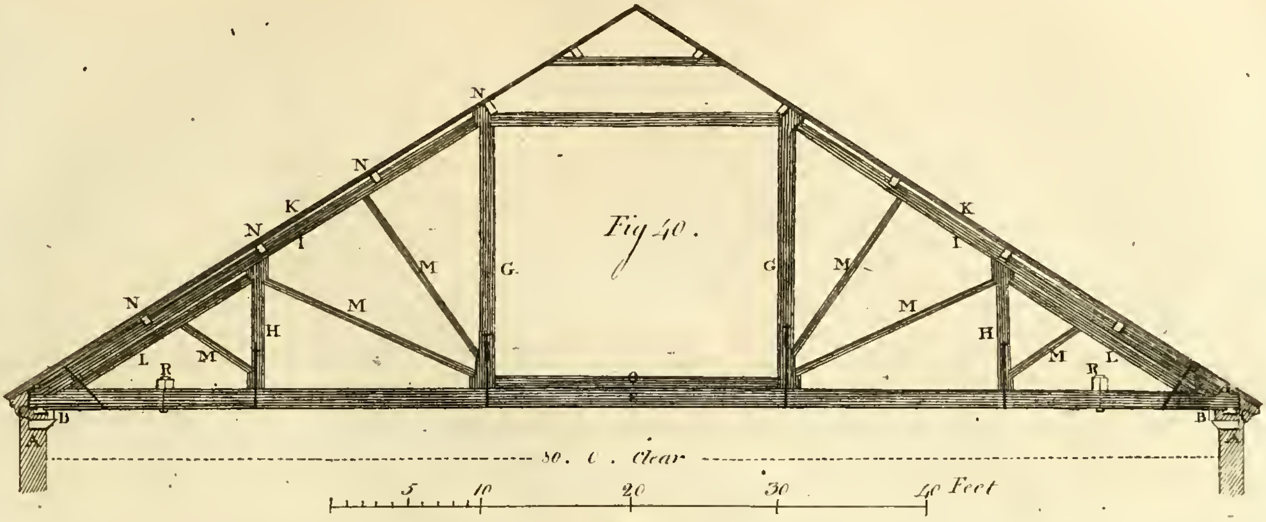
The intelligent reader will perceive that all thefe roofs are on one principle, depending on a trufs of three pieces and a ftraight tie-beam. This is indeed the great principle of a trufs, and is a ftep beyond the roof with two rafters and a king poft. It admits of much greater variety of forms, and of greater extent. We may fee, that even the middle part may be carried to any fpace, and yet be flat at top; for the trufs-beam may be fupported in the middle by an inverted king poft (of timber, not iron), carried by iron or wooden ties from its extremities: And the fame ties may carry the horizontal tie-beam K; for till K be torn afunder, or M, M, and P be crippled, nothing can fail. 47 Remarks.

The roof of St Martin's church in the Fields is conftructed on good principles, and every piece properly difpofed. But although its fpan does not exceed 40 feet from column to column, it contains more timber in a trufs than there is in one of Drury Lane theatre. The roof of the chapel at Greenwich, that of St Paul's, Covent Garden, that of Birmingham, and that of Drury Lane theatres, form a feries gradually more perfect. Such fpecimens afford excellent leffons to the artifts. We therefore account them a ufeful prefent to the public.

48 Project by Mr Nicholfon. There is a very ingenious project offered to the public by Mr Nicholfon (Carpenter's Affiftant, p. 68.) He propofes iron rods for king pofts, queen pofts, and all other fituations where beams perform the office of ties. This is in profecution of the notions which we publifhed in the article Roof of the *Encycl.* (fee n° 36, 37.) He receives the feet of the braces and ftruts in a focket very well connected with the foot of his iron king poft; and he fecures the feet of his queen pofts from being pufhed inwards, by interpofing a ftraining fill. He does not even mortife the foot of his principal rafter into the end of the tie-beam, but fets it in a focket like a fhoe, at the end of an iron bar, which is bolted into the tie-beam a good way back. All the parts are formed and difpofed with the precifion of a perfon thoroughly acquainted with the fubject; and we have not the fmalleft doubt of the fuccefs of the project, and the complete fecurity and durability of his roofs, and we expect to fee many of them executed. We abound in iron, but we muft fend abroad for building timber. This is therefore a valuable project; at the fame time, however, let us not over-rate its value. Iron is but about 12 times ftronger than red fir, and is more than 12 times heavier; nor is it cheaper, weight for weight, or ftrength for ftrength.

Our illuftrations and examples have been chiefly taken from roofs, becaufe they are the moft familiar inftances of the difficult problems of the art. We could have wifhed for more room even on this fubject. The conftruction of dome roofs has been (we think) miftaken, and the difficulty is much lefs than is imagined. We mean in refpect of ftrength; for we grant that the obliquity

CARPENTRY PLATE. XIII.



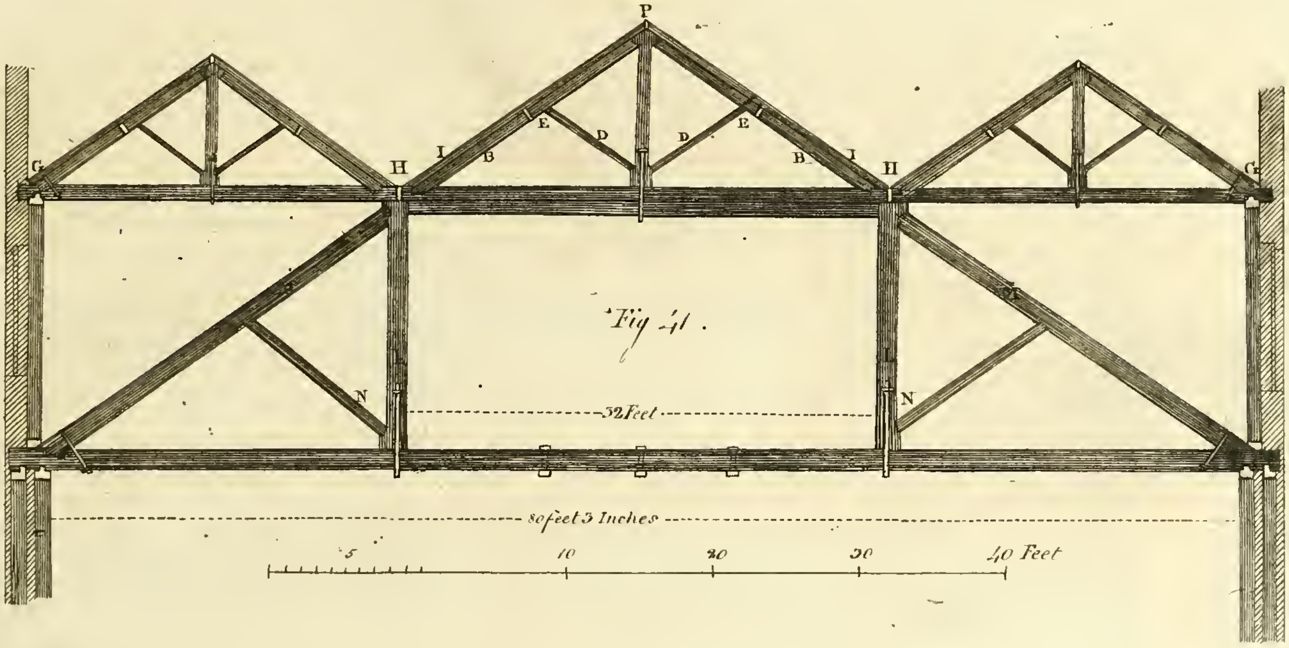
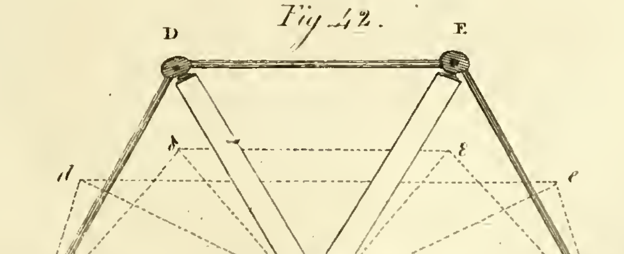


Fig 42.



H.B.W.fc.

obliquity of the joints, and a general intricacy, increaſes the trouble of workmanſhip exceedingly. Another opportunity may perhaps occur for conſidering this ſubject.

49 Wooden bridges. Wooden bridges form another claſs equally difficult and important; but our limits are already overpaſſed, and will not admit them. The principle on which they ſhould all be conſtructed, without exception, is that of a truſs, avoiding all lateral bearings on any of the timbers. In the application of this principle, we muſt farther remark, that the angles of our truſs ſhould be as acute as poſſible; therefore we ſhould make it of as few and as long pieces as we can, taking care to prevent the bending of the truſs beams by bridles, which embrace them, but without preſſing them to either ſide. When the truſs conſiſts of many pieces, the angles are very obtuſe; and the thruſts increaſe nearly in the duplicate proportion of the number of angles. The proper maxims will readily occur to the artiſt who conſiders with attention the ſpecimens of centres or coombs, which we ſhall give in the article CENTRE.

50 Framing of great levers. With reſpect to the frames of carpentry which occur in engines and great machines, the varieties are ſuch that it would require a volume to treat of them properly. The principles are already laid down; and if the reader be really intereſted in the ſtudy, he will engage in it with ſeriouſneſs, and cannot fail of being inſtructed. We recommend to his conſideration, as a ſpecimen of what may be done in this way, the working beam of Hornblower's ſteam engine (ſee *STEAM-Engine*, n° 84. *Encycl.*) When the beam muſt act by chains hung from the upper end of arch heads, the framing there given ſeems very ſcientifically conſtructed; at the ſame time, we think that a ſtrap of wrought iron, reaching the whole length of the upper bar (ſee the figure), would be vaſtly preferable to thoſe partial plates which the engineer has put there, for the bolts will ſoon work looſe.

But when arches are not neceſſary, the form employed by Mr Watt is vaſtly preferable, both for ſimplicity and for ſtrength. It conſiſts of a ſimple beam AB (fig. 42.), having the gudgeon C on the upper ſide. The two piſton rods are attached to wrought iron joints A and B. Two ſtrong ſtruts DC, EC reſt on the upper ſide of the gudgeon, and carry an iron ſtring ADEB, conſiſting of three pieces, connected with the ſtruts by proper joints of wrought iron. A more minute deſcription is not needed for a clear conception of the principle. No part of this is expoſed to a croſs ſtrain; even the beam AB might be ſawed through at the middle. The iron ſtring is the only part which is ſtretched; for AC, DC, EC, BC, are all in a ſtate of compreſſion. We have made the angles equal, that all may be as great as poſſible, and the preſſure on the ſtruts and ſtrings a minimum. Mr Watt makes them much lower, as $A\,d\,e\,B$, or $A\,\delta\,\epsilon\,B$. But this is for economy, becauſe the ſtrength is almoſt inſuperable. It might be made with wooden ſtrings; but the workmanſhip of the joints would more than compenſate the cheapneſs of the materials.

WE offer this article to the public with deference, and we hope for an indulgent reception of our eſſay on a ſubject which is in a manner new, and would require much ſtudy. We have beſtowed our chief attention on the ſtrength of the conſtruction, becauſe it is here that perſons of the profeſſion have the moſt ſcanty information. We beg them not to conſider our obſervations as too refined, and that they will ſtudy them with care. One principle runs through the whole; and when that is clearly conceived and familiar to the mind, we venture to ſay that the practitioner will find it of eaſy application, and that he will improve every performance by a continual reference to it. 51 Concluſion.

If this attempt to inſtruct our moſt valuable and much eſteemed artiſts ſhall appear to meet with their approbation, it may encourage us to engage in the ſerious taſk of compoſing a ſyſtem on the ſubject. But this is a great work, and will require much time and liberal contribution of knowledge from the eminent carpenters who do honour to this country by their works.

CAR

CAR

Carré. CARRE' (Lewis), was, in 1663, born in the province of Brie in France; and refuſing to enter into the ſervice of the church, for which his education was intended to fit him, he incurred the diſpleaſure of his father. His reſources being thus cut off, he was obliged to quit the univerſity, and go out into the world without employment or the means of ſubſiſtence. In this exigency he was ſomehow introduced to the celebrated Malebranche, and retained by him as an amanuenſis. Under this great maſter he ſtudied mathematics and metaphyſics, and could hardly fail to become ſtrongly attached to the latter ſcience. After reſiding ſeven years with Malebranche, he reſolved to enter upon ſome employment, which might procure him a leſs precarious eſtabliſhment than what could be enjoyed by the favour of any individual: and with that view he began at Paris a courſe of lectures in mathematics, metaphyſics, and moral philoſophy, to ſuch young ladies and gentlemen as choſe to put themſelves under his tuition. When we think of the maſter under whom he himſelf ſtudied thoſe ſciences, we cannot wonder that he made geometry ſerve merely as an introduction to his beloved metaphyſics; and indeed the order of his courſe deſerves to be univerſally adopted. It is ſurely much better to accuſtom the youthful mind to ſteady apprehenſion and patient thinking in the ſtudy of the ancient geometry, before it proceed to ſciences more abſtract, than to hurry it at once, as is the practice in ſome univerſities, into all the mazes and intricacies of what is called the firſt philoſophy. Carré.

But although M. Carré gave the preference to metaphyſics, he did not neglect mathematics; and while he taught both, he took care to make himſelf acquainted with all the new diſcoveries in the latter. This was all that his conſtant attendance on his pupils would allow him to do till the year 1697, when M. Varignon ſo remarkable for his extreme ſcrupulouſneſs in the choice of his eleves, took M. Carré to him in that ſtation. Soon after, viz. in the year 1700, our author, thinking himſelf bound to do ſomething that might render him worthy of that title, publiſhed the firſt complete work on the integral calculus, under the title of "A Method of

Carré.

of Measuring Surfaces and Solids, and finding their Centres of Gravity, Percussion, and Oscillation." He afterwards discovered some errors in the work, and was candid enough to own and correct them in a subsequent edition.

In a little time M. Carré became associate, and at length one of the pensioners of the Academy. And as this was a sufficient establishment for one who knew so well how to keep his desires within just bounds, he gave himself up entirely to study; and as he enjoyed the appointment of mechanician, he applied himself more particularly to mechanics. He took also a survey of every branch relating to music; such as the doctrine of sounds, and the description of musical instruments; though he despised the practice of music as a mere sensual pleasure. Some sketches of his ingenuity and industry in this way may be seen in the Memoirs of the French Academy of Sciences. M. Carré also composed some treatises on other branches of natural philosophy, and some on mathematical subjects; all which he bequeathed to that illustrious body, though it does not appear that any of them have yet been published. It is not unlikely that he was hindered from putting the last hand to them by a train of disorders proceeding from a bad digestion, which, after harrassing him during the space of five or six years, at length brought him to the grave in 1711, at 48 years of age.

Though he possessed a considerable degree of science and much ingenuity, like many other eminent men he had neglected in his youth to study the language of his native country. In consequence of this, one of the earliest of his female pupils, perceiving that his language was the reverse of elegant, told him pleasantly, that as an acknowledgment for the trouble which he had taken to teach her philosophy, she would in return teach him French; and he ever afterwards said, that from her lessons he had reaped great advantage. To this circumstance probably it was owing that he thought more highly of the genius of women than that of men.

The following is a chronological list of his memoirs printed in the volumes of the Academy.

1. The rectification of curve lines by tangents, 1701. 2. Solution of a problem proposed to geometricians, &c. 1701. 3. Reflections on the table of equations, 1701. 4. On the cause of the refraction of light, 1702. 5. Why the tides are always augmenting from Brest to St Malo, and diminishing along the coasts of Normandy, 1702. 6. The number and the names of musical instruments, 1702. 7. On the vinegar which causes small stones to roll upon an inclined plane, 1703. 8. On the rectification, &c. of the caustics by reflection, 1703. 9. Method for the rectification of curves, 1704. 10. Observations on the production of sound, 1704. 11. On a curve formed from a circle, 1705. 12. On the refraction of musket-balls in water, and on the resistance of that fluid, 1705. 13. Experiments on capillary tubes, 1705. 14. On the proportion of pipes to have a determinate quantity of water, 1705. 15. On the laws of motion, 1706. 16. On the properties of pendulums, with some new properties of the parabola, 1707. 17. On the proportion of cylinders, that their sounds may form the musical cords, 1709. 18. On the elasticity of the air, 1710. 19. On catoptrics, 1710. 20. On the Monochord: in the *Machines*, tom. 1. with some other pieces, not mathematical.

Carteret ‖ Cassini.

CARTERET, a maritime co. of Newbern district, N. Carolina, on Core and Pamlico Sounds. It contains 3732 inhabitants, including 713 slaves. Beaufort is the chief town.—*Morse.*

CASCABEL, the knob or button of metal behind the breech of a cannon, as a kind of handle by which to elevate and direct the piece; to which some add the fillet and ogees as far as the base-ring.

CASCO *Bay*, in the district of Maine, spreads N. W. between Cape Elizabeth on the S. W. and Cape Small Point on the N. E. Within these points, which are about 40 miles apart, are about 300 small islands, some of which are inhabited, and nearly all more or less cultivated. The land on these islands, and on the opposite coast on the main, is the best for agriculture of any on the sea coast of this country. Casco includes several bays. *Maquoit Bay* lies about 20 miles N. of Cape Elizabeth. The waters of Casco extend several arms or creeks of salt water into the country. The waters go up *Meadows River*, where vessels of a considerable size are carried by the tide, and where it flows within one mile of the waters of Kennebeck. On the E. side of Cape Elizabeth is the arm of the sea called *Stroudwater*. Farther E. is *Presumpscot River* formerly called Presumpca, or Presumpkeag, which rises in Sebago Pond. This river opens to the waters of Casco Bay on the E. of Portland; its extent is not great, but it has several valuable mills upon it. *Rayal's River* called by the natives Westecustego, falls into the bay 6 miles from Presumpscot River. It has a good harbor at its mouth for small vessels; and has several mills upon it; 2 miles higher a fall obstructs the navigation. Between it and Kennebeck there are no rivers; some creeks and harbors of Casco Bay throw themselves into the main land, affording harbors for small vessels, and intersecting the country in various forms.—*Morse.*

CASEMATE, or CAZEMATE, in fortification, a kind of vault or arch of stone-work, in that part of the flank of a bastion next the curtain; serving as a battery to defend the face of the opposite bastion, and the moat or ditch.

It is now seldom used, because the batteries of the enemy are apt to bury the artillery of the casemate in the ruins of the vault; beside, the great smoke made by the discharge of the cannon renders it intolerable to the men. So that, instead of the ancient covered casemates, later engineers have contrived open ones, only guarded by a parapet, &c.

CASEMATE is also used for a well with several subterraneous branches, dug in the passage of the bastion, till the miner is heard at work, and air given to the mine.

CASSINI (James), a celebrated French astronomer, was born at Paris February 18. 1677, being the younger son of Johannes Dominicus Cassini, of whom some account has been given in the *Encyclopædia*.

After his first studies in his father's house, in which it is not to be supposed that mathematics and astronomy would be neglected, he was sent to study philosophy at the Mazarine college, where the celebrated Varignon was then professor of mathematics. From the assistance of this eminent man young Cassini profited so well, that at 15 years of age he supported a mathematical thesis with great honour. At the age of 17 he was admitted a member of the Academy of Sciences; and the same year he accompanied

accompanied his father in a journey to Italy, where he affifted him in the verification of the meridian at Bologna and other meafurements. On his return he performed fimilar operations in a journey into Holland, where he difcovered fome errors in the meafure of the earth by Snell, the refult of which was communicated to the Academy in 1702. He made alfo a vifit to England in 1696, where he was made a member of the Royal Society. In 1712 he fucceeded his father as aftronomer royal at the obfervatory of Paris. In 1717 he gave to the Academy his refearches on the diftance of the fixed ftars; in which he fhewed that the whole annual orbit, of near 200 millions of miles diameter, is but as a point in comparifon of that diftance. The fame year he communicated alfo his difcoveries concerning the inclination of the orbits of the fatellites in general, and efpecially of thofe of Saturn's fatellites and ring. In 1725 he undertook to determine the caufe of the moon's libration, by which fhe fhews fometimes a little towards one fide, and fometimes a little on the other, of that half which is commonly behind or hid from our view.

In 1732 an important queftion in aftronomy exercifed the ingenuity of our author. His father had determined, by his obfervations, that the planet Venus revolved about her axis in the fpace of 23 hours; and M. Bianchini had publifhed a work in 1729, in which he fettled the period of the fame revolution at 24 days 8 hours. From an examination of Bianchini's obfervations which were upon the fpots in Venus, he difcovered that he had intermitted his obfervations for the fpace of three hours, from which caufe he had probably miftaken new fpots for the old ones, and fo had been led into the miftake. The probability is, that both had fallen into fome miftake, or that they had proceeded on very different principles; for otherwife fuch different refults are wholly unaccountable. Dr Herfchel feems fatisfied that the period of the revolution is lefs than Bianchini has made; but he does not fay what it is, or that it is not much greater than it was fuppofed by Caffini. Our author, after he had convicted Bianchini, as he thought, of error, determined the nature and quantity of the acceleration of the motion of Jupiter at half a fecond per year, and of that of the retardation of Saturn at two minutes per year; that thefe quantities would go on increafing for 2000 years, and then would decreafe again. In 1740 he publifhed his Aftronomical Tables, and his Elements of Aftronomy; very extenfive and accurate works.

Although aftronomy was the principal object of our author's confideration, he did not confine himfelf abfolutely to that branch, but made occafional excurfions into other fields. We owe alfo to him, for example, Experiments on Electricity, or the Light produced by Bodies by Friction; Experiments on the Recoil of Fire-arms; Refearches on the Rife of the Mercury in the Barometer at different Heights above the Level of the Sea; Reflections on the perfecting of Burning-glaffes; and other Memoirs.

The French Academy had properly judged, that one of its moft important objects was the meafurement of the earth. In 1669 Picard meafured a little more than a degree of latitude to the north of Paris; but as that extent appeared too fmall from which to conclude the whole circumference with fufficient accuracy, it was refolved to continue that meafurement on the meridian of Paris to the north and the fouth, through the whole extent of the country. Accordingly, in 1683, the late M. de la Hire continued that on the north fide of Paris, and the older Caffini that on the fouth fide. The latter was affifted in 1700 in the continuation of this operation by his fon our author. The fame work was farther continued by the fame academicians; and, finally, the part left unfinifhed by De la Hire in the north was finifhed in 1718 by our author, with the late Maraldi, and De la Hire the younger.

Thefe operations produced a confiderable degree of precifion. It appeared alfo, from this meafured extent of fix degrees, that the degrees were of different lengths in different parts of the meridian; and in fuch fort that our author concluded, in the volume publifhed for 1718, that they decreafed more and more towards the pole, and that therefore the figure of the earth was that of an oblong fpheroid, or having its axis longer than the equatorial diameter. He alfo meafured the perpendicular to the fame meridian, and compared the meafured diftance with the differences of longitude as before determined by the eclipfes of Jupiter's fatellites: whence he concluded that the length of the degrees of longitude was fmaller than it would be on a fphere, and that therefore again the figure of the earth was an oblong fpheroid, contrary to the determination of Newton by the theory of gravity. Though Newton was of all men the moft averfe from controverfy, the other mathematicians in Britain did not tamely fubmit to conclufions in direct oppofition to the fundamental doctrine of a philofopher of whofe talents the nation was juftly proud. The confequence was, that the French government fent two different fets of meafurers, the one to meafure a degree at the equator, the other at the polar circle; and the comparifon of the whole determined the figure to be an oblate fpheroid, contrary to Caffini's determination.

After a long and laborious life, James Caffini died in April 1756, in confequence of a fall, and was fucceeded in the Academy and Obfervatory by the fubject of the following article. He publifhed, A Treatife on the Magnitude and Figure of the Earth; as alfo, The Elements or Theory of the Planets, with Tables; befide an infinite number of papers in the Memoirs of the Academy, from the year 1699 to 1755.

Cassini de Thury (Cefar François), a celebrated French aftronomer, director of the obfervatory, penfioner aftronomer, and member of moft of the learned focieties of Europe, was born at Paris June 17. 1714, being the fecond fon of James Caffini, the fubject of the preceding memoir, whofe occupations and talents he inherited and fupported with great honour. He received his firft leffons in aftronomy and mathematics from MM. Maraldi and Camus; and made fuch a rapid progrefs, that when he was not more than ten years of age he calculated the phafes of a total eclipfe of the fun. At the age of eighteen he accompanied his father in his two journeys undertaken for drawing the perpendicular to the obfervatory meridian from Strafbourg to Breft. From that time a general chart of France was devifed; for which purpofe it was neceffary to traverfe the country by feveral lines parallel and perpendicular to the meridian of Paris, and our author was charged with the conduct of this bufinefs; in which he was fo fcrupulous as to meafure again what had been meafured ed by his father. This great work was publifhed in 1740, with a chart fhewing the new meridian of Paris, by two different feries of triangles, paffing along the fea coafts to Bayonne, traverfing the frontiers of Spain to the Mediterranean and Antibes, and thence along the eaftern limits of France to Dunkirk, with parallel and perpendicular lines defcribed at the diftance of 6000 toifes from one another, from fide to fide of the country.

A tour which, in 1741, our author made in Flanders, in the train of the king, gave rife, at his majefty's inftance, to the chart of France; relative to which Caffini publifhed different works, as well as a great number of the fheets of the chart itfelf. In 1761 he undertook an expedition into Germany, for the purpofe of continuing to Vienna the perpendicular of the Paris meridian; to unite the triangles of the chart of France with the points taken in Germany; to prepare the means of extending into that country the fame plan as in France; and thus to eftablifh fucceffively for all Europe a moft ufeful uniformity.—Our author was at Vienna the 6th of June 1761, the day of the tranfit of the planet Venus over the fun, of which he obferved as much as the ftate of the weather would permit him to do, and publifhed the account of it in his *Voyage en Allemagne*.

Finally, M. Caffini, always meditating the perfection of his grand defign, profited of the peace of 1783 to propofe the joining of certain points taken upon the Englifh coaft with thofe which had been determined on the coaft of France, and thus to connect the general chart of the latter with that of the Britifh ifles, like as he had before united it with thofe of Flanders and Germany. The propofal was favourably received by the Englifh government, and prefently carried into effect under the direction of the Royal Society, the execution being committed to the late General Roy. See the life of that general in this *Supplement*.

Between the years 1735 and 1770, M. Caffini publifhed, in the volumes of Memoirs of the French Academy, a prodigious number of pieces, confifting chiefly of aftronomical obfervations and queftions; among which are obfervable, refearches concerning the parallax of the fun, the Moon, Mars, and Venus; on aftronomical refractions, and the effect caufed in their quantity and laws by the weather; numerous obfervations on the obliquity of the ecliptic, and on the law of its variations. In fhort, he cultivated aftronomy for fifty years, the moft important for that fcience that ever elapfed for the magnitude and variety of objects, in which he commonly fuftained a principal fhare.

M. Caffini was of a very ftrong and vigorous conftitution, which carried him through the many laborious operations in geography and aftronomy which he conducted. An habitual retention of urine, however, rendered the laft twelve years of his life very painful and diftreffing, till it was at length terminated by the fmallpox the 4th of September 1784, in the 71ft year of his age. He was fucceeded in the academy, and as director of the obfervatory, by his only fon John-Dominic Caffini, the fourth in order of direct defcent who has filled that honourable ftation.

CASTINE, the fhire town of Hancock co. diftrict of Maine, is fituated on Penobfcot bay. It was taken from the town of Penobfcot, and incorporated in Feb. 1796. It is named after a French gentleman who refided here 130 years ago, as alfo

Castine *River*, which is about 14 miles long, is navigable for 6 miles, and has feveral mills at the head of it. It empties into Penobfcot bay.—*Morse*.

CASTLETON, a townfhip and river in Rutland co. Vermont, 20 miles S. E. of Mount Independence, at Ticonderoga. Lake Bombazon is chiefly in this town and fends its waters into Caftleton River which, rifing in Pittsford, paffes through this town in a S. wefterly courfe, and falls into Pultney River in the town of Fairhaven, a little below Col. Lyon's iron works. Fort Warner ftands in this town. Inhabitants 805.—*ib.*

CASTRAMETATION, the art or act of encamping an army.

CASWELL *Co.* in Hillfborough diftrict, N. Carolina, borders on Virginia N. It contains 10,096 inhabitants, of whom 2,736 are flaves. Leefburg is the chief town.—*Morse*.

CATABAW *Indians*, a fmall tribe who have one town called Catabaw, fituated on the river of that name, N. lat. 34. 49. on the boundary line between N. and S. Carolina, and contains about 450 inhabitants, of which about 150 are fighting men. They are the only tribe which refides in the ftate: 144 000 acres of land were granted them by the proprietary government. Thefe are the remains of a formidable nation, the braveft and moft generous enemy the fix nations had; but they have degenerated fince they have been furrounded by the whites. —*ib.*

CATACAUSTICS, or Catacaustic Curves, in the higher geometry, are the fpecies of cauftic curves formed by reflection.

CATACOUSTICS, or Cataphonics, is the fcience of reflected founds; or that part of acouftics which treats of the properties of echoes.

CATALOGUES of Books, is a fubject of which a very curious hiftory has been given to the world by Profeffor Beckmann. In the Encyclopædia mention has been made of fome of the moft valuable catalogues, their defects pointed out, and rules given for making them more perfect; but nothing has there been faid of their origin, or of the ufes which might be made of the oldeft catalogues.

According to the Profeffor, George Willer, whom fome improperly call Viller, and others Walter, a bookfeller at Augfburg, who kept a very large fhop, and frequented the Franckfort fairs, firft fell upon the plan of caufing to be printed, before every fair, a catalogue of all the new books, in which the fize and printers names were marked Le Mire, better known under the name of Miræus, fays, that catalogues were firft printed in the year 1554; but Labbe (A), Reimann (B) and Heumann (C), who took their information from Le Mire, make the year erroneoufly to be 1564.

Willer's

(A) Labbe, Bibliotheca Bibliothecarum. Lipfiæ, 1682, 12mo, p. 112.

(B) Einleitung in die *Hiftoriam Literariam*, i. p. 203.

(C) Confpectus Reip. Litter. c. vi. § 2. p. 316.

Catalogues.

Willer's catalogues were printed till the year 1592 by Nicol. Baſſæus, printer at Franckfort. Other bookſellers, however, muſt have ſoon publiſhed catalogues of the like kind, though that of Willer continued a long time to be the principal.

In all theſe catalogues, which are in quarto and not paged, the following order is obſerved. The Latin books occupy the firſt place, beginning with the Proteſtant theological works, perhaps becauſe Willer was a Lutheran; then come the Catholic; and after theſe, books of juriſprudence, medicine, philoſophy, poetry, and muſic. The ſecond place is aſſigned to German books, which are arranged in the ſame manner.

The bookſellers of Leipſic ſoon perceived the advantage of catalogues, and began not only to reprint thoſe of Franckfort, but alſo to enlarge them with many books which had not been brought to the fairs in that city. Our author had for ſome time in his cuſtody, *Catalogus univerſalis pro nundinis Francofurtenſibus vernalibus, de anno* 1600; or, A catalogue of all the books on ſale in Book-ſtreet, Franckfort, and alſo of the books publiſhed at Leipſic, which have not been brought to Franckfort, with the permiſſion of his highneſs the elector of Saxony, to thoſe new works which have appeared at Leipſic. Printed at Leipſic by Abraham Lamberg, and to be had at his ſhop. On the September catalogue of the ſame year, it is ſaid that it is printed from the Franckfort copy with additions. He found an Imperial privilege for the firſt time on the Franckfort September catalogue of 1616: *Cum gratia et privilegio ſpeciali ſ. caeſ. maj. Proſtat. apud J. Krugerum Auguſtanum.*

Reimmann ſays, that after Willer's death the catalogue was publiſhed by the Leipſic bookſeller Henning Groſſe, and by his ſon and grandſon. The council of Franckfort cauſed ſeveral regulations to be iſſued reſpecting catalogues; an account of which may be ſeen in D. Orth's *Treatiſe on the Imperial Fairs at Franckfort.* After the buſineſs of book-ſelling was drawn from Franckfort to Leipſic, occaſioned principally by the reſtrictions to which it was ſubjected at the former by the cenſors, no more catalogues were printed there; and the ſhops in Book-ſtreet were gradually converted into taverns (A).

"In the 16th century there were few libraries; and theſe, which did not contain many books, were in monaſteries, and conſiſted principally of theological, philoſophical, and hiſtorical works, with a few, however, on juriſprudence and medicine; while thoſe which treated of agriculture, manufactures, and trade, were thought unworthy of the notice of the learned, or of being preſerved in large collections. The number of theſe works was, nevertheleſs, far from being inconſiderable; and at any rate, many of them would have been of great uſe, as they would have ſerved to illuſtrate the inſtructive hiſtory of the arts. Catalogues which might have given occaſion to inquiries after books, that may be ſtill ſomewhere preſerved, have ſuffered the fate of tombſtones, which, being waſted and crumbled to pieces by the deſtroying hand of time, become no longer legible. A complete ſeries of them perhaps is nowhere to be found, at leaſt I do not remember (ſays the Profeſſor) to have ever ſeen one in any library."

Catalogues ‖ Catalogue of the Stars.

This loſs, however, he thinks, might be in ſome meaſure ſupplied by the catalogues of Cleſs and Draudius; who, by the deſire of ſome bookſellers, collected together all the catalogues which had been publiſhed at the different fairs in different years. The work of Cleſs has the following title: *Unius ſæculi ejuſque virorum litteratorum monumentis tum florentiſſimi, tum fertiliſſimi, ab anno* 1500 *ad* 1602 *nundinarum autumnalium incluſive, elenchus conſummatiſſimus—deſumtus partim ex ſingularum nundinarum catalogis, partim ex bibliothecis.* Auctore Joanne Cleſſio, Winecceuſi, Hannoio, philoſopho ac medico.—By the editor's preface, it appears that the firſt edition was publiſhed in 1592. The order is almoſt the ſame as that obſerved by Willer in his catalogues.

The work of Draudius, which was printed in ſeveral quarto volumes for the firſt time in 1611, and afterwards in 1625, is far larger, more complete, and more methodical. Our author, however, confeſſes, that he never ſaw a perfect copy of either edition. This catalogue conſiſts of three parts; of which the firſt has the title of *Bibliotheca claſſica, ſive Catalogus officinalis, in quo ſinguli ſingularum facultatum ac profeſſionum libri, qui in quavis fere lingua extant—recenſentur; uſque ad annum* 1624 *incluſive.* Auctore M. Georgio Draudio.—It contains Latin works on theology, juriſprudence, medicine, hiſtory, geography, and politics. The copy in the library of the univerſity of Gottingen ends at page 1304, which has, however, a catch-word, that ſeems to indicate a deficiency.—The ſecond part is entitled, *Bibliotheca claſſica ſive Catalogus officinalis, in quo philoſophici artiumque adeo humaniorum, poetici etiam et muſici libri uſque ad annum* 1624 *continentur.* This part, containing Latin books alſo, begins at page 1298, and ends with page 1654, which is followed by an index of all the authors mentioned.—A ſmaller volume, of 302 pages, without an index, has for title, *Bibliotheca exotica, ſive Catalogus officinalis librorum peregrinis linguis uſualibus ſcriptorum.* And a third part, forming 759 pages, beſides an index of the authors, is called, *Bibliotheca librorum Germanicorum claſſica;* that is, A catalogue of all the books printed in the German language till the year 1625.

We have reaſon to believe that there are other editions of this catalogue than thoſe mentioned by Profeſſor Beckman; and it might become ſome prince or great man, for it is not a work for a bookſeller, to compare all the editions together, and publiſh a new one more correct than any that is at preſent extant. This indeed would be an expenſive and not an eaſy taſk; for our author obſerves, that all the oldeſt catalogues had the ſame faults as thoſe of later date, and that theſe faults have been copied by Draudius. Many books are mentioned which were never printed, and many titles, names, and dates, are given incorrectly; but Draudius nevertheleſs is well worth the attention of any one who may be inclined to employ his time and ingenuity on the hiſtory of literature; and his work certainly was of uſe to Haller when he compoſed his *Bibliotheca.*

CATALOGUES *of the Stars,* have uſually been diſpoſed, either

(A) Joh. Adolp. Stock, Frankfurter Chronik, p. 77.

either as collected into certain figures called *conſtellations*, or according to their right aſcenſions, that is, the order of their paſſing over the meridian.

Of the principal catalogues, according to the firſt of theſe forms, an account has been given in the *Encyclopædia*. The firſt catalogue, we believe, that was printed in the new or ſecond form, according to the order of the right aſcenſions, is that of De la Caille, given in his Ephemerides for the ten years between 1755 and 1765, and printed in 1755. It contains the right aſcenſions and declinations of 307 ſtars, adapted to the beginning of the year 1750. In 1757 De la Caille publiſhed his *Aſtronomiæ Fundamenta*, containing a catalogue of the right aſcenſions and declinations of 398 ſtars, likewiſe adapted to the beginning of 1750. And in 1763, the year after his death, was publiſhed the *Cœlum Auſtrale Stelliferum* of the ſame author; containing a catalogue of the places of 1942 ſtars, all ſituated to the ſouthward of the tropic of Capricorn, and obſerved by him while he was at the Cape of Good Hope in 1751 and 1752; their places being alſo adapted to the beginning of 1750. In the ſame year was publiſhed his Ephemerides for the ten years between 1765 and 1775; in the introduction to which are given the places of 515 zodiacal ſtars, all deduced from the obſervations of the ſame author; the places adapted to the beginning of the year 1765.

In the Nautical Almanac for 1773, is given a catalogue of 387 ſtars, in right aſcenſion, declination, longitude, and latitude, derived from the obſervations of the late celebrated Dr Bradley, and adjuſted to the beginning of the year 1760. This ſmall catalogue, and the reſults of about 1200 obſervations of the moon, are all that the public have yet ſeen of the multiplied labours of this moſt accurate and indefatigable obſerver, although he has now (1798) been dead upwards of 36 years.

In 1775 was publiſhed a thin volume, intitled, *Opera Inedita*, containing ſeveral papers of the late Tobias Mayer, and among them a catalogue of the right aſcenſions and declinations of 998 ſtars, which may be occulted by the moon and planets; the places being adapted to the beginning of the year 1756.

At the end of the firſt volume of "Aſtronomical Obſervations made at the Royal Obſervatory at Greenwich," publiſhed in 1776, Dr Maſkelyne, the preſent aſtronomer royal, has given a catalogue of the places of 34 principal ſtars, in right aſcenſion and north polar diſtance, adapted to the beginning of the year 1770.

Theſe being the reſult of ſeveral years repeated obſervations, made with the utmoſt care, and the beſt inſtruments, it may be preſumed are exceedingly accurate.

In 1782, M. Bode of Berlin publiſhed a very extenſive catalogue of 5058 of the fixed ſtars, collected from the obſervations of Flamſteed, Bradley, Hevelius, Mayer, De la Caille, Meſſier, Monnier, D'Arquier, and other aſtronomers; all adapted to the beginning of the year 1780; and accompanied with a celeſtial atlas or ſet of maps of the conſtellations, engraved in a moſt delicate and beautiful manner.

To theſe may be added Dr Herſchel's catalogue of double ſtars printed in the Phil. Tranſ. for 1782 and 1783; Meſſier's nebulæ and cluſters of ſtars, publiſhed in the *Connoiſſance des Temps* for 1784; and Herſchel's catalogue of the ſame kind, given in the Phil. Tranſ. for 1786.

In 1789 Mr Francis Wollaſton publiſhed "A Specimen of a General Aſtronomical Catalogue, in Zones of North-polar Diſtance, and adapted to January 1. 1790." Theſe ſtars are collected from all the catalogues before-mentioned, from that of Hevelius downwards. This work contains five diſtinct catalogues; viz. Dr Maſkelyne's new catalogue of 36 principal ſtars; a general catalogue of all the ſtars, in zones of north-polar diſtance; an index to the general catalogue; a catalogue of all the ſtars, in the order in which they paſs the meridian; and a catalogue of zodiacal ſtars, in longitude and latitude.

Finally, in 1792, Dr Zach publiſhed at Gotha, *Tabulæ Motuum Solis*; to which is annexed a new catalogue of the principal fixed ſtars, from his own obſervations made in the years 1787, 1788, 1789, 1790. This catalogue contains the right aſcenſions and declinations of 381 principal ſtars, adapted to the beginning of the year 1800.—*Hutton's Mathematical Dictionary.*

Beſides theſe two methods of forming *catalogues* of the ſtars, Dr Herſchel has conceived a new one, in which the comparative brightneſs of the ſtars is accurately expreſſed. It is long ſince aſtronomers were firſt led to arrange the ſtars in claſſes of different magnitudes by their various degrees of brilliancy or luſtre. Brightneſs and ſize have at all times been conſidered as ſynonymous terms; ſo that the brighteſt ſtars have been referred to the claſs comprehending thoſe of the firſt magnitude; and as the ſubſequent orders of ſtars have been ſuppoſed to decreaſe in luſtre, their magnitude has been determined in the ſame decreaſing progreſſion: but the want of ſome fixed and ſatisfactory ſtandard of luſtre has been the ſource of conſiderable confuſion and uncertainty in ſettling the relative magnitudes of the ſtars. A ſtar marked 1. 2m. is ſuppoſed to be between the firſt and ſecond magnitude; but 2. 1m. intimates, that the ſtar is nearly of the ſecond magnitude, and that it partakes ſomewhat of the luſtre of a ſtar of the firſt order. Such ſubdiviſions may be of ſome uſe in aſcertaining ſtars of the firſt, ſecond, and third claſſes; but the expreſſions 5m, 5.6m, 6.5m, 6m, muſt be very vague and indefinite. Dr Herſchel obſerves that he has found them ſo in fact; and he therefore conſiders this method of pointing out the different luſtre of ſtars as a reference to an imaginary ſtandard. If any dependence could be placed on this method of magnitudes, "it would follow, that no leſs than eleven ſtars in the conſtellation of the Lion, namely, $\beta\ \sigma\ \pi\ \xi$ A *b c d* 54. 48, 72, had all undergone a change in their luſtre ſince Flamſteed's time: For if the idea of magnitudes had been a clear one, our author, who marked β 1.2m. and γ 2m. ought to be underſtood to mean that β is larger than γ; but we now find that actually γ is larger than β. Every one of the eleven ſtars (ſays Dr Herſchel) which I have pointed out may be reduced to the ſame contradiction."

The author has pointed out the inſtances of the inſufficiency of this method, and of the uncertain concluſions that are deduced from it in determining the comparative brightneſs of ſtars found not only in Mr Flamſteed's catalogue, but alſo in the catalogues of other aſtronomers. It is ſufficiently apparent that the preſent method of expreſſing the brightneſs of the ſtars is very defective.

Catalogue of the Stars. defective. Dr Herſchel therefore propoſes a different mode, that is more preciſe and ſatisfactory.

"I place each ſtar (he ſays), inſtead of giving its magnitude, into a ſhort ſeries, conſtructed upon the order of brightneſs of the neareſt proper ſtars. For inſtance, to expreſs the luſtre of D, I ſay CDE. By this ſhort notation, inſtead of referring the ſtar D to an imaginary uncertain ſtandard, I refer it to a preciſe and determined exiſting one. C is a ſtar that has a greater luſtre than D, and E is another of leſs brightneſs than D. Both C and E are neighbouring ſtars, choſen in ſuch a manner that I may ſee them at the ſame time with D, and therefore may be able to compare them properly. The luſtre of C is in the ſame manner aſcertained by BCD; that of B by ABC; and alſo the brightneſs of E by DEF; and that of F by EFG.

"That this is the moſt natural, as well as the moſt effectual way to expreſs the brightneſs of a ſtar, and by that means to detect any change that may happen in its luſtre, will appear, when we conſider what is requiſite to aſcertain ſuch a change. We can certainly not wiſh for a more deciſive evidence, than to be aſſured, by actual inſpection, that a certain ſtar is now no longer more or leſs bright than ſuch other ſtars to which it has been formerly compared; provided we are at the ſame time aſſured that thoſe other ſtars remain ſtill in their former unaltered luſtre. But if the ſtar D will no longer ſtand in its former order CDE, it muſt have undergone a change; and if that order is now to be expreſſed by CED, the ſtar has loſt ſome part of its luſtre; if, on the contrary, it ought now to be denoted by DCE, its brightneſs muſt have had ſome addition. Then, if we ſhould doubt the ſtability of C and E, we have recourſe to the orders BCD and DEF, which expreſs their luſtre; or even to ABC and EFG, which continue the ſeries both ways. Now having before us the ſeries BCDEF, or if neceſſary even the more extended one ABCDEFG, it will be impoſſible to miſtake a change of brightneſs in D, when every member of the ſeries is found in its proper order except D."

In the author's journal or catalogue, in which the order of the luſtre of the ſtars is fixed, each ſtar bears its own proper name or number, *e g.* "the brightneſs of the ſtar δ Leonis may be expreſſed by β δ ε Leonis, or better by 94—68—17 Leonis; theſe being the numbers which the three above ſtars bear in the Britiſh catalogue of fixed ſtars."

This method of arrangement occurred to Dr Herſchel ſo early as the year 1782; but he was diverted from the regular purſuit of it by a variety of other aſtronomical engagements. After many trials, he propoſed, in the Tranſactions of the Royal Society of London for 1796, the plan which appeared to him the moſt eligible. It is as follows:—Inſtead of denoting particular ſtars by letters, he makes uſe of numbers; and in his choice of the ſtars which are to expreſs the luſtre of any particular one, he directs his firſt view to perfect equality. When two ſtars ſeem to be ſimilar both in brightneſs and magnitude, he puts down their numbers together, ſeparated merely by a point, as 30.24 Leonis; but if two ſtars, which at firſt ſeemed alike in their luſtre, appeared on a longer inſpection to be different, and the preference ſhould be always decidedly in favour of the ſame ſtar, he ſeparates theſe ſtars by a comma, thus, 41,94 Leonis. This order muſt not be varied; nor can three ſuch ſtars, as 20, 40, 39, Libræ, admit of a different arrangement. If the ſtate of the heavens ſhould be ſuch as to require a different order in theſe numbers, we may certainly infer that a change has taken place in the luſtre of one or more of them. When two ſtars differ very little in brightneſs, but ſo that the preference of the one to the other is indiſputable, the numbers that expreſs them are ſeparated by a ſhort line as 17—70 Leonis, or 68—17—70 Leonis. When two ſtars differ ſo much in brightneſs, that one or two other ſtars might be interpoſed between them, and ſtill leave ſufficient room for diſtinction, they are diſtinguiſhed by a line and comma, thus, —, or by two lines, as 32— —41 Leonis. A greater difference than this is denoted by a broken line, thus — — — 29 Bootis. On the whole, the author obſerves, the marks and diſtinctions which he has adopted cannot poſſibly be miſtaken; "a point denoting equality of luſtre; a comma indicating the leaſt perceptible difference; a ſhort line to mark a decided but ſmall ſuperiority; a line and comma, or double line, to expreſs a conſiderable and ſtriking exceſs of brightneſs; and a broken line to mark any other ſuperiority which is to be looked upon as of no uſe in eſtimations that are intended for the purpoſe of directing changes."

The difficulties that attend this arrangement are not diſguiſed; but the importance and utility of it more than compenſate for the labour which it muſt neceſſarily require. By a method of this kind, many diſcoveries of changeable and periodical ſtars might probably have been made, which have eſcaped the moſt diligent and accurate obſervers. We might then, as the author ſuggeſts, be enabled to reſolve a problem in which we are all immediately concerned.

"Who, for inſtance, would not wiſh to know what degree of permanency we ought to aſcribe to the luſtre of our ſun? Not only the ſtability of our climates, but the very exiſtence of the whole animal and vegetable creation itſelf, is involved in the queſtion. Where can we hope to receive information upon this ſubject but from aſtronomical obſervations? If it be allowed to admit the ſimilarity of ſtars with our ſun as a point eſtabliſhed, how neceſſary will it be to take notice of the ſate of our neighbouring *ſuns*, in order to gueſs at that of our own! That *ſtar*, which among the multitude we have dignified by the name of *ſun*, to-morrow may ſlowly begin to undergo a gradual decay of brightneſs, like β Leonis, α Ceti, α Draconis, δ Urſæ majoris, and many other diminiſhing ſtars that will be mentioned in my catalogues. It may ſuddenly increaſe, like the wonderful ſtar in the back of Caſſiopea's chair, and the no leſs remarkable one in the foot of Serpentarius; or gradually come on like β Geminorum, β Ceti, ζ Sagittarii, and many other increaſing ſtars, for which I alſo refer to my catalogues; and, laſtly, it may turn into a periodical one of 25 days duration, as Algol is one of three days, δ Cephei of five, β Lyræ of ſix, η Antinoi of ſeven days, and as many others as are of various periods."

Having thus explained the general principle on which this catalogue is formed, as we find it in the author's firſt memoir on the ſubject, we muſt refer the reader to the Doctor's own account for its particular arrangement; obſerving only that the catalogue ſubjoined comprehends nine conſtellations, which are arranged in al-

 phabetical

phabetical order, with the comparative brightnefs of the ftars accurately ftated. In a fubfequent paper, publifhed in the fame volume, he has completely verified the utility of his method by experience, and fhewn that there is no permanent change of luftre in the ftars. In the notes to his firft catalogue he mentioned α Herculis as a periodical ftar. By a feries of obfervations on this ftar, compared with κ Ophiuchi, which was moft conveniently fituated for his purpofe, he has been able not only to confirm this opinion, but to afcertain its period. His obfervations are arranged in a table, by means of which he determines that this ftar had gone through four fucceffive changes in an interval of 241 days; and therefore the duration of its period muft be about 60 days and a quarter. This fact concurs with other circumftances in evincing the rotatory motion of the ftars on their axes. "Dark fpots, or large portions of the furface, lefs luminous than the reft, turned alternately in certain directions, either towards or from us, will account for all the phenomena of periodical changes in the luftre of the ftars, fo fatisfactorily, that we certainly need not look out for any other caufe." If it be alleged that the periods in the change of luftre of fome ftars, fuch as Algol, β Lyræ, δ Cephei, and η Antinoi, are fhort, being only 3, 5, 6, and 7 days refpectively; while thofe of ο Ceti, and of the changeable ftar in Hydra, and that in the neck of the Swan, are long, amounting to 331, 394, and 497 days; and that we cannot afcribe phenomena fo different in their duration to the fame caufe—it may be anfwered to this objection, that the force of it is founded on our limited acquaintance with the ftate of the heavens. To the 7 ftars, the periodical changes of which were before known, we may now add α Herculis, which performs a revolution of its changes in 60 days.

"The ftep from the rotation of α Herculis to that of ο Ceti is far lefs confiderable than that from the period of Algol to the rotation of α Herculis; and thus a link in the chain is now fupplied, which removes the objection that arofe from the vacancy." The rotation of the fifth fatellite of Saturn is proved by the change obfervable in its light; and "this variation of light, owing to the alternate expofition of a more or lefs bright hemifphere of this periodical fatellite, plainly indicates, that the fimilar phenomenon of a changeable ftar arifes from the various luftre of the different parts of its furface, fucceffively turned to us by its rotatory motion."

Befides, we perceive a greater fimilarity between the fun and the ftars, by means of the fpots that muft be admitted to exift on their furfaces, as well as on that of the fun.

Dr Herfchel farther obferves, that the ftars, befides a rotatory motion on their axes, may have other movements; "fuch as nutations or changes in the inclination of their axes; which, added to bodies much flattened by quick rotatory motions, or furrounded by rings like Saturn, will eafily account for many new phenomena that may then offer themfelves to our extended views." To this paper is likewife fubjoined a catalogue of nine conftellations; and the author promifes to give the whole of them in fucceffive fhort catalogues on the fame plan.

CATAWESSY, a townfhip in Northumberland co. Pennfylvania, fituated on the S. E. bank of the E. branch of Sufquehannah River oppofite the mouth of Fifhing Creek, and about 20 miles N. E. of Sunbury. —*Morse.*

CATENARIA, or CATENARY CURVE. See *Encycl.* and ARCH in this *Supplement*.

CATHARINE II. emprefs of all the Ruffias, acted fo confpicuous a part on the theatre of the world; poffeffed fuch uncommon powers of mind, highly cultivated by fcience and literature; and was fuch a patronefs of fcience and literature in others—that it cannot be deemed foreign from a work of this nature to give fome account of the principal events of her more private life.

SOPHIA AUGUSTA FREDERICA, who, upon her marriage to the grandfon of Peter the Great, affumed the name CATHARINE ALEXIEVNA, was born at *Stettin* on the 2d of May 1729. Her father was Chriftian Auguftus, prince of Anhalt Zerbft-Dornburg, at that time major general in the Pruffian fervice, commander in chief of the regiments of infantry, and governor of the town and fortrefs of Stettin. Her mother, who was born princefs of Holftein Eutin, was a woman of great parts and beauty, of nearly the fame age with the prince royal of Pruffia, afterwards Frederic the Great, with whom fhe kept up a regular correfpondence, and who afterwards contributed to the aggrandifement of her daughter. This accomplifhed princefs took upon herfelf the care of educating the young Sophia, whom fhe brought up in the fimpleft manner, and would not fuffer to exhibit the leaft fymptoms of that pride to which fhe had fome propenfity from her earlieft childhood. The confequence of this falutary reftraint was, that good humour, intelligence, and fpirit, were even then the ftriking features of her youthful character. Being naturally addicted to reading, to reflection, to learning, and to employment, fhe was taught the French and other fafhionable languages; and was inftructed to read fuch books chiefly as might make her acquainted with hiftory and with the principles of fcience; whilft the doctrines of the Lutheran religion were carefully explained to her by a divine, who little thought how foon his illuftrious pupil would embrace another faith.

The emprefs Elizabeth, who then fwayed the fceptre of Ruffia, had in early life been promifed in marriage to the young prince of Holftein-Eutin, brother to the princefs of Anhalt Zerbft; but at the inftant when the marriage was about to be celebrated, the prince fell fick and died. Elizabeth, who loved him to excefs, became inconfolable, and in the bitternefs of her grief made a vow of celibacy. This vow, though fenfual, and even lafcivious, fhe kept fo far as never publicly to acknowledge any man as a hufband; and upon her afcending the throne of her anceftors, fhe called her nephew the Duke of Holftein Gottorp to her court, where he was folemnly proclaimed, when fourteen years of age, Grand Duke, with the title of Imperial Highnefs, and declared fucceffor to the Emprefs Elizabeth. To fecure the fucceffion in the family of Peter the Great, the Emprefs was very defirous to have her nephew married; and the princefs of Anhalt Zerbft, not ignorant of the tender remembrance which fhe ftill preferved for her brother, conceived the idea of placing, by means of it, her daughter on the throne of Ruffia. She communicated her plan to the king of Pruffia, who not only applauded it, but lent her his affiftance to carry it into execution.

Full

Catharine.

Full of ambitious hopes, therefore, the princefs repaired with her daughter to St Peterfburgh, where fhe was received with friendfhip by Elizabeth, and where the young Sophia foon made a confiderable impreffion on the mind of the Grand Duke. As Peter was well made, of a good figure, and, though uneducated, not deftitute of natural talents, the attachment became reciprocal; and the princefs of Zerbft, throwing herfelf at the feet of the emprefs, affured her, that the two lovers were attached to each other by a paffion unconquerable; and calling to her mind the love which fhe had herfelf borne to the prince of Holftein, conjured her to promote the happinefs of that prince's niece. The ftratagem fucceeded. The choice of Elizabeth was next day announced to the council and to the foreign minifters; and preparations were made for celebrating the marriage with a magnificence worthy of the heir of the throne of the Ruffias. In the mean time the Grand Duke was feized with the fmall pox, from which, though he recovered, it was with fuch a change of features, as rendered him, from being comely, almoft hideous, and converted the love of the young princefs of Anhalt, if indeed fhe ever felt for him that paffion, into horror and difguft. She was not, however, of a difpofition to let a disfigured countenance frighten her from a throne. She embraced the Greek religion, changed her name from Sophia Augufta Frederica to Catharina Alexievna, and with the entire approbation of Elizabeth was married to her nephew the Grand Duke.

For fome time this ill matched pair lived together, though without love, yet on terms apparently decent; but a mutual diflike gradually took place between them, which the courtiers quickly difcovered, and were at pains to foment into hatred. Peter was now ugly and his mind was uninformed. Catharine, if not a beauty, was at leaft a lovely woman, and highly accomplifhed. She could find no entertainment in his converfation, and he felt himfelf degraded by her fuperiority. A faction was formed at court, headed by the great chancellor Beftucheff, to exclude the Grand Duke from the throne, and to place Catharine at the head of affairs; and to accomplifh this end, every art was employed to fill the feeble mind of the emprefs with jealoufies of her nephew, and with a contempt of his character. He was reprefented at one time as extremely ambitious, and capable of the moft daring enterprifes, to get immediate poffeffion of the throne; and at another, as a wretch given up to drunkennefs and to every unprincely vice.

The confequence of the firft of thefe accufations was, that he was kept at a diftance from his aunt, and a ftranger to public affairs; and being wholly unemployed, that time which his education had not fitted him to fill up with reading, reflection, and rational converfation, hung fo heavy on his mind, that it was no difficult matter for thofe diffipated young men, who were placed about him for that very purpofe, to initiate him in the habits of drunkennefs and the other mean practices to which it was pretended he had long been devoted. In fuch a fchool, it was no wonder that he became a proficient in grovelling diffipation: or that, being unpolifhed, and even of rude manners, he chofe for his companions fome of the loweft of the people.

Catharine, in the mean time, languifhed for that happinefs which fhe could not find in the fociety of her hufband. She was fond of pleafure; but it was that comparatively refined pleafure which fhe had enjoyed at the court of Berlin. She loved balls, mufic, and elegant converfation, and could take no fhare in the drunken revels of Peter. Among the young men with whom he was furrounded, his chamberlain Soltikoff was particularly remarked for the elegance of his tafte and the graces of his perfon; and though yet fcarcely more than a boy in years, he was faid to have obtained the favours of feveral ladies of the court. Succefs had made him confident and ambitious; and his ambition prompted him to afpire at making a conqueft even of the Grand Duchefs. By ftudying her tafte, and contriving to amufe her, he was at laft fuccefsful; and obtained from her Imperial Highnefs every favour which he could wifh; but he enjoyed not his fortune with moderation, and his enemies contrived to get him placed in an honourable office at a diftance from the court. He was commiffioned to repair to Stockholm, with the title of Envoy Extraordinary, to notify to the king of Sweden the birth of Paul Petrovitch, of whom the Grand Duchefs had juft been delivered.* The prefumptuous Soltikoff, proud of the employment, fet off with hafte to Sweden, and left it with equal fpeed. But fcarcely had he quitted Stockholm, on the wings of love and ambition, when he was ftopped on the road by a courier, who put into his hands an order for him to go immediately to Hamburgh, and there to refide in the quality of minifter plenipotentiary from the court of Ruffia.

* Oct. 1. 1754.

Catharine for fome time preferved her attachment to the exiled chamberlain: but all at once the prefence of a ftranger, whom fortune had brought to the court of Ruffia, made her forget the lover whom fhe no longer faw. This perfon was Staniflaus Poniatowfky, the late king of Poland, who firft made his appearance at St Peterfburg in the train of the Britifh ambaffador, and very quickly gained the affections of the Grand Duchefs. In carrying on this intrigue, the lovers were not fo cautious as to deceive the eyes of the envious courtiers, who reported to the emprefs not only all that they faw, but whatever they fufpected. Elizabeth was incenfed, and commanded Poniatowfky to quit without delay the dominions of Ruffia. The accomplifhed Pole obeyed; but foon returned clothed with a character which made him in fome degree independent of the emprefs.

The Count de Bruhl, then prime minifter to the king of Poland, faw of what importance it was to his mafter to have a powerful intereft at the court of Ruffia. He was likewife no ftranger to the paffion which the Grand Duchefs entertained for Poniatowfky; and having got that nobleman decorated with the order of the White Eagle, he fent him back to St Peterfburgh in the quality of minifter plenipotentiary from the republic and king of Poland. Nor was this all that Bruhl did for the two lovers. Being informed by the chancellor Beftucheff, that the Grand Duke and Grand Duchefs were languifhing in a penury unworthy of their rank, he remitted to Poniatowfky 6000 ducats, to be employed in fuch a manner as he might judge beft for fecuring the favour of the prince and his confort. The ambaffador profited by thefe counfels and benefactions. He was already fure of the Grand Duchefs's heart, and he very quickly gained the favour of her hufband. He

talked

Catharine. talked English and German with him; drank, smoked, abused the French, and extolled the king of Prussia with unlimited praise.

The Grand Duchess was so blinded by her passion, that she was never without Poniatowsky in her company. She devoted to him the whole of her time; and she made this intimacy so little a secret, that public report was loud to her prejudice. In the mean time she was delivered of the Princess Anne†, who lived only fifteen months. The Grand Duke was the only person about court who seemed to know nothing of what was passing. His whole time was occupied in copying, with servile affectation, the air, the manners, the tone of the king of Prussia; and in dressing a little army at Oranienbaum in the Prussian uniform. His eyes, however, were at last opened. Some of the courtiers, from hatred to the chancellor, who countenanced the intrigue between the Grand Duchess and the Polish ambassador, roused his jealousy in order to destroy their enemy. They succeeded. He forbade his wife to be seen with Poniatowsky, and prevailed with the empress to deprive the chancellor of his office, and to banish him to an estate which he had 120 versts beyond Moscow.

† February 1758.

Catharine had now to support at once the aversion of her husband, the indignation of the empress, the insulting disdain of a court, which a few days before was lavish of its assiduities and smiles; and what afflicted her most of all, the dread of losing for ever her favourite Poniatowsky. Her courage, however, did not forsake her. Poniatowsky was indeed recalled, and left Russia, after suffering some deserved indignities from the Grand Duke, who about this time formed a connection with one of the daughters of the Senator Vorontzoff, brother to the new chancellor. This lady, Elizabeth Romanovna Vorontzoff, was elder sister to the Princess Dashkoff, who acted so conspicuous a part in the revolution which set the crown on the head of Catharine. She was beautiful, but vain; and possessed not either the wit or the understanding of her sister.

In the mean time the health of the empress visibly declining, Catharine was very desirous of being reconciled to her: but the irritated sovereign would listen to no accommodation, except on terms too humiliating for the haughty spirit of the Grand Duchess. Catharine, therefore, absented herself from court, and asked permission to retire into Germany. This, as she had foreseen, was refused. Elizabeth was too fond of the young Paul Petrovitch to permit the departure of his mother, and thereby expose him to the danger of being at some future period declared illegitimate. She took the Grand Duchess again into favour; and it is thought, that had she lived a little longer than she did, she would have excluded Peter from the throne, and declared Paul her immediate successor.

While the empress was meditating the aggrandizement of the young prince and his mother, the Grand Duke had conceived a plan for degrading them both. He had resolved, at the moment his aunt should close her eyes, to assemble his troops, to get himself proclaimed emperor, to repudiate the Grand Duchess, to declare the young Paul Petrovitch illegitimate, and publicly to marry his mistress Elizabeth Romanovna Vorontzoff. We have shown elsewhere (see Russia, n° 72. *Encycl.*) how this plan, when almost ready to be carried into execution, was betrayed to Catharine, who, ever since her caballing with the Chancellor Bestucheff, had resolved, by some means or other, to snatch the sceptre from the feeble hand of her husband. At present, we believe she was not acquainted with it; and though she had, she could not now have turned it to her advantage, as her party, ever since the disgrace of Bestucheff, was without a leader of any abilities.

Catharine.

Amid these distractions caused by the prospect of the death of the empress, and the known hatred of the Grand Duke and Duchess to each other, Count Panin, preceptor to the young prince, devoted himself entirely to Catharine. He wished to see her possessed of all the power of the empire; but he was afraid to proceed to the extremity to which she proposed to go, and to deprive Peter of the name of Emperor. He contrived therefore to procure an apparent reconciliation between the Grand Duke and his consort, as well as between him and his aunt Elizabeth; and he had almost persuaded the silly prince not to assume the sovereign power on the death of the empress, till he should be solemnly invested with it by a decree of the senate. Could he obtain this point, he knew that the power of Peter would be limited, and the authority secured to his wife and his son. He was, however, disappointed. Catharine herself disapproved of this plan, and concurred with the real friends of her husband in advising him "to conform to established custom in assuming the reins of empire."

He had hardly received this advice when word was brought him that the Empress Elizabeth was dead (A); and the courtiers pressed in crowds about him. He accosted them with dignity, received the oaths of the officers of his guard, and seemed at once to have laid aside his weakness. In an hour he got on horseback, traversed the streets of St Petersburg, and distributed money among the multitude and the soldiers. He had been so treated by his aunt, that he could not possibly be grieved at her death; but in paying the last duties to her remains, he betrayed no indecent elation. The first actions of his reign were prudent and patriotic, and such as would have done honour to a greater prince. He appeared to be reconciled to his wife, in whose company he spent much of his time; he recalled from prison and banishment 17,000 persons, some of them of rank and of great talents, who had been the victims of Elizabeth's jealous timidity; he permitted the nobility to bear arms or not at their own discretion, freeing them at the same time from the extreme servitude under which they had been held by his immediate predecessors; and he abolished *the secret committee*, an infamous inquisitorial tribunal, which ever since the reign of the father of Peter the Great had been the chief engine of Russian despotism.

He neglected, however, one thing; which, among the people over whom he was appointed to reign, would have contributed more to the security of his throne than all the wise and beneficent edicts which he had published. He made no preparations to be crowned at Moscow. Instead of complying with this ancient ceremony, and humouring the prejudices of his superstitious subjects,

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(A) Christmas-day 1761 according to the Russian calendar, or the 5th of January 1762 according to ours.

Catharine.

jects, he thought of nothing but of war with Denmark, and of a personal interview with the king of Prussia in Germany. His admiration of that great monarch hurried him indeed into the most extravagant follies. Not contented with giving him peace, and entering into an offensive and defensive alliance with him, he had the meanness to solicit a commission in his army, and to accept of the rank of major-general. Of this title he seemed more vain than of that of Emperor of all the Russias. He constantly wore the Prussian uniform; introduced among his troops the Prussian discipline, which, though better than their own, was disagreeable, because it was new, and much more because it was German; and he raised his uncle, a man of no military talents, and a foreigner, to the dignity of generalissimo of the Russian armies; giving him at the same time the particular command of the horse-guards, a body of men which had never before been under any command but that of the supreme head of the empire. Nor did his infatuated predilection for Germany, a country abhorred by the Russians, stop even here: He disbanded the noble guards which had placed Elizabeth on the throne, dismissed the horse-guards from the service which they performed at court, and substituted his Holstein guards in their place.

Whilst he was thus alienating from himself the affections of the army, he contrived to disgust another order of men, whose attachment he should have laboured above all things to retain. He was at pains to shew his preference of the Lutheran faith and worship to the doctrines and ceremonies of the Greek church; he attempted to make some alterations in the dress of the monks; he annexed great part of the possessions of the church to the domains of the crown; and he banished the archbishop of Novogorod, who opposed these innovations; and found himself obliged suddenly to recal him.

He had now returned to his former courses. He shut himself up for whole days with his mistress and drunken companions; he compelled the nobility and ladies of the court to sit in company with buffoons and comedians; he insulted every foreign minister but the ministers of Great-Britain and Prussia; and he made no secret of his intention to repudiate the empress, declare Paul Petrovitch illegitimate, and marry the Countess Vorontzoff. Convinced, however, as it would seem, that he could not be a father, he resolved to adopt Prince Ivan, the descendant of the elder brother of Peter the Great, whom Elizabeth had dethroned and confined in prison, to declare him his successor, and to unite him in marriage with the young princess of Holstein Beck, who was then at St Petersburgh, and whom he cherished as his daughter.

This inconsistent and weak conduct of the emperor turned the attention of all orders of men to the empress, who made it her sole employment to gain those hearts which he was losing. Instructed from her infancy in the arts of dissimulation, it was not difficult for her to affect, in the sight of the multitude, sentiments the most foreign to her mind. The pupil of the French philosophers put on the air of a bigot to the most superstitious ceremonies of the Greek religion, and treated the ministers of that religion with the profoundest reverence. And whilst her husband was getting drunk amidst a rabble of buffoons, and disgusting every person of decency who approached him, she kept her court with a mixture of dignity and affability, which attracted to her all who, by capacity, courage, or reputation, were capable of serving her.

Catharine.

Correct, however, as her public conduct appeared, her private life was not less licentious than formerly. While yet Grand Duchess, she had formed a very tender connection with Gregory Orloff, a man of mean birth, and of no education, but possessed at once of personal beauty and the most daring courage. He had an inferior commission in the artillery, while his two brothers were common soldiers in the regiments of guards. The intrigue which she carried on with him was known only to one of her women named Catharine Ivanovna; nor did Orloff himself for some time suspect the rank of the lady who so lavishly conferred upon him her favours in secret. At last finding him intrepid and discreet, she discovered herself, unveiled to him all her ambitious designs, and easily prevailed with him and his brothers to enter with zeal into her conspiracy against the emperor. Orloff likewise gained over Bibikoff his friend, a Lieutenant Passick, with other officers; and by their means easily seduced some regiments of the guards. The Princess Dashkoff was strongly attached to Catharine, we believe, from worthy motives, and had frequent meetings with Orloff on the business of the conspiracy, without suspecting that he was so much as known to the empress. Count Panin, too, and the Hetman of the Kossacks, were determined to tumble Peter from the throne; but they were not inclined to go all the lengths proposed by Catharine and her two favourites. Hoping to enjoy the actual power of the empire themselves, they were for declaring Paul Petrovitch emperor in the room of his father, and conferring upon his mother the name and authority only of regent; while the princess and Orloff, knowing the sentiments and wishes of the empress, were resolved to vest her with sovereign power, or to perish themselves in the hazardous attempt.

In the mean time the anniversary of the patron saints of Russia was at hand, when Peter had determined, at the conclusion of the festival, to divorce the empress, shut her up in prison, declare her son illegitimate, and publickly marry his mistress. As they who plan a conspiracy are always more vigilant than those against whom it is directed, the friends of Catharine were carefully informed of all that passed about the emperor, whilst he was kept in total ignorance of their proceedings. It was therefore necessary for them to unite in the same plan, and to carry it quickly into execution; for delay or divisions would involve them all in one common ruin. The empress contrived to bring over the Hetman entirely to her views; and the Princess Dashkoff, by the sacrifice, it has been said, of her charms, found little difficulty in reconciling Count Panin to the same measures. They now agreed to seize the Tzar on his arrival at Peterhoff, an Imperial palace on the shore of the Gulf of Cronstadt, where he proposed to celebrate the approaching festival; and they were waiting impatiently for the moment of action, when all at once their plot was discovered.

Passick, who has been mentioned among the conspirators, had gained the soldiers of the company of guards in which he was a lieutenant; but one of them, who thought that his captain was in the secret, asked that officer

Catharine. officer one evening, When they were to take up arms against the emperor? The captain, surprised, had recourse to dissimulation, and easily drew from the soldier all that he knew of the conspiracy. It was nine o'clock at night. Passick was put under arrest; but found means to slip into the hands of a man who had been placed as a spy over him by the Princess Dashkoff, a scrap of paper containing these words, " Proceed to execution this instant, or we are undone." The man was desired to carry it to the Hetman, by whom he would be handsomely rewarded; but he hurried with it to the princess, who instantly communicated the intelligence to the other conspirators. She herself put on man's apparel, and hastened to the place where she was accustomed to meet Orloff and his friends; where she found them, as impatient as herself to carry their plot into immediate execution.

During this awful crisis the empress was at Peterhoff, at the distance of 25 versts from St Petersburgh; and one of the brothers of Gregory Orloff, named Alexius, undertook to find her out, whilst he himself, with his other brother and Bibikoff his friend, repaired to the barracks for the purpose of instructing the soldiers of their party how to act on the first signal. Alexius Orloff carried with him a short note from the Princess Dashkoff, but neglected to deliver it; and the empress, being suddenly roused from a sound sleep, was much alarmed, when she saw at the side of her bed a soldier of whom she knew nothing. Her alarm was increased when the stranger said, " Your majesty has not a moment to lose; get ready to follow me;" and instantly disappeared. She rose, however, and calling her woman Ivanovna, they disguised themselves in such a manner that they could not be known by the sentinels about the palace; and the soldier returning, they hurried with him to a coach which was waiting at the garden gate. Orloff took the reins, but drove with such fury that the horses soon fell down; and they were obliged to travel part of the way on foot. They had not, however, gone far, when they met a light country cart; and she who was aspiring to the throne of the greatest empire in the world, was glad to enter the capital of that empire in this humble vehicle.

It was seven in the morning when she arrived in St Petersburgh: and to the soldiers, who gathered about her in great numbers, she said, that " her danger had driven her to the necessity of coming to ask their assistance; that the Tzar had intended, that very night, to put her and her son to death; and that she had so great confidence in their dispositions, as to put herself entirely into their hands." They immediately shouted, " Long live the empress!" And the chaplain of one of the regiments fetching a crucifix, received their oaths of fidelity.

The troops, however, were not unanimous in this revolt. Though Gregory Orloff was treasurer of the artillery, and well enough beloved by the soldiers, that corps refused to follow him until he should produce the orders of Villebois their general; and that officer, withheld either by fidelity to the emperor or by fear, presumed to speak to Catharine of the obstacles which yet remained for her to surmount; adding, that she ought to have foreseen them. She haughtily replied, that " she had not sent for him to ask what she ought to have foreseen, but to know how he intended to act." " To obey your majesty," returned Villebois; and putting himself at the head of his regiment, he immediately joined the conspirators. So ripe indeed were the minds of all men for this revolt, that in the space of two hours the empress found herself surrounded by 2000 warriors, together with great part of the inhabitants of Petersburgh; and with that numerous train of attendants she repaired to the church of Kasan, where the archbishop of Novogorod, setting the Imperial crown on her head, proclaimed her sovereign of all the Russias, declaring, at the same time, Paul Petrovitch her successor.

Matters had now proceeded by much too far to admit of any compromise between Catharine and her husband: but had the infatuated Tzar put his affairs wholly into the hands of Marshal Munich, that intrepid veteran would have tumbled the empress from her throne almost as quickly as she had got possession of it. He acted, however, a very different part. Upon receiving intelligence of what had been done at St Petersburgh, he asked indeed the Marshal's advice, but suffered himself to be guided by his mistress and timid companions. Through their terrors and his own irresolution opportunities were lost which could never be recovered; for though his Holstein guards, with tears in their eyes, swore that they were all ready to sacrifice their lives in his service, and though the old Marshal offered to lead them against the rebels, saying to the emperor, " I will go before you, and their swords shall not reach you till they have pierced my body," he was persuaded to treat with the empress, to acknowledge his misconduct, and to offer to share with her the sovereign power. At last he was weak enough to abandon his troops, and to surrender at discretion to his consort; whose creatures hurried him from Oranienbaum to Peterhoff, stripped him of all his clothes, and after leaving him for some time in his shirt, a butt to the outrages of an insolent soldiery, threw over him an old morning gown, and shut him up alone, with a guard at the door of his wretched apartment. On the 29th of June, O. S.* 1762, Count Panin was sent to him by the empress; and after a long conference, prevailed with him to write and sign a solemn resignation of his crown, and a declaration of his utter incapacity to govern so great an empire.

* July 10.

The revolution was now complete, and Peter seemed to enjoy some composure of mind; but in the evening he was carried a prisoner to Ropscha, a small Imperial palace, at the distance of 20 versts from Peterhoff, where he was murdered on the 17th of July, just one week after his deposition. Of the manner of his death different accounts have been given. By some he is said to have been poisoned; by others, to have been strangled by one of the Orloffs; and a few have thought that he perished by the same means as Henry VI. of England. Whether the empress was accessary to his death is not known; though it is certain, that so far from making any inquiry after his murderers, she affected to believe that he had died naturally of the *piles!*

The first care of Catharine was to reward those who had been the principal actors in the revolt. Panin was made prime minister; the Orloffs received the title of Count; and the favourite Gregory was appointed lieutenant-general of the Russian armies, and knight of the order of St Alexander Nefsky, the second order of the empire. Several officers of the guards were promoted, of whom 24 received considerable estates; and among the

Catharine. the soldiers, whom ſhe treated with the greateſt affability, brandy and beer were liberally diſtributed. The chancellor Beſtucheff, who had been the moſt inveterate enemy of Peter, was recalled from his exile, reſtored to his rank of field-marſhal, and had an annual penſion ſettled upon him of 20,000 rubles. To the friends of the emperor ſhe behaved with great moderation. Prince George, whom he had conſtituted Duke of Courland, was indeed obliged to renounce his title; but the adminiſtration of Holſtein was committed to him, and he ever after ſerved the empreſs with zeal and fidelity.

The news of the revolution was ſoon ſpread over Europe; and none of the ſovereigns, though they knew by what ſteps Catharine had mounted the throne, heſitated for a moment to acknowledge her title. She was not, however, at perfect eaſe in her own mind; nor was her right recogniſed by all her ſubjects. Tho' ſhe publiſhed manifeſtos, ſetting forth the intentions of the late emperor towards her and her ſon, which made reſiſtance neceſſary; though in theſe papers ſhe attributed her elevation to the wiſhes of her people and the providence of God; and though ſhe called upon all who were ſincerely attached to the orthodox faith of the Greek church, to conſider the ſudden death of Peter as the judgment of heaven in favour of the revolution; yet in the diſtant provinces no exultations were heard; both ſoldiers and peaſants obſerved a gloomy ſilence. Even at Moſcow, ſo great was the diſaffection to Catharine's government, that it was ſome time before ſhe could venture to go to that city to be crowned; and ſhe found in it at laſt ſo cold a reception, that ſhe very quickly returned to St Peterſburgh.

Nor was this the only cauſe of her uneaſineſs. The connection between Orloff and her became viſible, and gave juſt offence to her other friends. The princeſs of Daſhkoff firſt perceived it; and when ſhe preſumed to expoſtulate with the empreſs on the meanneſs and imprudence of her paſſion, ſhe was baniſhed from the court to Moſcow. Count Panin and the Hetman ſaw with indignation that they had dethroned the grandſon of Peter the great, to aggrandiſe a rude and low born upſtart. Cabals and conſpiracies were entered into by high and low, both againſt Catharine and againſt her favourite; and it required all her abilities and firmneſs to preſerve at once her throne and her lover. On one occaſion ſhe hoped to obtain from the Princeſs Daſhkoff ſufficient proof that Panin and the Hetman of the Koſſacks were concerned in a plot which had juſt been diſcovered; and with this view ſhe wrote to her a letter of four pages, filled with the moſt tender epithets and the moſt magnificent promiſes, conjuring her in the name of their long ſtanding friendſhip, to reveal what ſhe knew of the recent conſpiracies. With becoming magnanimity, the princeſs replied, "Madam, I have heard nothing; but if I had heard any thing, I ſhould take good care how I ſpoke of it. What is it you require of me? That I ſhould expire upon a ſcaffold? I am ready to mount it."

Catharine, deſpairing of conquering ſuch a ſpirit, attempted to attach to her thoſe whom ſhe dared not to puniſh. Some of the inferior conſpirators were baniſhed to Siberia, while Panin and the Hetman, whom ſhe moſt dreaded, received additional marks of her favour. In the mean time, to gain the affections of the people at large, ſhe paid the utmoſt attention to the adminiſtration of juſtice; formed magnificent eſtabliſhments for Catharine. the education of the youth of both ſexes; founded hoſpitals for orphans, for the ſick, and for lying-in women; invited foreigners of all nations, poſſeſſed of any merit, to ſettle in different parts of her vaſt territories; increaſed the naval force of the empire; and gave ſuch encouragement to the cultivation of every elegant and uſeful art, that in the ſhort ſpace of a year and a half from her acceſſion to the throne, the national improvement of Ruſſia was viſible.

In the good fortune and glory of Catharine, no one rejoiced more ſincerely than Count Poniatowſky. He approached towards the confines of Ruſſia, and wrote to her in the tendereſt ſtyle of congratulation, requeſting permiſſion to pay his reſpects to her in the capital of her empire. It is not improbable that he flattered himſelf with the hopes that ſhe would give him her hand in marriage, and thus raiſe him to the throne of the Tzars; but ſhe had promiſed to the Empreſs Elizabeth, that ſhe would never again ſee the count; and to that promiſe ſhe at preſent adhered. She wrote to him, however, in the moſt affectionate terms; and tho' ſhe gave him no encouragement to repair to St Peterſburgh, ſhe aſſured him that ſhe had other proſpects in view for his aggrandiſement, and that he might depend upon her perpetual friendſhip: and ſhe ſoon appeared to be as good as her word. On the death of Auguſtus III. ſhe raiſed her former favourite to the throne of Poland, in oppoſition to the wiſhes of the courts of Vienna and Verſailles, as well as of a great majority of the Poliſh nobles. She defeated the intrigues of the two foreign courts by more ſkilfully conducted intrigues of her own; and, by pouring her armies into the republic, ſhe ſo completely overawed the nuncios, that Poniatowſky was choſen by the unanimous ſuffrages of the diet which met for the election of a ſovereign; and, on the 7th of September 1764, was proclaimed King of Poland and Grand Duke of Lithuania, by the name of Staniſlaus Auguſtus.

Whilſt ſhe was thus diſpoſing of foreign kingdoms, ſhe was kept under perpetual dread of being tumbled from the throne of her own vaſt empire. Her want of title to that throne was now ſeen by all ranks of her ſubjects; the good qualities of Peter the third were remembered, and his failings and faults forgotten. His fate was univerſally lamented; and, except the conſpirators, who may be ſaid to have embrued their hands in his blood, there was hardly a Ruſſian who did not regret that the ſovereignty had paſſed from the ancient family of the Tzars to a foreigner, allied only by marriage to the blood royal. Even the conſpirators themſelves had loſt much of their regard for Catharine. The princeſs of Daſhkoff was a ſecond time baniſhed to Moſcow; and, to magnify her own importance, ſhe ſpoke freely of the means by which the empreſs, whom ſhe accuſed of ingratitude, had been raiſed to the throne. The inhabitants of Moſcow, who never favoured the uſurpation, were thus made ripe for a revolt. At St Peterſburgh, Count Panin felt himſelf uneaſy under the predominant influence of the favourite, and tried in vain to divert Catharine's affections to a new object. She received a few ſecret viſits from a handſome young man, and then appointed him to a lucrative and honourable employment in ſome diſtant province of the empire; when Orloff recovered his former

Catharine. mer afcendency, which through his own careleffnefs he had nearly loft. In this ftate of the public mind, confpiracies were very frequent; and as the general object of them was to place on the throne prince Ivan, who was again languifhing in the dungeon from which Peter had taken him, the emprefs had given to his guard an order, figned by her own hand, to put that unfortunate prince to death, fhould any attempt be made to liberate him from his prifon. An attempt was made by a very inferior officer, as fome have fuppofed, by the inftructions of Catharine, and her bloody order was inftantly obeyed. The affaffins were rewarded and promoted in the army; but the officer who attempted to refcue the prince was condemned to death, and fuffered unexpectedly the fentence of the law. The brothers and fifters of Ivan, who had been kept in a prifon different from his, were fent to Denmark; and, to provide them with neceffaries fuitable to their rank, the emprefs made them a prefent of 200,000 rubles, and paid annually to the maintenance of their dignity a penfion of thirty thoufand.

The throne of Catharine was now firmly eftablifhed by the death or renunciation of every perfon who was defcended of the imperial family; and fhe had leifure to turn her thoughts to the aggrandifement of the empire. It was foon feen that this was the object which fhe had in view when fhe raifed Count Poniatowfky to the throne of Poland, and that fhe was not actuated on that occafion by any remains of her former attachment. We have elfewhere fhewn (fee Poland, *Encycl.* n° 98—115) under what pretences fhe invaded the kingdom of him who had formerly been one of her moft favoured lovers, and by what means fhe annexed great part of it to the territories of Ruffia. But it is not through her wars that in this article we mean to trace her character: It is not as a fovereign and heroine that her life is entitled to a place in a general repofitory of arts, fciences, and mifcellaneous literature, but as a patronefs of art and of fcience, and as the legiflatrix of a vaft empire, who employed all her talents and all her power for the civilization of a great part of the human race.

Under the article Russia *(Encycl.)*, we have mentioned the famous *code of laws for a great empire*, and the propofed *convention of deputies from all the claffes*, which Catharine and the princefs Dafhkoff fo artfully employed as means to bring about the revolution which feated the former on the throne. The ftates actually met in the ancient capital of the empire, and the fovereign's inftructions for framing a new code of laws was read amidft reiterated burfts of applaufe. All prefent extolled the fagacity, the wifdom, the humanity of the emprefs; but fear and flattery had a greater fhare in thefe exclamations than any juft knowledge of the fubject. The deputies of the Samoiedes alone had the courage to fpeak freely. One of them ftood up, and, in the name of himfelf and his brethren, faid, "We are a fimple and honeft people. We quietly tend our reindeer. We are in no want of a new code; but make laws for the Ruffians, our neighbours, that may put a ftop to their depredations." The following fittings did not pafs fo quietly. A debate about the liberation of the boors was carried on with fuch warmth, that fatal confequences were to be apprehended; and the deputies were difmiffed to their refpective provinces in the manner which we have elfewhere related. Previous, however, to the diffolution of this affembly, the members were required to fignalize the meeting by fome confpicuous act of gratitude; and, by a general acclamation, the titles of Great, Wise, Prudent, and Mother of the Country, were decreed to the emprefs. With affumed modefty fhe accepted only of the laft, "as the moft benign and glorious recompence for her labours and folicitudes in behalf of a people whom fhe loved."

For that people fhe did indeed labour, and labour moft ufefully. She introduced into the adminiftration of juftice the greateft reformation of which the half civilized ftate of Ruffia would perhaps admit. She fpared neither trouble nor expence to diffufe over the empire the light of fcience, and the benefits of ufeful and elegant arts; and fhe protected, as far as fhe could, the poor from the oppreffions of the rich. About the middle of 1767, fhe conceived the idea of fending feveral learned men to travel through the interior of her vaft dominions, to determine the geographical pofition of the principal places, to mark their temperature, and to examine into the nature of their foil, their vegetable and mineral productions, and the manners of the people by whom they were inhabited. To this employment fhe appointed Pallas, Gmelin, Euler, and many others of the higheft eminence in the republic of letters; from whofe journals of thefe interefting travels large additions have been made to the general ftock of ufeful knowledge. This furvey of the empire, and the maps made from it, had Catharine done nothing elfe, would alone have been fufficient to render her name immortal. Well convinced in her own mind, that it is not fo much by the power of arms, as by precedence in fcience, that nations obtain a confpicuous place in the annals of the world, with a laudable zeal fhe encouraged artifts and fcholars of all denominations. She granted new privileges to the two academies of fciences and the arts; encouraged fuch of the youth as had behaved well in thefe national inftitutes, to travel for farther improvement over Europe, by beftowing upon them, for three years, large penfions to defray their expence; and, to remove as much as poffible the Ruffian prejudice againft all kinds of learning, fhe granted patents of nobility to thofe who, during their education, had conducted themfelves with propriety, and become proficients in any branch of ufeful or elegant knowledge. Still farther to encourage the fine arts in her dominions, fhe affigned an annual fum of 5000 rubles for the tranflation of foreign literary works into the Ruffian language.

In the year 1768, the fmall-pox raged at St Peterfburgh, and proved fatal to vaft numbers of all ranks and of every age. The emprefs was defirous to introduce the practice of inoculation among her fubjects; and refolved to fet the example by having herfelf and her fon inoculated. With this view, fhe applied for a phyfician from England: and Dr Thomas Dimfdale of Hertford being recommended to her, he repaired with his fon to the capital of Ruffia, where he inoculated firft the emprefs, then the grand duke, and afterwards many of the nobility. The experiment proving fuccefsful, he was created a baron of the empire, appointed actual counfellor of ftate, and phyfician to her imperial majefty, with a penfion of L. 500 fterling a-year, a-year, to be paid him in England, befides L. 10,000 which he immediately received. So popular was the emprefs at this period, that, by a decree of the fenate, the anniverfary of her recovery from the fmall-pox was enjoined to be celebrated as a religious feftival; and it has ever fince been obferved as fuch.

She was now engaged in war with the Turks, of which a fufficient account for a work of this nature has been given under the title TURKEY *(Encycl.)*; but there was one tranfaction of her and her friends, of which no mention was made in that article, though it is of importance to him who would form a juft eftimate of her perfonal character.

We have noticed the fenfuality of the emprefs Elizabeth. She bore three children to the grand veneur Alexy Gregorievitch Razumoffky, to whom, indeed, fhe is faid to have been clandeftinely married. Of thefe children the youngeft was a girl, brought up under the name of princefs Tarrakanoff. Prince Radzivil, who has been mentioned in the article POLAND *(Encycl.)*, irritated at Catharine's cruelties to his countrymen, conceived the project of placing the young princefs on the throne of her anceftors; and, having gained over the perfons to whom her education was entrufted, he carried her off to Rome as a place of fafety. Catharine, in return, feized his large eftates; and he and the princefs were reduced to extreme poverty. Radzivil repaired to Poland in order to learn what could be done to forward his great enterprife; and fcarcely had he arrived there when an offer was made to reftore to him his poffeffions, upon condition of his carrying his ward to St Peterfburgh. This he refufed; but had the bafenefs to promife, that he would give himfelf no farther concern about the daughter of Elizabeth; and he was put in poffeffion of all his eftates.

By the inftructions of the emprefs, Alexius Orloff, who nominally commanded the Ruffian fleet at the Dardanelles, repaired to Rome, got accefs to young Tarrakanoff, and found means to perfuade her that all Ruffia was ready to revolt from Catharine, and place her on the throne of her mother. To convince her of his fincerity, he pretended to feel for her the tendereft and moft refpectful paffion; and the unfufpicious lady was induced to accept of him as a hufband. The ruffian who had affaffinated the grandfon of Peter the Great, did not hefitate to feduce and betray his granddaughter. Under pretence of having the marriage ceremony performed according to the rites of the Greek church, he fuborned fome fubaltern villains to perfonate priefts and lawyers; thus combining profanation with impofture againft the unprotected and too confident Tarrakanoff.

Having been treated for fome days, both at Rome and at Leghorn, with all the refpect due to a fovereign, the unfufpecting princefs expreffed a wifh to go on board a Ruffian fhip of war. This was juft what Orloff wanted. Attended by a numerous and obfequious train, fhe was rowed from the fhore in a boat with magnificent enfigns, hoifted upon the deck of the fhip in a fplendid chair, and immediately handcuffed. In vain did fhe throw herfelf at the feet of her pretended hufband, and conjure him by every thing tender which had paffed between them. She was carried down into the hold; the next day the veffel failed for St Peterfburgh; where, upon her arrival, the princefs was fhut up in the fortrefs; and what became of her fince was never known. Such were the means which Catharine fcrupled not to employ in order to get rid of all pretenders to her throne.

Soon after this fervice rendered to her by Alexius Orloff, fhe difmiffed his brother Gregory from her favour, and connected herfelf with Vaffiltchikoff, a fub-lieutenant of the guards. The former favourite had indeed become infolent, and, as Catharine thought, ungrateful. He afpired to nothing lefs than the throne. From love to himfelf and to a fon which fhe had born to him, fhe offered to enter into a fecret marriage; but with this propofal the proud prince (A) was not fatisfied, and hoped that his refufal would impel her to receive him publicly as her hufband and partner in power. He was miftaken. She divefted him of all his employments; but gave him a penfion of 150,000 rubles, a handfome fervice of plate, and an eftate with 6000 peafants upon it; and, thus enriched, he fet out upon a journey through various parts of Europe. He returned, however, much fooner than was expected; the new favourite was handfomely rewarded, and fent to a diftance; Orloff was reftored to all his offices, and his baleful influence was again felt.

He attempted to perfuade the emprefs to difmifs Panin from the court; but the grand duke interpofed in behalf of his old preceptor; and, for once, Catharine liftened to the entreaties of her fon. When a dreadful rebellion, under a Koffak of the name of Pugetfhoff, who pretended to be Peter III. efcaped from his affaffins, was fhaking the throne to its foundation—the influence of Orloff was fuch as to prevent the emprefs, for fome time, from employing her ableft general againft the rebels, becaufe that general was Panin, brother to the minifter. Danger, however, at laft prevailed over the favourite: Panin was fent againft Pugetfhoff; the rebellion was crufhed; and Catharine found leifure to give fomething like a legal conftitution to the empire. In that work, the laws and regulations eftablifhed for the government of the various provinces, and for the equitable adminiftration of juftice through the whole of her vaft dominions, evinces the greateft wifdom and fagacity in their author, as well as a proper regard to the practicable liberties and rights of men. In the capital, fhe eftablifhed the moft perfect police, by which the internal tranquillity of a great city was, perhaps, ever maintained; and whilft her private conduct was far from correct, fhe was acting in the capacity of fovereign, fo as to deferve, indeed, the appellation of *Mother of her people.*

To follow her through all her wars and intrigues with foreign courts, would fwell this article to the fize of a volume. Such a narrative, too, belongs rather to the hiftory of Ruffia than to the memoirs of Catharine; in which it is the bufinefs of the biographer to develope the private character of the woman rather than to detail the exploits of the fovereign. Her partition of Poland, and afterwards the annihilation of it as an independent

(A) She had fome time before obtained for him a patent, creating him a prince of the Roman empire.

Catharine. dependent republic; her encroachments on the territories of the grand fignior; her formation of the armed neutrality; the influence which fhe maintained over the courts of Sweden and Denmark; and the art with which fhe threw the weight of Ruffia fometimes into the fcale of Auftria, and fometimes into that of Pruffia, juft as the interefts of her own dominions required the one or the other to preponderate—fhew how admirably fhe was qualified to guide the helm of a great empire in all its tranfactions with foreign ftates. We fpeak not of the equity of her proceedings; for it muft be confeffed, that equity formed no barrier againft her ambition; and that fhe never failed to fubjugate thofe whom fhe pretended to take under her protection. Her ruling paffion was to enlarge her own territories, already fo very extenfive; and, for the attainment of that object, fhe contrived the moft judicious plans, which fhe executed with vigour. In this part of her conduct, however, fhe has been equalled by other monarchs; but in the zeal and the wifdom with which fhe endeavoured to introduce among her half-favage fubjects the bleffings of knowledge and induftry, fhe ftands unrivalled, except, perhaps, by her predeceffor Peter the Great. Of this we need bring no other proof, in addition to what has been already ftated, than that fhe founded in St Peterfburgh alone thirty-one feminaries, where 6800 children of both fexes were educated at the annual expence to the government of 754,335 rubles. She fuperintended herfelf the education of her grandchildren, and wrote for them books of inftruction. If it be true, that "every man acquainted with the common principles of human action, will look with veneration on the writer who is at one time combating Locke, and at another making a catechifm for children in their fourth year;" with what veneration fhould we look upon the emprefs of Ruffia, could we forget the means by which fhe obtained that elevation from which fhe frequently defcended for a fimilar employment? This fhe did, not for her own defcendants alone, but alfo for the children of others; of whom fhe had always a great number in her apartments, who fhared in the inftruction given to her grandchildren, and whofe careffes fhe returned with extreme complaifance.

Her greateft weaknefs was furely that grofs paffion which her panegyrifts have dignified with the name of love: but to fuch an appellation it had no claim, if love be any thing more than a fexual appetite. Befides Gregory Orloff, fhe had not fewer than ten favourites after the death of her hufband; and of thefe fhe feems to have felt a refined affection for none but Lanfkoi, a young Pole of a very ancient family, and of elegant manners, and the famous Potemkin, to whom fhe is faid fecretly to have given her hand, and who preferved her friendfhip, if not her affection, to the end of his life. To Lanfkoi, whofe education had been much neglected, fhe condefcended to become preceptrix; and, as he made great progrefs in the acquifition of ufeful knowledge, fhe admired in him her own creation. Potemkin, though not amiable, deferved her favour for the fidelity and abilities with which he ferved her, both in the council and in the field; and in him, when fhe had ceafed to look on him with the eyes of love, fhe refpected the intriguing politician and intrepid commander, who had formed plans for driving the Turks out of Europe, and fetting her on the throne of Byzantium. Her other favourites had nothing to recommend them but mafculine beauty and corporeal ftrength. One of them, however, thought it neceffary to have a library in the grand houfe, of which the emprefs, upon receiving him into favour, had made him a prefent; and defired the principal bookfeller to fill his fhelves. The man afked him what books he would pleafe to have. "You underftand that better than I (replied the favourite); that is your bufinefs. You know the proper affortments; I have deftined a large room to receive them. Let there be large books at the bottom, and fmaller and fmaller up to the top; that is the way they ftand in the emprefs's library!" In the converfation of fuch men, the cultivated mind of Catharine could enjoy no interchange of fentiments. Catharine.

We know not whether that more than Afiatic magnificence, which fhe difplayed on every public occafion, fhould be confidered as an inftance of weaknefs or of wifdom. If fhe delighted in balls, and mafquerades, and fumptuous entertainments, and drefs loaded with jewels and every kind of fplendid ornament, for their own fakes, fhe betrayed a weaknefs unworthy of that fovereign who held in her hand the balance of Europe, and at whofe nod the greateft powers of Afia trembled: but if fhe introduced fuch fplendour into her court merely to divert the attention of the Ruffians from the means by which fhe got poffeffion of the throne, and to wean them from their own favage and flovenly manners; even this may perhaps be confidered as one of her moft mafterly ftrokes in politics.

Her ambition was boundlefs; but, if fuch a phrafe may be allowed, it was not always true ambition. When the French republic had eftablifhed itfelf on the ruins of monarchy, and was propagating new theories of government through all Europe, true ambition would furely have led the autocratrix of the north to unite her forces with thofe of the coalefced powers, in order to crufh the horrid hydra before its anarchical principles could be introduced among her own barbarous fubjects. Such would certainly have been the advice of her favourite Potemkin, who longed to lead a Ruffian army into France, even before the murder of the unfortunate Louis. That general, however, had died in October 1791; and when Britain, Auftria, and Pruffia, were leagued againft the new republic, Catharine looked coolly on, in hopes, it is probable, of availing herfelf of their weaknefs, when exhaufted by a long and bloody war. She gave refuge, indeed, in her dominions to many emigrants from France, and fent a fquadron of fhips to co-operate with the navy of England: but in this laft meafure fhe regarded merely her own immediate intereft; for her crazy fhips were repaired by Britifh carpenters at the expence of the Britifh government, and her officers had an opportunity of learning the evolutions of the Britifh navy. She had likewife other profpects in view when fhe lent to the allies this flender aid. She meditated a new war with Turkey; and, depending upon meeting with no oppofition, if fhe fhould not receive affiftance from England and Auftria, fhe flattered herfelf with accomplifhing her darling project of driving the Ottomans out of Europe, and of reigning in Conftantinople. But fhe was difappointed. On the morning of the 9th of November 1796, fhe was feized with what her principal phyfician judged a fit of apoplexy; and, at 10 o'clock in the evening

evening of the following day, expired, in the 68th year of her age, leaving behind her the character of one of the greateft fovereigns that ever fwayed a fceptre.

After this long detail of the incidents of her life, it is needlefs to inform the reader that Catharine II. had no religion, and, of courfe, no principles of morality, which could induce her in every inftance to do to others as fhe would have them do to her. She was a profeffed difciple of the French philofophers; by fome of whom fhe was ridiculed, and by others cheated. The incenfe which fhe paid to the genius of Voltaire did not hinder him from frequently breaking his jefts upon the autocratrix of Ruffia and her fucceffive favourites; and Diderot, whom fhe careffed, fold to her an immenfe library, when he poffeffed hardly a book, and was obliged to ranfack Germany and France for volumes to enable him to fulfil his bargain. Such is the friendfhip, and fuch the gratitude, which fubfift among the amiable pupils of nature, and the philanthropic advocates for the rights of man.

CAUDA *Capricorni*, a fixed ftar of the fourth magnitude, in the tail of Capricorn; called alfo, by the Arabs, *Dineb Algedi;* and γ by Bayer.

CAUDA *Ceti*, a fixed ftar of the third magnitude; called alfo, by the Arabs, *Dineb Kaetos;* marked β by Bayer.

CAUDA *Cygni*, a fixed ftar of the fecond magnitude, in the Swan's-tail; called by the Arabs *Dineb Adigege*, or *Eldegiagich;* and marked α by Bayer.

CAUDA *Delphini*, a fixed ftar of the third magnitude, in the tail of the Dolphin; marked ϵ by Bayer.

CAUDA *Draconis*, or Dragon's tail, the moon's fouthern or defcending node.

CAUDA *Leonis*, a fixed ftar of the firft magnitude, in the Lion's tail; called alfo, by the Arabs, *Dineb Eleced;* and marked β by Bayer. It is called alfo *Lucida Cauda*.

CAUDA *Urfæ Majoris*, a fixed ftar of the third magnitude, in the tip of the Great Bear's tail; called alfo, by the Arabs, *Alalioth*, and *Benenath;* and marked η by Bayer.

CAUDA *Urfæ Minoris*, a fixed ftar of the third magnitude, at the end of the Leffer Bear's tail; called alfo the *Pole Star*, and, by the Arabs, *Alrukabah;* and marked α by Bayer.

CAVENDISH, a townfhip in Windfor co. Vermont, W. of Weathersfield, on Black river, having 491 inhabitants. Upon this river, and within this townfhip, the channel has been worn down 100 feet, and rocks of very large dimenfions have been undermined and thrown down one upon another. Holes are wrought in the rocks of various dimenfions, and forms; fome cylindrical, from 1 to 8 feet in diameter, and from 1 to 15 feet in depth; others are of a fpherical form from 6 to 20 feet diameter, worn almoft perfectly fmooth, into the folid body of a rock.—*Morse*.

CAUSE has been defined, we think, with accuracy in the Encyclopædia, and the doctrine ftated which we believe to be true. Objections however have been made to that doctrine, of which we have endeavoured to remove fome, under the title ACTION, in this Supplement; and the doctrine itfelf has been well illuftrated (at leaft fuch is our opinion) in the fupplementary article ASTRONOMY. We have, therefore, very little to add here on the fubject of caufes, though it is the moft important fubject which can employ the mind of man. What is the relation between a phyfical caufe and that which is termed its effect—between heat, for inftance, and the fufion of metals? Is it a *neceffary connection*, or only a *conjunction*, difcovered by experience to be *conftant?*

If by *neceffary* connection be meant that kind of connection of which the contrary cannot be conceived, we do not think that the connection of any phyfical caufe with its effect can be called neceffary. We fee no difficulty in conceiving, that fire, inftead of fufing gold, might fix mercury. This *may* indeed be impoffible; and we might perhaps fee the impoffibility, did we as completely know the nature of fire and of metals as we know the relations of pure geometry. We know that the three angles of a plain triangle cannot poffibly be either greater or lefs than two right angles; for in this comparifon nothing is hid from our mental view. We do not, however, perceive the impoffibility of mercury being fixed, as clay is hardened, by heat; for of *heat*, and mercury, and clay, we know very little, and that little is the offspring of experience.

But if the connection between caufe and effect be not *neceffary*, are we not deprived of the means of demonftrating the great fundamental truth of religion? We have nowhere faid, that the connection between caufe and effect is not neceffary; but only, that we do not perceive the neceffary connection between what are called *phyfical* caufes and their effects. That every event is, and muft be, brought about by *fome caufe*, or fome *agency*, we hold to be a felf-evident truth, which no man can deny who underftands the terms in which it is expreffed; but what or where the agency is, we can very feldom, if ever, know, except when we think of our own voluntary actions. When a change is obferved, we cannot doubt of its being produced by fomething: either the thing changed is animated and has produced the change by its own agency, juft as we move our heads and legs by an act of volition; or if it be inanimated, and of itfelf incapable of agency, the change has been produced by fomething external, denominated a *caufe*. But all external caufes, which are not likewife agents, in the proper fenfe of the word, may be traced, we think, as effects up to fome agency; and therefore, in our opinion, there is no real, ultimate, efficient, caufe but mind, or that which is endued with power. In proof of this doctrine, if it need any proof, we can only refer to what has been faid elfewhere on our notions of *power* and of *phyfical caufes*. See *(Encycl.)* METAPHYSICS n° 109, &c.—PHILOSOPHY and PHYSICS *paffim*—and *(Suppl.)* ACTION and ASTRONOMY.

CAYAHAGA, or *Cayuga*, fometimes called the Great river, empties in at the S. bank of lake Erie, 40 miles eaftward of the mouth of Huron; having an Indian town of the fame name on its banks. It is navigable for boats; and its mouth is wide, and deep enough to receive large floops from the lake. Near this are the celebrated rocks which project over the lake. They are feveral miles in length, and rife 40 or 50 feet perpendicular out of the water. Some parts of them confift of feveral ftrata of different colours, lying in a horizontal direction; and fo exactly parallel, that they refemble the work of art. The view from the land is grand, but the water prefents the moft magnificent profpect of this fublime work of nature; it is attended, however,

however, with great danger; for if the leaft ftorm arifes, the force of the furf is fuch that no veffel can efcape being dafhed to pieces againft the rocks. Col. Broadfhead fuffered fhipwreck here in the late war and loft a number of his men, when a ftrong wind arofe, fo that the laft canoe narrowly efcaped. The heathen Indians, when they pafs this impending danger, offer a facrifice of tobacco to the water.

Part of the boundary line between the U. S. A. and the Indians, begins at the mouth of Cayahoga, and runs up the fame to the portage between that and the Tufcarawa branch of the Mufkingum.

The Cayuga nation, confifting of 500 Indians, 40 of whom refide in the United States, the reft in Canada, receive of the ftate of New-York an annuity of 2300 dollars, befides 50 dollars granted to one of their chiefs, as a confideration for lands fold by them to the ftate, and 500 dollars from the United States, agreeably to the treaty of 1794.—*Morse.*

CAYUGA, a beautiful lake in Onondaga co. New-York, from 35 to 40 miles long, about 2 miles wide, in fome places 3, and abounds with falmon, bafs, catfifh, eels, &c. It lies between Seneca and Owafco lake, and at the N. end empties into Scayace River which is the S. eaftern part of Seneca River whofe waters run to lake Ontario. On each fide of the lake is a ferry houfe, where good attendance is given. The refervation lands of the Cayuga Indians lie on both fides of the lake, at its northern end.—*ib.*

CEDAR *Point*, a port of entry in Charles co. Maryland, on the E. fide of Potowmac River, about 12 miles below Port Tobacco, and 96 S. by W. of Baltimore. Its exports are chiefly tobacco and Indian corn, and in 1794, amounted in value to 18,593 dollars.—*ib.*

1 Definition. CENTER, or CENTRE, a word borrowed from the French name *ceintre* or *cintre*, given to the frame of timber by which the brick or ftone of arched vaulting is fupported during its erection and from which it receives its form and curvature.

2 Purpofe of this article. It is not our intention to defcribe the variety of conftructions which may be adopted in eafy fituations, where the arches are of fmall extent, and where fufficient foundation can be had in every part of it for fupporting the frame. In fuch cafes, the frequency of the props which we can fet up difpenfes with much care; and a frame of very flight timbers, connected together in an ordinary way, will fuffice for carrying the weight, and for keeping it in exact fhape. But, when the arches have a wide fpan, and confequently a very great weight, and when we cannot fet up intermediate pillars, either for want of a foundation in the foft bottom of a river, or becaufe the arch is turned between two lofty piers, as in the dome of a ftately cathedral—we are then obliged to reft every thing on the piers themfelves; and the framing which is to fupport our arch before the keyftone is fet, muft itfelf be an arch, depending on the mutual abutment of its beams. One fhould think that this view of the conftruction of a centre would offer itfelf at the firft, naturally derived from the erection it was to affift: but it has not been fo. When intermediate pillars were not employed, it was ufual to frame the mould for the arch with little attention to any thing but its fhape, and then to crofs it and recrofs it in all directions with other pieces of timber, till it was thought fo bound together that it could be lifted in any pofition, and, when loaded with any weight, could not change its fhape. The frame was then raifed in a lump, like any folid body of the fame fhape, and fet in its place. This is the way ftill practifed by many country artifts, who, having no clear principles to guide them, do not ftop till they have made a load of timber almoft equal to the weight which it is to carry.

But this artlefs method, befides leading the employer into great expence, is frequently fatal to the undertaker, from the unfkilfulnefs of the conftruction. The beams which connect its extremities, are made alfo to fupport the middle by means of pofts which reft on them. They are therefore expofed to a tranfverfe or crofs ftrain, which they are not able to bear. Their number muft therefore be increafed, and this increafes the load. Some of thefe crofs ftrains are derived from beams which are preffed very obliquely, and therefore exert a prodigious thruft on their fupports. The beams are alfo greatly weakened by the mortifes which are cut in them to receive the tenons of the croffing beams: and thus the whole is exceedingly weak, in proportion to what the fame quantity of timber may be made by a proper difpofition of its parts.

3 General principles of conftruction. The principles from which we are to derive this difpofition are the general mechanical principles of carpentry, of which we have given fome account in that article. Thefe furnifh one general rule: When we would give the utmoft ftrength poffible to a frame of carpentry, every piece fhould be fo difpofed that it is fubject to no ftrain but what either pufhes or draws it in the direction of its length: and, if we would be indebted to timber alone for the force or ftrength of the centre, we muft reft all on the firft of thefe ftrains; for when the ftraining force tends to *draw* a beam out of its place, it muft be held there by a mortife and tenon, which poffeffes but a very trifling force, or by iron ftraps and bolts. Cafes occur where it may be very difficult to make every ftrain a thruft, and the beft artifts admit of ties; and indeed where we can admit a tie-beam connecting the two feet of our frame, we need feek no better fecurity. But this may fometimes be very inconvenient. When it is the arch of a bridge that we are to fupport, fuch a tie-beam would totally ftop the paffage of fmall craft up and down the river. It would often be in the water, and thus expofed to the moft fatal accidents by frefhes, &c. Interrupted ties, therefore, muft be employed, whofe joint or meetings muft be fupported by fomething analogous to the king-pofts of roofs. When this is judicioufly done, the fecurity is abundantly good. But great judgment is neceffary, and a very fcrupulous attention to the difpofition of the pieces. It is by no means an eafy matter to difcern whether a beam, which makes a part of our centre is in a ftate of compreffion or in a ftate of extenfion. In fome works of the moft eminent carpenters even of this day, we fee pieces confidered as ftruts (and confiderable dependence had on them in this capacity), while they are certainly performing the office of tie-beams, and fhould be fecured accordingly. This was the cafe in the boldeft centre (we think) that has been executed in Europe, that of the bridge of Orleans, by Mr Hupeau. Yet it is evidently of great confequence not to be miftaken in this point; for when we are miftaken, and the piece is ftretched which we imagine to be compreffed, we not only are deprived of fome

fupport

Center. support that we expected, but the expected support has become an additional load.

4 How to distinguish a strut from a tie.

To ascertain this point, we may suppose the piers to yield a little to the pressure of the archstones on the centre frames. The feet, therefore, fly outwards, and the shape is altered by the sinking of the crown. We must draw our frame anew for this new state of things, and must notice what pieces must be made longer than before. All such pieces have been acting the part of tie beams.

But a centre has still another office to sustain; it must keep the arch in its form; that is, while the load on the centre is continually increasing, as the masons lay on more courses of arch-stones, the frame must not yield and go out of shape, sinking under the weight on the haunches, and rising in the crown, which is not yet carrying any load. The frame must not be supple; and must derive its stiffness, not from the closeness and strength of its joints, which are quite insignificant when set in competition with such immense strains, but from struts or ties, properly disposed, which hinder any of the angles from changing its amplitude.

5 How to secure stiffness and strength.

It is obvious, from all that has been said, that the strength and stiffness of the whole must be found in the triangles into which this frame of carpentry may be resolved. We have seen that the strains which one piece produces on two others, with which it meets in one point, depends on the angles of their intersection; and that it is greater as an obtuse angle is more obtuse, or an acute angle more acute. And this suggests to us the general maxim, "to avoid as much as possible all very obtuse angles." Acute angles, which are not necessarily accompanied by obtuse ones, are not so hurtful; because the strain here can never exceed the straining force; whereas, in the case of an obtuse angle, it may surpass it in any degree.

Such are the general rules on this subject. Although something of the mutual abutment of timbers, and the support derived from it, has been long perceived, and employed by the carpenters in roofing, and also (doubtless) in the forming of centres, yet it is a matter of historical fact, that no general and distinct views had been taken of it till about the beginning of this century, or a little earlier. Fontana has preserved the figure of the frames on which the arches of St Peter's at Rome were turned. The one employed for the dome is constructed with very little skill; and those for the arches of the nave and transepts, though incomparably superior, and of considerable simplicity and strength, are yet far inferior to others which have been employed in later times. It is much to be regretted that no trace remains of the forms employed by the great architect and consummate mechanician Sir Christopher Wren. We should doubtless have seen in them every thing that science and great sagacity could suggest. We are told, indeed, that his centering for the dome of St Paul's was a wonder of its kind; begun in the air at the height of 160 feet from the ground, and without making use of even a projecting corniche whereon to rest it.

6 The earliest theory, on scientific principles,

The earliest theory of the kind that we have met with, that is proposed on scientific principles, and with the express purpose of serving as a lesson, are two centres by Mr Pitot of the Academy of Sciences, about the beginning of this century. As they have considerable merit (greatly resembling those employed by Michael Angelo in the nave of St Peter's), and afford some good maxims, we shall give a short account of them. We crave the excuse of the artists if we should employ their terms of art somewhat aukwardly, not being very familiarly acquainted with them. Indeed, we observe very great differences, and even ambiguity, in the terms employed.

What we shall describe under the name of a *centre* is (properly speaking) only one frame, truss, or rib, of a centre. They are set up in vertical planes, parallel to each other, at the distance of 5, 6, 7, or 8 feet, like the trusses or main couples of a roof. Bridging joists are laid across them.—In smaller works these are laid sparingly, but of considerable scantling, and are boarded over; but for great arches, a bridging joist is laid for every course of archstones, with blockings between to keep them at their proper distances. The stones are not laid immediately on these joists, but beams of soft wood are laid along each joist, on which the stone is laid. These beams are afterwards cut out with the chissel, in order to separate the centre from the ring of stones, which must now support each other by their mutual abutment.

The centre is distinguishable into two parts, ALLB (fig. 1.) and LDL, which are pretty independent of each other, or at least act separately. The horizontal STRETCHER LL cuts the semicircle ADB half way between the spring and the crown of the arch; the arches AL,LD, being 45° each. This stretcher is divided in the same proportion in the points G and H; that is, GH is one half of LL, and LG, HL are each one-fourth of LL nearly. Each end is supported by two STRUTS EI, GI, which rest below on a SOLE OR BED properly supported. The interval between the heads of the struts GI, HK is filled up by the STRAINING BEAM GH, abutting in a proper manner on the struts (see CARPENTRY, *Supplement*). The extremities L, L, are united in like manner by butting joints, with the heads of the outer struts. The ARCH MOULDS AP, BP, are connected with the struts by cross pieces PQ, which we shall call BRIDLES, which come inwards on each side of the struts (being double), and are bolted to them. This may be called the lower part of the frame. The upper part consists of the king post DR, supported on each side by the two struts or braces ML, ON, mortised into the post, and also mortised into the stretcher, at the points L, N, where it is supported by the struts below. The arches LD, LD are connected with the struts by the bridles PQ, in the same manner as below. 7 Illustrated Plate XIV.

8 Propriety of this arrangement.

There is a great propriety in many parts of this arrangement. The lower parts or haunches of the arch press very lightly on the centres. Each archstone is lying on an inclined plane, and tends to slide down only with its relative weight; that is, its weight is to its tendency to slide down the joint as radius to the sine of elevation of the joint. Now it is only by this tendency to slide down the joint that they press on the centering, which in every part of the arch is perpendicular to the joint: But the pressure on the joint, arising from this cause, is much less than this, by reason of the friction of the joints. A block of dry freestone will not slide down at all; and therefore will not press on the centering, if the joint be not elevated 35 degrees at least. But the archstones are not laid in this manner, by sliding them down along the joint, but are laid on the centres, and slide

ſlide down *their* ſlope, till they touch the blocks on which they are to reſt; ſo that, in laying the archſtones, we are by no means allowed to make the great deduction from their weight juſt now mentioned, and which Mr Couplet preſcribes (Mem. Acad. Sciences, 1729). But there is another cauſe which diminiſhes the preſſure on the centres; each block ſlides down the planks on which it is laid, and preſſes on the block below it, in the direction of the tangent to the arch. This preſſure is tranſmitted through this block, in the ſame direction, to the next, and through it to the third, &c. In this manner it is plain that, as the arch advances, there is a tangential preſſure on the lower archſtones, which diminiſhes their preſſure on the frame, and, if ſufficiently great, might even puſh them away from it. Mr Couplet has given an analyſis of this preſſure, and ſhews, that in a ſemicircular arch of uniform thickneſs none of the arch ſtones below 30° preſs on the frames. But he (without ſaying ſo) calculates on the ſuppoſition that the blocks deſcend along the circumference of this frame in the ſame manner as if it were perfectly ſmooth. As this is far from being the caſe, and as the obſtructions are to the laſt degree various and irregular, it is quite uſeleſs to inſtitute any calculation on the ſubject. A little reflection will convince the reader, that in this caſe the obſtruction ariſing from friction *muſt* be taken into account, and that it *muſt not* be taken into account in eſtimating the preſſure of each ſucceſſive courſe of ſtones as they are laid. It is enough that we ſee that the preſſure of the lower courſes of archſtones on the frame is diminiſhed. Mr Couplet ſays, that the whole preſſure of a ſemicircular arch is but $\frac{4}{5}$ths of its weight; but it is much greater, for the reaſon juſt now given. We have tried, with a well-made wooden model (of which the circumference was rubbed with black lead to render it more ſlippery), whether *any* part of the wooden blocks repreſenting the archſtones were detached from the frame by the tangential preſſure of the ſuperior blocks; but we could not ſay confidently that any were ſo detached. We perceived that all kept hold of a thin ſlip of Chineſe paper (alſo rubbed with black lead) between them and the frame, ſo that a ſenſible force was required to pull it out. From a combination of circumſtances, which would be tedious to relate, we believe that the centres carry more than two-thirds of the weight of the arch before the keyſtone is ſet. In elliptical and lower pitched circular arches, the proportion is ſtill greater.

9 By a centre of M. Pitot's.

It ſeems reaſonable enough, therefore, to diſpoſe the framing in the manner propoſed by Pitot, directing the main ſupport to the upper maſs of the arch, which preſſes moſt on the frame. We ſhall derive another advantage from this conſtruction, which has not occurred to Mr Pitot.

There is an evident propriety in the manner in which he has diſtributed the ſupports of the upper part. The ſtruts which carry the king poſt ſpring from thoſe points of the ſtretcher where it reſts on the ſtruts below: thus the ſtretcher, on which all depends, bears no tranſverſe ſtrains. It is ſtretched by the ſtrut above it, and it is compreſſed in a ſmall degree between the ſtruts below it, at leaſt by the outer ones. Mr Pitot propoſes the ſtraining beam GH as a lateral ſupport to the ſtretcher, which may therefore be of two pieces: but although it *does* augment its ſtrength, it does not ſeem neceſſary for it. The ſtretcher is abundantly carried by the ſtrap, which may and ſhould ſuſpend it from the king poſt. The great uſe of the ſtraining piece is to give a firm abutment to the inner ſtruts, without allowing any lateral ſtrain on the ſtretcher. *N. B.* Great care muſt be taken to make the hold ſufficiently firm and extenſive between the ſtretcher and the upper ſtruts, ſo that its coheſion to reſiſt the thruſts from theſe ſtruts may be much employed.

The only imperfection that we find in this frame is the lateral ſtrains which are brought upon the upper ſtruts by the bridles, which certainly tranſmit to them part of the weight of the archſtones on the curves. The ſpace between the curves and ML ſhould alſo have been truſſed. Mr Pitot's form is, however, extremely ſtiff; and the cauſing the middle bridle to reach down to the ſtretcher, ſeems to ſecure the upper ſtruts from all riſk of bending.

This centre gives a very diſtinct view of the offices of all the parts, and makes therefore a proper introduction to the general ſubject. It is the ſimpleſt that can be in its principle, becauſe all the eſſential parts are ſubjected to one kind of ſtrain. The ſtretcher LL is the only exception, and its extenſion is rather a collateral circumſtance than a ſtep in the general ſupport.

10 The ſtrength of this frame

The examination of the ſtrength of the frame is extremely eaſy. Mr Pitot gives it for an arch of 60 feet ſpan, and ſuppoſes the archſtones 7 feet long, which is a monſtrous thickneſs for ſo ſmall an arch; 4 feet is an abundant allowance, but we ſhall abide by his conſtruction. He gives the following ſcantlings of the parts:

The ring or circumference conſiſts of pieces of oak 12 inches broad and 6 thick.

The ſtretcher LL is 12 inches ſquare.

The ſtraining piece GH is alſo 12 by 12.

The lower ſtruts 10 by 8.

The king poſt 12 by 12.

The upper ſtruts 10 by 6.

The bridles 20 by 8.

Theſe dimenſions are French, which is about $\frac{1}{17}$th larger than ours, and the ſuperficial dimenſions (by which the ſection and the abſolute ſtrength is meaſured) is almoſt $\frac{1}{8}$th larger than ours. The cubic foot, by which the ſtones are meaſured, exceeds ours nearly $\frac{1}{5}$th. The pound is deficient about $\frac{1}{13}$th. But ſince very nice calculation is neither eaſy nor neceſſary on this ſubject, it is needleſs to depart from the French meaſures, which would occaſion many fractional parts and a troubleſome reduction.

The arch is ſuppoſed to be built of ſtone which weighed 160 pounds per foot. Mr Pitot, by a computation (in which he has committed a miſtake), ſays, that only $\frac{11}{14}$ths of this weight is carried by the frame. We believe, however, that this is nearer the truth than Mr Couplet's aſſumption of $\frac{4}{5}$ths already mentioned.

Mr Pitot farther aſſumes, that a ſquare inch of ſound oak will carry 8640 pounds. By his language we ſhould imagine that it will not carry much more: but this is very far below the ſtrength of any Britiſh oak that we have tried; ſo far, indeed, that we rather imagine that he means that this load may be laid on it with perfect ſecurity for any time. But to compenſate for knots and other accidental imperfections, he aſſumes 7200 as the meaſure of its abſolute force.

He

Center.

He computes the load on each frame to be 707520 pounds, which he reduces to $\frac{11}{14}$ths, or 555908 pounds.

The abſolute force of each of the lower ſtruts is 576000 (at 7200 per inch), and that of the curves 518400. Mr Pitot, conſidering that the curves are kept from bending outwards by the arch ſtones which preſs on them, thinks that they may be conſidered as acting preciſely as the outer ſtruts EI. We have no objection to this ſuppoſition.

11 Computed.

With theſe data we may compute the load which the lower truſs can ſafely bear by the rule delivered in the article CARPENTRY. We therefore proceed as follows:

Meaſure off by a ſcale of equal parts $a\,s$, $a\,t$, each 576000, and add $t\,v$ 518400. Complete the parallelogram $a\,v\,x\,s$, and draw the vertical $x\,c$, meeting the horizontal line a C in c. Make $c\,b$ equal to $c\,a$. Join $x\,b$, and complete the parallelogram $a\,x\,b\,y$. It is evident that the diagonal $x\,y$ will repreſent the load which theſe pieces can carry; for the line $a\,v$ is the united force of the curve AP and the ſtrut IE, and $a\,s$ is the ſtrength of IG. Theſe two are equivalent to $a\,x$. $x\,b$ is, in like manner, equivalent to the ſupport on the other ſide, and $x\,y$ is the load which will juſt balance the two ſupports $a\,x$ and $b\,x$.

When $x\,y$ is meaſured on the ſame ſcale, it will be found = 2850000 pounds. This is more than five times the load which actually lies on the frame. It is therefore vaſtly ſtronger than is neceſſary. Half of each of the linear dimenſions would have been quite ſufficient, and the ſtruts needed only to be 5 inches by 4. Even this would have carried twice the weight, and would have borne the load really laid on it with perfect ſafety.

We proceed to meaſure the ſtrength of the upper part. The force of each ſtrut is 432000, and that of the curve is 518400; therefore, having drawn M v parallel to the ſtrut ON, make M v = 432000, and M s = 432000 + 518400. Complete the parallelogram M $s\,r\,v$. Draw the horizontal line $r\,k$, cutting the vertical MC in k, and make $k\,y$ = M k. It is plain, from what was done for the lower part, that M y will meaſure the load which can be carried by the upper part. This will be found = 1160000. This is alſo greatly ſuperior to the load; but not in ſo great a proportion as the other part. The chief part of the load lies on the upper part; but the chief reaſon of the difference is the greater obliquity of the upper ſtruts. This ſhortens the diagonal M y of the parallelogram of forces. Mr Pitot ſhould have adverted to this; and inſtead of making the upper ſtruts more ſlender than the lower, he ſhould have made them ſtouter.

The ſtrain on the ſtretcher LL is not calculated. It is meaſured by $r'\,k'$, when M y is the load actually lying on the upper part. Leſs than the ſixth part of the coheſion of the ſtretcher is more than ſufficient for the horizontal thruſt; and there is no difficulty of making the foot joints of the ſtruts abundantly ſtrong for the purpoſe.

The reader will perceive that the computation juſt now given does not ſtate the proportions of the ſtrains *actually exerted* on the different pieces, but the load on the whole, on the ſuppoſition that each piece is ſubjected to a ſtrain proportioned to its ſtrength. The other calculation is much more complicated, but is not neceſſary here.

Center.

This centre has a very palpable defect. If the piers ſhould yield to the load, and the feet of the centre fly out, the lower part will exert a very conſiderable ſtrain on the ſtretcher, tending to break it acroſs between N and L, and on the other ſide. HKF of the lower part is firmly bound together, and cannot change its ſhape, and will therefore act like a lever, turning round the point F. It will draw the ſtrut HK away from its abutment with GH, and the ſtretcher will be ſtrained acroſs at the place between H and F, where it is bolted with the bridle. This may be reſiſted in ſome degree by an iron ſtrap uniting ON and HK; but there will ſtill be a want of proportional ſtrength. Indeed, in an arch of ſuch height (a ſemicircle), there is but little riſk of this yielding of the piers; but it is an imperfection.

12 A centre on the ſame principles for an elliptical arch.

The centre (fig. 2.) is conſtructed on the ſame principle preciſely for an elliptical arch (A). The calculation of its ſtrength is nearly the ſame alſo; only the two upper ſtruts of a ſide being parallel, the parallelogram M $s\,r\,v$ (of fig. 1.) is not needed, and in its ſtead we meaſure off on ON a line to repreſent twice its ſtrength. This comes in place of M r' of fig. 1.—*N. B.* The calculation proceeds on the ſuppoſition that the ſhort ſtraining piece MM makes but one firm body with the king poſt. Mr Pitot employed this piece (we preſume) to ſeparate the heads of the ſtruts, that their obliquity might be leſſened thereby: and this is a good thought; for when the angle formed by the ſtruts on each ſide is very open, the ſtrain on them becomes very great.

The ſtretcher of this frame is ſcarfed in the middle. Suppoſe this joint to yield a little, there is a danger of the lower ſtrut ON loſing its hold, and ceaſing to join in the ſupport; for when the crown ſinks by the lengthening of the ſtretcher, the triangle ORN of fig. 2. will be more diſtorted than the ſpace above it, and ON will be looſened. But this will not be the caſe when the ſinking of the crown ariſes from the mere compreſſion of the ſtruts. Nor will it happen at all in the centre, fig. 1. On the contrary, the ſtrut ON will abut more firmly by the yielding of the foot of ML.

The figure of this arch of Mr Pitot's conſiſts of three arches of circles, each of 60 degrees. As it is elegant, it will not be unacceptable to the artiſt to have a conſtruction for this purpoſe.

13 How to conſtruct ſuch an arch.

Make BY = CD, and CZ = $\frac{1}{2}$ CY. Deſcribe the ſemicircle ZÆY, and make ZS = ZÆ. S is the centre of the ſide arches, each of 60 degrees. The centre T of the arch, which unites theſe two, is at the angle of an equilateral triangle STS.

This conſtruction of Mr Pitot's makes a handſome oval, and very near an ellipſis, but lies a little without it. We ſhall add another of our own, which coincides with the ellipſe in eight points, and furniſhes the artiſt, by

(A) It is the middle arch of the bridge at Liſle Adam, of which Mr Pitot had the direction. It is of 80 feet ſpan, and riſes 31 feet.

Center. by the way, a rule for drawing an infinite variety of ovals.

Let AB, DE (fig. 2. N° 2.) be the axes of an ellipse, C the centre, and F, *f* the two foci. Make C *b* = CD, and describe a circle A D *b e* passing through the three given points A, D, and *b*. It may be demonstrated, that if from any point P of the arch AD be drawn a chord PD, and if a line P R *r* be drawn, making the angle DPR=PDC, and meeting the two axes in the points R and *r*, then R and *r* will be the centres of circles, which will form a quarter APD of an oval, which has AB and DE for its two axes.

We want an oval which shall coincide as much as possible with an ellipsis? The most likely method for this is to find the very point P where the ellipsis cuts the circle AD *b e*. The easiest way for the artist is to describe an arch of a circle *a m*, having AB for its radius, and the remote focus *f* for its centre. Then set one foot of the compasses on any point P, and try whether the distance PF from the nearest focus F is exactly equal to its distance P *m* from that circle. Shifting the foot of the compasses from one point of the arch to another, will soon discover the point. This being found, draw PD, make the angle DP *r* = PD *r*, and R and *r* are the centres wanted. Then make C *s* = CR, and we get the centres for the other side.

The geometer will not relish this mechanical construction. He may therefore proceed as follows: Draw D *d* parallel to AB, cutting the circle in *d*. Draw *e d*, cutting AC in N. Draw CG parallel to A *e*, and make the angle CG *i* = AD *e*. Bisect CN in O, and join O *i*. Make OM, OM′= O *i*, and draw MP, M′P′ perpendicular to AB. These ordinates will cut the circle AD *b e* in the points P and P′, where it is cut by the ellipse. We leave the demonstration as a geometrical exercise for the dilettante.

14 Centre for the nave of St Peter's.

We said, that this centering of Mr Pitot's resembled in principle the one employed by Michael Angelo for the nave and transepts of St Peter's church at Rome. Fontana, who has preserved this, ascribes the construction of it to one of the name of San Gallo. A sketch of it is given in fig. 3. It is, however, so much superior, and so different in principle, from that employed for the cupola, that we cannot think it the invention of the same person. It is, like Pitot's, not only divisible, but really divided into two parts, of which the upper carries by much the greatest part of the load. The pieces are judiciously disposed, and every important beam is amply secured against all transverse strains. Its only fault is a great profusion of strength. The innermost polygon *a g h b* is quite superfluous, because no strain can force in the struts which rest on the angles. Should the piers yield outwards, this polygon will be loose, and can do no service. Nor is the triangle *g i h* of any use, if the king post above it be strapped to the tie-beam and straining sill. Perhaps the inventor considered the king post as a pillar, and wished to secure the tie-beam against its cross strain. This centering, however, must be allowed to be very well composed; and we expect that the well-informed reader will join us in preferring it to Mr Pitot's, both for simplicity of principle, for scientific propriety, and for strength.

There is one considerable advantage which may be derived from the actual division of the truss into two parts. If the tie-beam LL, instead of resting on the stretcher EF, had rested on a row of chocks formed like double wedges, placed above each other, head to point, the upper part of the centering might be struck independent of the lower, and this might be done gradually, beginning at the outer ends of the stretcher. By this procedure, the joints of the archstones will close on the haunches, and will almost relieve the lower centering, so that all can be pulled out together. Thus may the arch settle and consolidate in perfect safety, without any chance of breaking the bond of the mortar in any part; an accident which frequently happens in great arches. This procedure is peculiarly advisable for low pitched or elliptical arches. But this will be more clearly seen afterwards, when we treat of the internal movements of an arch of masonry.

This may suffice for an account of the more simple construction of trussed centres; and we proceed to such as have a much greater complication of principle. We shall take for examples some constructed by Mr Perronet, a very celebrated French architect.

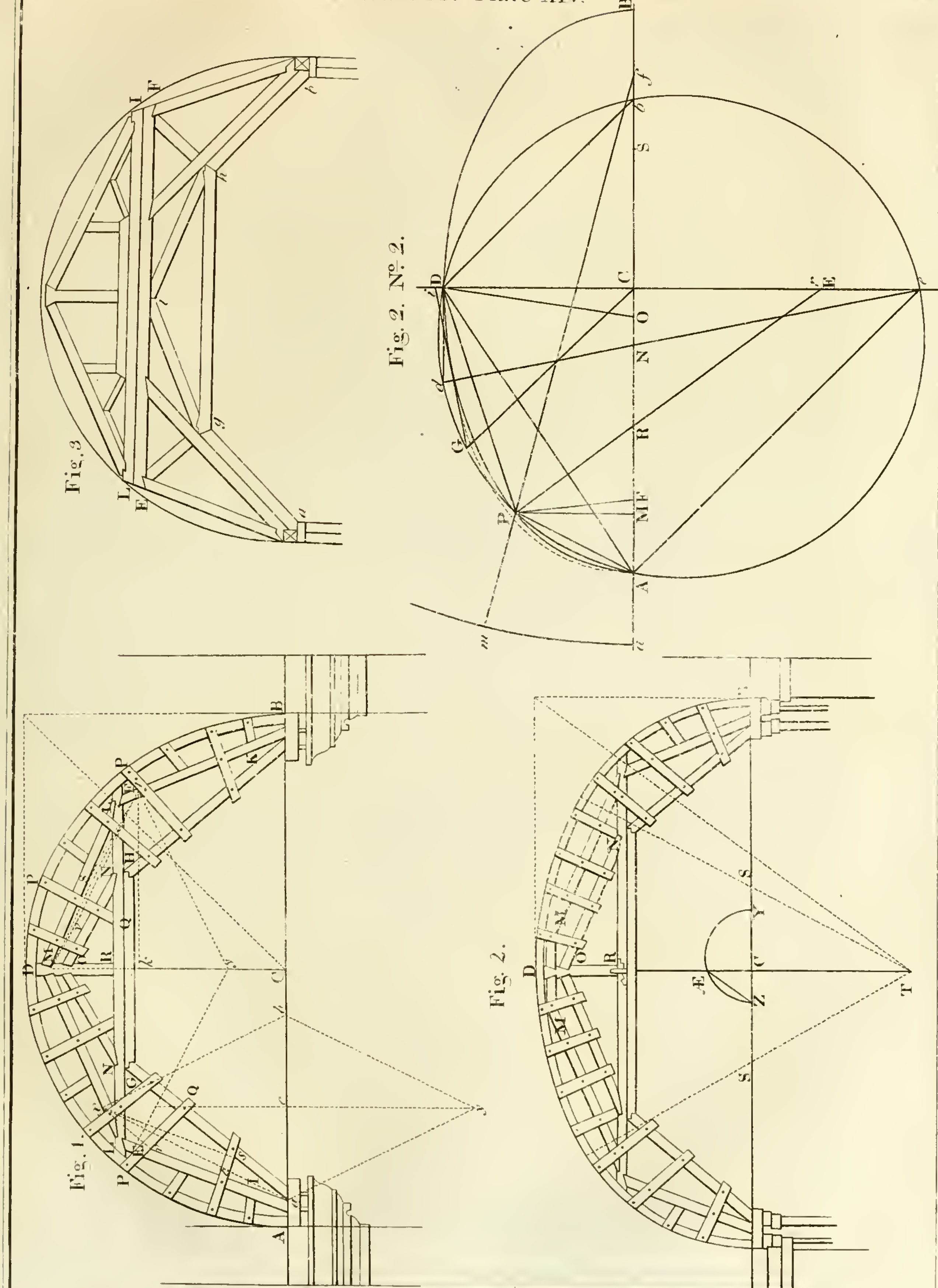
15 Perronet's maxim of construction.

Mr Perronet's general maxim of construction is to make the truss consist of several courses of separate trusses, independent (as he thinks) of each other, and thus to employ the joint support of them all. In this construction it is not intended to make use of one truss, or part of one truss, to support another, as in the former set, and as is practised in the roofs of St Paul's church, Covent Garden, and in Drury Lane theatre. Each truss spans over the whole distance of the piers, and would stand alone (having, however, a tottering equilibrium). It consists of a number of struts, set end to end, and forming a polygon. These trusses are so arranged, that the angles of one are in the middle of the sides of the next, as when a polygon is inscribed in a circle, and another (of the same number of sides) is circumscribed by lines which touch the circle in the angles of the inscribed polygon. By this construction the angles of the alternate trusses lie in lines pointing towards the centre of the curve. King posts are therefore placed in this direction between the adjoining beams of the trusses. These king posts consist of two beams, one on each side of the truss, and embrace the truss-beams between them, meeting in the middle of their thickness. The abutting beams are mortised, half into each half of the post. The other beam which makes the base of the triangle, passes through the post, and a strong bolt is driven through the joint, and secured by a key or a nut. In this manner is the whole united; and it is expected, that when the load is laid on the uppermost truss, it will all butt together, forcing down the king posts, and therefore pressing them on the beams of all the inferior trusses, causing them also to abutt on each other, and thus bear a share of the load. Mr Perronet does not assume the invention to himself; but says, that it was invented and practised by Mr Mansard de Sagonne at the great bridge of Moulins. It is much more ancient, and is the work of the celebrated physician and architect Perrault; as may be seen in the collection of machines and inventions of that gentleman published after his death, and also in the great collection of inventions approved of by the Academy of Sciences. It is this which we propose to examine.

16 Centering employed for the bridge of Cravant.

Fig. 4. represents the centering employed for the bridge of Cravant. The arches are elliptical, of 60 feet span and 20 feet rise. The archstones are four feet thick,

CENTRES. Plate XIV.



Center. thick, and weigh 176 pounds per foot. The truſs-beams were from 15 to 18 feet long, and their ſection was 9 inches by 8. Each half of the king poſts was about 7 feet long, and its ſection 9 inches by 8. The whole was of oak. The five truſſes were $5\frac{1}{2}$ feet aſunder. The whole weight of the arch was 1350000 lbs. which we may call 600 tons (it is 558). This is about 112 tons for each truſs. We muſt allow near 90 tons of this really to preſs the truſs. A great part of this preſſure is borne by the four beams which make the feet of the truſs, coupled in pairs on each ſide. The diagonal of the parallelogram of forces drawn for theſe beams is, to one of the ſides, in the proportion of 360 to 285. Therefore ſay, as 360 to 285; ſo is 90 to $71\frac{1}{4}$ tons, the thruſt on each foot. The ſection of each is 144 inches. We may with the utmoſt ſafety lay three tons on every inch for ever. This amounts to 432 tons, which is more than ſix times the ſtrain really preſſing the foot beams in the direction of their length; nay, the upper truſs alone is able to carry much more than its load. The abſolute ſtrength of its foot-beam is 216 tons. It is much more advantageouſly placed; for the diagonal of the parallelogram of forces correſponding to its poſition is to the ſide as 438 to 285. This gives $58\frac{6}{10}$ tons for the ſtrain on each foot; which is not much above the fourth part of what it is able to carry for ever. No doubt can therefore be entertained of the ſuperabundant ſtrength of this centering. We ſee that the upper row of ſtruts is quite ſufficient, and all that is wanted is to procure ſtiffneſs for it; for it muſt be carefully kept in mind, that this upper row is not like an equilibrated arch. It will be very unequally loaded as the work advances. The haunches of the frame will be preſſed down, and the joints at the crown raiſed up. This muſt be reſiſted.

Here then we may gather, by the way, a uſeful leſſon. Let the outer row of ſtruts be appropriated to the carriage of the load, and let the reſt be employed for giving ſtiffneſs. For this purpoſe let the outer row have abundant ſtrength. The advantages of this method are conſiderable. The poſition of the beams of the exterior row is more advantageous, when (as in this example) the whole is made to reſt on a narrow foot: for this obliges us to make the laſt angle, at leaſt of the lower row, more open, which increaſes the ſtrain on the ſtrut; beſides, it is next to impoſſible to diſtribute the compreſſing thruſts among the different rows of the truſs-beams; and a beam which, during one period of the maſon work, is acting the part of a ſtrut, in another period is bearing no ſtrain but its own weight, and in another it is ſtretched as a tie. A third advantage is, that, in a caſe like this, where all reſts on a narrow foot, and the lower row of beams are bearing a great part of the thruſt, the horizontal thruſt on the pier is very great, and may puſh it aſide. This is the moſt ruinous accident that can happen. An inch or two of yielding will cauſe the crown of the arch to ſink prodigiouſly, and will inſtantly derange all the bearings of the abutting beams: but when the lower beams already act as ties, and are quite adequate to their office, we render the frame perfectly ſtiff or unchangeable in its form, and take away the horizontal thruſt from the piers *entirely*. This advantage is the more valuable, becauſe the very circumſtance which obliges us to reſt all on a narrow foot, places this foot on the very top of the pier, and makes the horizontal thruſt the more dangerous.

But, to proceed in our examination of the centering of Cravant bridge, let us ſuppoſe, that the king poſts are removed, and that the beams are joined by compaſs joints. If the pier ſhall yield in the ſmalleſt degree, both rows of ſtruts muſt ſink; and ſince the angles (at leaſt the outermoſt) of the lower row are more open than thoſe of the upper row, the crown of the lower row will ſink more than that of the upper.

The angles of the alternate rows muſt therefore ſeparate a little. Now reſtore the king poſts; they prevent this ſeparation. Therefore *they are ſtretched*; therefore the beams of the lower row are alſo ſtretched; conſequently they no longer butt on their mortiſes, and muſt be held in their places by bolts. Thus it appears that, in this kind of ſagging, the original diſtribution of the load among the different rows of beams is changed, and the upper row becomes loaded beyond our expectation.

If the ſagging of the whole truſs proceed only from the compreſſion of the timbers, the caſe is different, and we *may* preſerve the original diſtribution of mutual abutment more accurately. But in this caſe the ſtiffneſs of the frame ariſes chiefly from croſs ſtrains. Suppoſe that the frame is loaded with archſtones on each ſide up to the poſts HC, *hc*; the angles E and *e* are preſſed down, and the beams EOF, *eo* F puſh up the point F. This cannot riſe without bending the beams EOF, *eo* F; becauſe O and *o* are held down by the double king poſts, which graſp the beams between them. There is therefore a croſs ſtrain on the beams. Obſerve alſo, that the triangle EHF does not preſerve its ſhape by the connection of its joints; for although the ſtrut beams are mortiſed into the king poſt, they are in very ſhallow mortiſes, rather for ſteadying them than for holding them together. Mr Perronet did not even pin them, thinking that their abutment was very great. The triangle is kept in ſhape by the baſe EF, which is firmly bolted into the middle poſt at O. Had theſe interſections not been ſtrongly bolted, we imagine that the centres of ſome of Mr Perronet's bridges would have yielded much more than they did; yet ſome of them yielded to a degree that our artiſts would have thought very dangerous. Mr Perronet was obliged to load the crown of the centering with very great weights, increaſing them as the work advanced, to prevent the frames from going out of ſhape: in one arch of 120 feet he laid on 45 tons. Notwithſtanding this imperfection, which is perhaps unavoidable, this mode of framing is undoubtedly very judicious, and perhaps the beſt which can be employed without depending on iron work.

17 For the bridge of Nogent.

Fig. 5. repreſents another, conſtructed by Perronet for an arch of 90 feet ſpan and 28 feet riſe. The truſſes were 7 feet apart, and the arch was $4\frac{1}{2}$ thick; ſo that the unreduced load on each frame was very nearly 235 tons. The ſcantling of the ſtruts was 15 by 12 inches. The principle is the ſame as that of the former. The chief difference is, that in this centre the outer truſs-beam of the lower row is not coupled with the middle row, but kept nearly parallel to the outer beam of the upper row. This adds greatly to the ſtrength of the foot, and takes off much of the horizontal thruſt from the pier.

Mr Perronet has ſhewn great judgment in cauſing the polygon of the inner row of truſs-beams gradually to approach the polygon of the outer row. By this

 diſpoſition,

Center. difpofition, the angles of the inner polygon are more acute than thofe of the outer. A little attention will fhew, that the general fagging of all the polygons will keep the abutments of the lower one nearer, or exactly, to their original quantity. We muft indeed except the foot-beam. It is ftill too oblique; and, inftead of converging to the foot of the upper row, it fhould have diverged from it. Had this been done, this centre is almoft perfect in its kind. As it is, it is at leaft fix times ftronger than was abfolutely neceffary. We fhall have occafion to refer to this figure on another occafion.

18 St Maxence. This maxim is better exemplified by Mr Perronet in the centering of the bridge of St Maxence, exhibited in fig. 5. n° 2. than in that of Nogent, fig. 5. n° 1. But we think that a horizontal trufs-beam *a b* fhould have been inferted (in a fubordinate manner) between the king pofts next the crown on each fide. This would prevent the crown from rifing while the haunches only are loaded, without impairing the fine abutments of *c d*, *c d*, when the arch is nearly completed. This is an excellent centering, but is not likely to be of much ufe in thefe kingdoms; becaufe the arch itfelf will be confidered as ungraceful and ugly, looking like a huge lintel. Perronet fays, that he preferred it to the ellipfe, becaufe it was lighter on the piers, which were thin. But the failure of one arch muft be immediately followed by the ruin of all. We know much better methods of lightening the piers.

19 Neuilly, and Fig. 6. reprefents the centering of the bridge of Neuilly, near Paris, alfo by Perronet. The arch has 120 feet fpan, and 30 feet rife, and is 5 feet thick. The frames are 6 feet apart, and each carries an abfolute (that is, not reduced to $\frac{11}{17}$ or to $\frac{4}{7}$) load of 350 tons. The ftrut beams are 17 by 14 inches in fcantling. The king pofts are of 15 by 9 each half; and the horizontal bridles which bind the different frames together in five places, are alfo 15 by 9 each half. There are eight other horizontal binders of 9 inches fquare.

This is one of the moft remarkable arches in the world; not altogether on account of its width (for there are feveral much wider), but for the flatnefs at the crown; for about 26 feet on each fide of the middle it was intended to be a portion of a circle of 150 feet radius. An arch (femicircular) of 300 feet fpan might therefore be eafily conftructed, and would be much ftronger than this, becaufe its horizontal thruft at the crown would be vaftly greater, and would keep it more firmly united.

The bolts of this centre are differently placed from thofe of the former; and the change is judicious. Mr Perronet had doubtlefs found by this time, that the ftiffnefs of his framing depended on the tranfverfe ftrength of the beams; and therefore he was careful not to weaken them by the bolts. But notwithftanding all his care, the framing funk upwards of 13 inches before the keyftones were laid; and during the progrefs of the work, the crown rofe and funk, by various fteps, as the loading was extended along it. When 20 courfes were laid on each fide, and about 16 tons laid on the crown of each frame, it funk about an inch. When 46 courfes were laid, and the crown loaded with 50 tons, it funk about half an inch more. It continued finking as the work advanced; and when the keyftone was fet it had funk 13¼ inches. But this finking was not general; on the contrary the frame had rifen greatly at the very haunches, fo as to open the upper part of the joints, many of which gaped an inch; and this opening of the joints gradually extended from the haunches towards the crown, in the neighbourhood of which they opened on the under fide. This evidently arofe from a want of ftiffnefs in the frame. But thefe joints clofed again when the centres were ftruck, as will be mentioned afterwards.

We have taken particular notice of the movements and twifting of this centre, becaufe we think that they indicate a deficiency, not only of ftiffnefs, but of abutment among the trufs beams. The whole has been too flexible, becaufe the angles are too obtufe: This arifes from their multiplicity. When the intercepted arches have fo little curvature, the power of the load to prefs it inward increafes very faft. When the intercepted arch is reduced to one half, this power is more than doubled; and it is alfo doubled when the radius of curvature is doubled. The king-pofts fhould have been further apart near the crown, fo that the quantity of arch between them fhould compenfate for its diminifhed curvature.

The power of withftanding any given ineqnality of load would therefore have been greater, had the centre confifted of fewer pieces, and their angles of meeting been proportionally more acute. The greateft improvement would have been, to place the foot of the lower tier of trufs-beams on the very foot of the pier, and to have alfo feparated it at the head from the reft with a longer king-poft, and thus to have made the diftances of the beams on the king-pofts increafe gradually from the crown to the fpring. This would have made all the angles of abutment more acute, and would have produced a greater preffure on all the lower tiers when the frame fagged.

Fig. 7. reprefents the centering of the bridge of Orleans. The arch has 100 feet fpan, and rifes 30, and the archftones are 6 feet long. It is the conftruction of Mr Hupeau, the firft architect of the bridge. It is the boldeft work of the kind that we have feen, and is conftructed on clear principles. The main abutments are few in number. Becaufe the beams of the outer polygon are long, they are very well fupported by ftraining beams in the middle; and the ftruts or braces which fupport and butt on them, are made to reft on points carried entirely by *ties*. The inventor, however, feems to have thought that the angles of the inner polygon were fupported by mutual compreffion, as in the outer polygon. But it is plain that the whole inner polygon may be formed of iron rods. Not but that both polygons *may* be in a ftate of compreffion (this is very poffible); but the fmalleft fagging of the frame will change the proportions of the preffures at the angles of the two polygons. The preffures on the exterior angles will increafe, and thofe on the lower or interior angles will diminifh moft rapidly; fo that the abutments in the lower polygon will be next to nothing. Such points could bear very little preffure from the braces which fupport the middle of the long bearings of the upper beams, and their preffures muft be borne chiefly by the joints fupported by the king-pofts. The king-pofts would then be in a ftate of extenfion. It is difficult, however, to decide what is the precife ftate of the preffure at thefe interior angles. 20 Orleans.

The

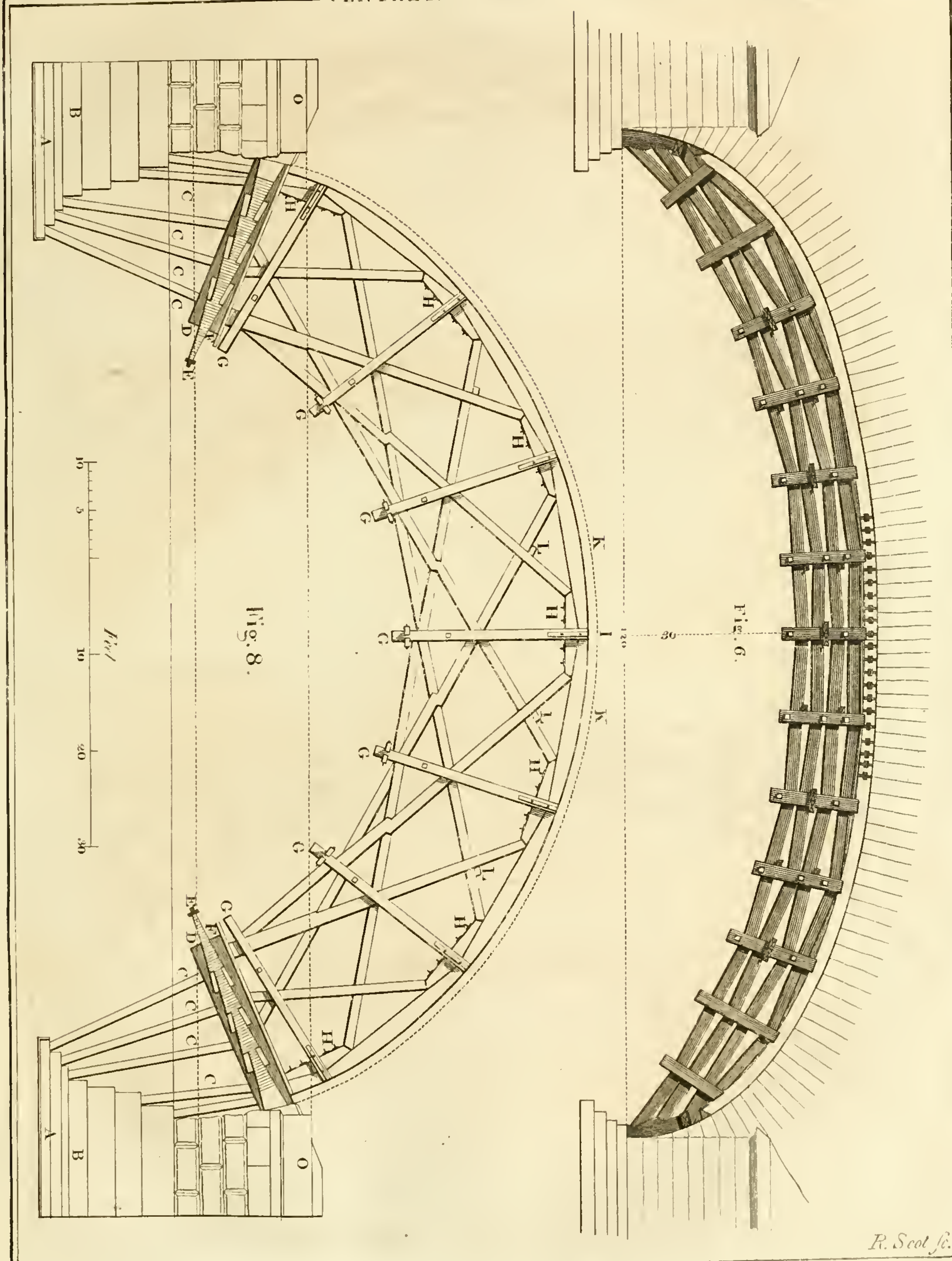


Fig. 8.
Fig. 6.
feet
R. Scot sc.

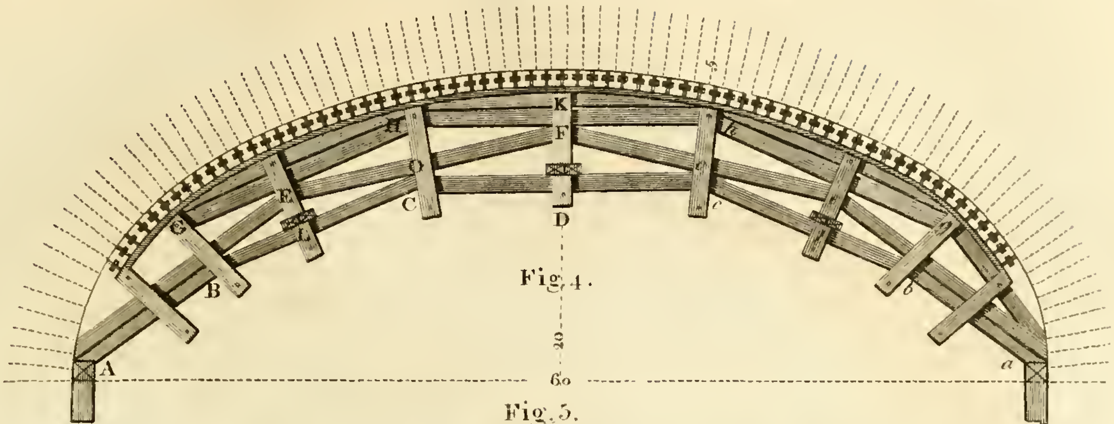


Fig. 4.

Fig. 5.

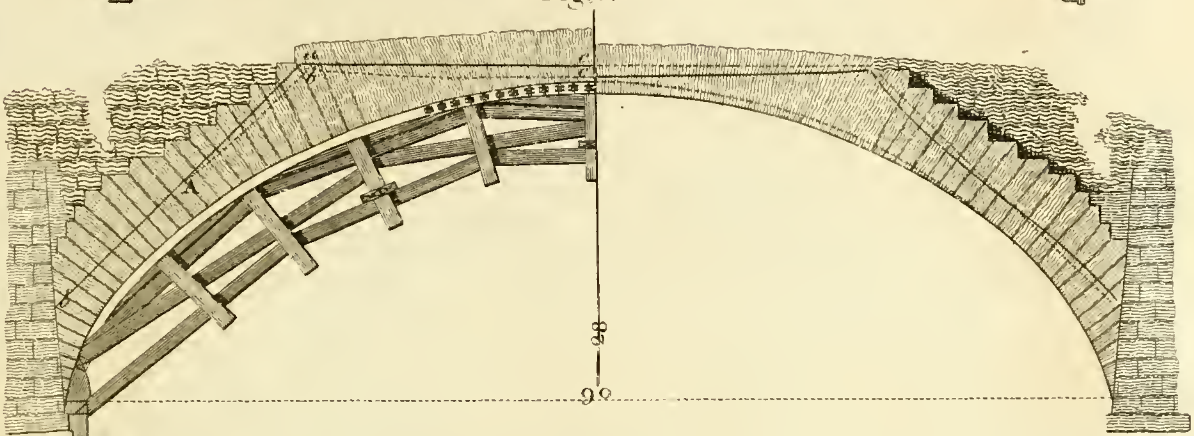


Fig. 5. N.º 2.

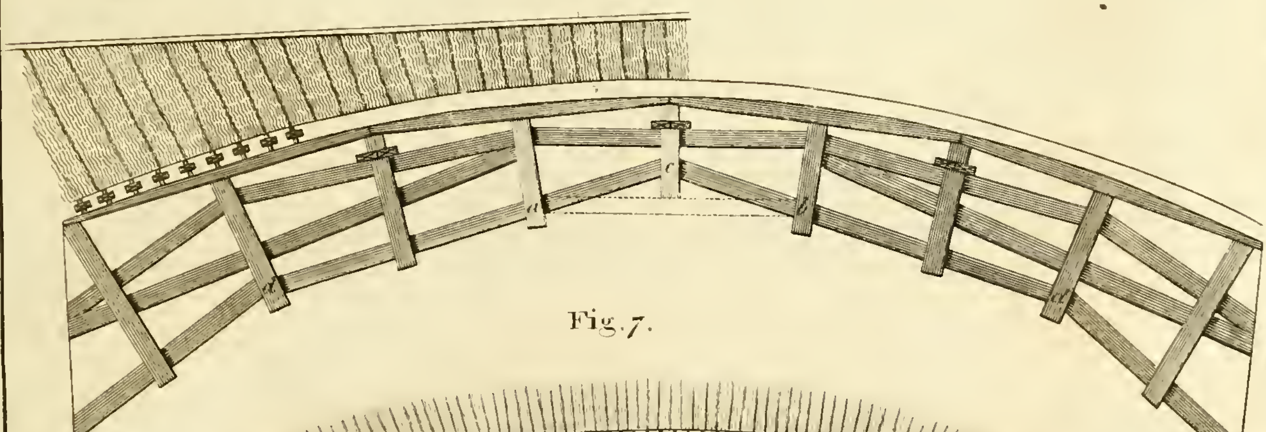
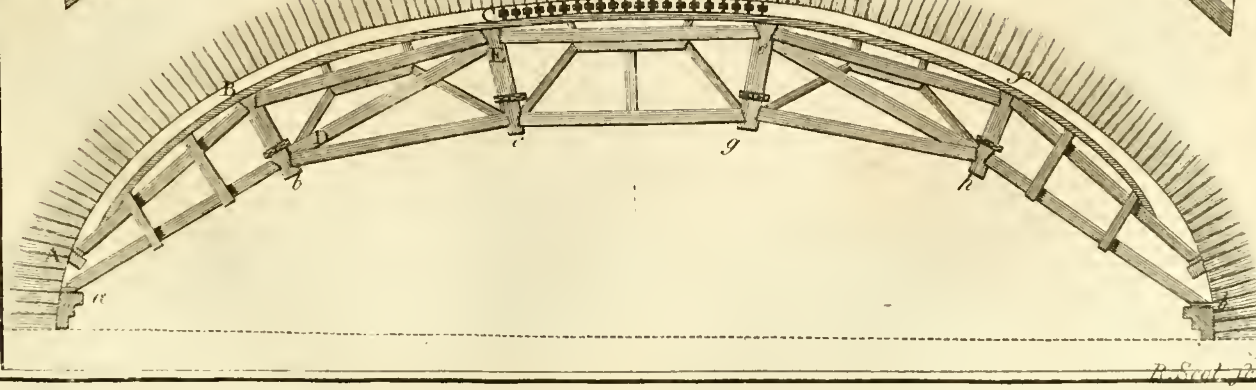


Fig. 7.



B. Scot sc.

Center.

21 Instructive history of this centre.

The history of the erection of this bridge will throw much light on this point, and is very instructive. Mr Hupeau died before any of the arches were carried farther than a very few of the first courses. Mr Perronet succeeded to the charge, and finished the bridge. As the work advanced, the crown of the frame rose very much. It was loaded; and it sunk as remarkably. This shewed that the lower polygon was giving very little aid. Mr Perronet then thought the frame too weak, and inserted the long beam DE, making the diagonal of the quadrangle, and very nearly in the direction of the lower beam *a b*, but falling rather below this line. He now found the frame abundantly strong. It is evident that the truss is now changed exceedingly, and consists of only the two long sides, and the short straining beam lying horizontally between their heads. The whole centering consists now of one great truss *a* E *e b*, and its long sides *a* E, *e b*, are trussed up at B and *f*. Had this simple idea been made the principle of the construction, it would have been excellent. The angle *a* DE might have been about 176°, and the polygon D *c g b* employed only for giving a slight support to this great angle, so as not to allow it to exceed 180°. But Mr Perronet found, that the joint *c*, at the foot of the post E *c*, was about to *draw loose*, and he was obliged to bolt long pieces of timber on each side of the joint, embracing both beams. These were evidently acting the same part as iron straps would have done; a complete proof that, whatever may have been the original pressures, there was no abutment now at the point *c*, and that the beams that met there were not in a state of compression, but were on the stretch. Mr Perronet says that he put these cheeks to the joints *to stiffen* them. But this was not their office; because the adjoining beams were not struts, but ties, as we have now proved.

We may therefore conclude, that the outer polygon, with the assistance of the pieces *a b*, DE, were carrying the whole load. We do not know the distance between the frames; but supposing them seven feet apart, and the arch 6 feet thick, and weighing 170 pounds per foot, we learn the load. The beams were 16 inches square. If we now calculate what they would bear at the same very moderate rate allowed to the other centres, we find that the beams AB and *a b* are not loaded to one-sixth of their strength.

We have given this centre as a fine example of what carpentry is able to perform, and because, by its simplicity, it is a sort of text on which the intelligent artist may make many comments. We may see plainly that, if the lower polygon had been formed of iron rods, firmly bolted into the feet of the king-posts, it would have maintained its shape completely. The service done by the beam DE was not so much an increase of abutment as a discharge of the weight and of the *pull* at the joint *c*. Therefore, in cases where the feet of the truss are *necessarily* confined to a very narrow space, we should be careful to make the upper polygon sufficient to carry the whole load (say by doubling its beams), and we may then make the lower polygon of slender dimensions, provided we secure the joints on the king-posts by iron straps which embrace a considerable portion of the tie on each side of the joint.

We are far from thinking that these centres are of the best kind that could be employed in their situation; but they are excellent in their kind; and a careful study of them will teach the artist much of his profession. When we have a clear conception of the state of strain in which the parts of a frame really are, we know what should be done in order to draw all the advantage possible from our materials. We have said in another place, that where we can give our joints sufficient connection (as by straps and bolts, or by cheeks or fishes), it is better to use ties than struts, because ties never bend.

22 All these centres good in their kind.

We do not approve of Mr Perronet's practice of giving his trusses such narrow feet. By bringing the foot of the lower polygon farther down, we greatly diminish all the strains, and throw more load on the lower polygon; and we do not see any of Mr Perronet's centres where this might not have been done. He seems to affect a great span, to shew the wonders of his art; but our object is to teach how to make the best centre of a given quantity of materials; and how to make the most perfect centre, when we are not limited in this respect, nor in the extent of our fixed points.

23 Excellence of the centre employed for Blackfriars bridge.

We shall conclude this series of examples with one where no such affectation takes place. This is the centering of the bridge at Blackfriars, London. The span of the arch is 100 feet, and its height from the spring is about 43. The drawing fig. 8. is sufficiently minute to convey a distinct notion of the whole construction. We need not be very particular in our observations, after what has been said on the general principles of construction. The leading maxim, in the present example, seems to be, *that every part of the arch shall be supported by a simple truss of two legs resting, one on each pier.* H, H, &c. are called APRON PIECES to strengthen the exterior joints, and to make the RING as stiff in itself as possible. From the ends of this apron-piece proceed the two legs of each truss. These legs are 12 inches square: They are not of an entire piece, but of several, meeting in firm abutment. Some of their meetings are secured by the double king-posts, which grasp them firmly between them, and are held together by bolts. At other intersections, the beams appear halved into each other; a practice which cannot but weaken them much, and would endanger their breaking by cross strains, if it were possible for the frame to change its shape. But the great breadth of this frame is an effectual stop to any such change. The fact was, that *no sinking or twisting whatever* was observed during the progress of the mason work. Three points in a straight line were marked on purpose for this observation, and were observed every day. The arch was more than six feet thick; and yet the sinking of the crown, before setting the key-stones, did not amount to one inch.

The centre employs about one-third more timber than Perronet's great centre in proportion to the span of the arch; but the circumference increases in a greater proportion than this, because it is more elevated. In every way of making a comparison of the dimensions, Mr Mylne's arch employs more timber; but it is *beyond all comparison* stronger. The great elevation is partly the reason of this. But the disposition of the timbers is also much more advantageous, and may be copied even in the low pitched arches of Neuilly. The simple truss, reaching from pier to pier for the middle point of the arch, gives the strong support where it is most of all wanted; and in the lateral points H, although

Center. though one leg of the truſs is very oblique, the other compenſates for it by its upright poſition.

The chief peculiarity of this centre is to be ſeen in its baſe. This demands a more particular attention; but we muſt firſt make ſome obſervations on the condition of an arch, as it reſts on the centering after the keyſtones are all ſet, and on the gradual transference of the preſſure from the boards of the centering to the joints of the archſtones.

24 Obſervations on the ſtate of an arch as it reſts on the centering.

While all the archſtones lie on the centering, the lower courſes are alſo leaning pretty ſtrongly on each other. But the mortar is hardly compreſſed in the joints; and leaſt of all in the joints near the crown. Suppoſe the arch to be Catenarean, or of any other ſhape that is perfectly equilibrated: When the centering is gradually withdrawn, all the archſtones follow it. Their wedge-like form makes this impoſſible, without the middle ones ſqueezing the lateral ones aſide. This compreſſes the mortar between them. As the ſtones thus come nearer to each other, thoſe near the crown muſt deſcend more than thoſe near the haunches, before every ſtone has leſſened its diſtance from the next by the ſame quantity; for example, by the hundredth part of an inch. This circumſtance alone muſt cauſe a ſinking in the crown, and a change of ſhape. But the joints near the crown are *already* more open than thoſe near the haunches. This produces a ſtill greater change of form before all is ſettled. Some maſons endeavour to remedy, or at leaſt to diminiſh, this, by uſing no mortar in the joints near the crown. They lay the ſtones dry, and even force them together by wedges and blocks laid between the ſtones on oppoſite ſides of the crown: They afterwards pour in fine cement. This appears a good practice. Perronet rejects it, becauſe the wedging ſometimes breaks the ſtones. We ſhould not think this any great harm; becauſe the fracture will make them cloſe where they would otherwiſe lie hollow. But, after all our care, there is ſtill a ſinking of the crown of the arch. By gradually withdrawing the centering, the joints cloſe, the archſtones begin to butt on each other, and to force aſide the lateral courſes. This abutment gradually increaſing, the preſſure on the haunches of the centering is gradually diminiſhed by the mutual abutment, and ceaſes entirely in that courſe, which is the loweſt that formerly preſſed it: it then ceaſes in the courſe above, and then in the third, and ſo on. And, in this manner, not only the centering quits the arch, gradually, from the bottom to the top, *by its own retiring from it*, but the arch alſo quits the centering *by changing its ſhape*. If the centering were now puſhed up again, it would touch the arch firſt at the crown; and it muſt *lift up* that part gradually before it come again in contact with the haunches. It is evident, therefore, that an arch, built on a centre of a ſhape perfectly ſuited to equilibration, will not be in equilibrio when the centering is removed. It is therefore neceſſary to form the centering in ſuch a manner (by raiſing the crown), that it ſhall *leave* the arch of a proper form. This is a very delicate taſk, requiring a previous knowledge of the enſuing change of form. This cannot be aſcertained by the help of any theory we are acquainted with.

But, ſuppoſe this attained, there is another difficulty: While the work advances, the centering is warped by the load laid on it, and continually increaſing on each ſide. The firſt preſſure on the centering forces down the haunches, and raiſes the crown. The arch is therefore leſs curved at the haunches than is intended: the joints, however, accommodate themſelves to this form, and are cloſe, and filled with mortar. When the maſons approach the middle of the arch, the frame ſinks there, and riſes up at the haunches. This opens all the joints in that place on the *upper* ſide. By the time that the keyſtones are ſet, this warping has gone farther; and joints are opened on the *under* ſide near the crown. It is true we are here ſpeaking rather of an extreme caſe, when the centering is *very* flexible; but this occurred to Mr Perronet in the two great bridges of Neuilly and of Mantz. In this laſt one, the crown ſunk above a foot before the key was ſet, and the joints at the haunches opened above an inch *above*, while ſome nearer the crown opened near a quarter of an inch *below*.

25 A delicate buſineſs to ſtrike the centering.

In this condition of things, it is a delicate buſineſs to ſtrike the centering. Were it removed in an inſtant, all would probably come down; for the archſtones are not yet abutting on each other, and the joints in the middle are open below. Mr Perronet's method appears to us to be very judicious. He began to detach the centering at the very bottom, on each ſide equally, where the preſſure on the centering is very ſlight. He cut away the blocks which were immediately under each archſtone. He proceeded gradually upwards in this way with ſome ſpeed, till all was detached that had been put out of ſhape by the bending of the centering. This being no longer ſupported, ſunk inward, till it was ſtopped by the abutment which it found on the archſtones near the crown which were ſtill reſting on their blocks. During part of this proceſs, the open joints opened ſtill more, and looked alarming. This was owing to the removal of the load from the haunches of the centering. This allowed the crown to ſink ſtill more, by forcing out the arch ſtones at the haunches. He now pauſed ſome days; and during this time the two haunches, now hanging in the air, gradually preſſed in toward the centering, their outer joints cloſing in the meanwhile. The haunches were now preſſing pretty hard on the arch ſtones nearer the crown. He then proceeded more ſlowly, deſtroying the blocks and bridgings of theſe upper archſtones. As ſoon as he deſtroyed the ſupport of one, it immediately yielded to the preſſure of the haunch; and if the joint between it and the one adjoining toward the crown happened to be open, whether on the under or the upper ſide, it immediately cloſed on it. But in proceeding thus, he found every ſtone ſink a little while it cloſed on its neighbour; and this was like to produce a ragged ſoffet, which is a deformity. He therefore did not allow them to ſink ſo much. In the places of the blocks and bridgings which he had cut away, he ſet ſmall billets, ſtanding on their ends, between the centering and the archſtones. Theſe allowed the pendulous arch to puſh toward the crown without ſenſibly deſcending; for the billets were puſhed out of the perpendicular, and ſome of them tumbled down. Proceeding in this way, he advanced to the very next courſe to the keyſtone on each ſide, the joints cloſing all the way as he advanced. The laſt job was very troubleſome; we mean the detaching the three uppermoſt courſes from the centering: for the whole elaſticity of the centering was now trying to unbend, and preſſing hard againſt them. He found that they were lifted up; for the joints

joints beyond them, which had cloſed completely, now opened again below: but this job was finiſhed in one day, and the centre ſprung up two or three inches, and the whole arch ſunk about ſix inches. This was an anxious time; for he dreaded the great momentum of ſuch a vaſt maſs of matter. It was hard to ſay where it would ſtop. He had the pleaſure to ſee that it ſtopped very ſoon, ſettling ſlowly as the mortar was compreſſed, and after one or two days ſettling no more. This ſettling was very conſiderable both in the bridge at Neuilly and in that at Mantz. In the former, the ſinking during the work amounted to 13 inches. It ſunk ſix inches more when the blocks and bridgings were taken out, and $1\frac{1}{2}$ when the little ſtandards were deſtroyed, and $1\frac{1}{4}$ more next day; ſo that the whole ſinking of the *pendulous* arch was $9\frac{1}{2}$ inches, beſides what it had ſunk by the bending and compreſſion of the centering.

The crown of the centering was an arch of a circle deſcribed with a radius of 150 feet; but by the ſinking of the arch its ſhape was conſiderably changed, and about 60 feet of it, formed an arch of a circle whoſe radius was 244 feet. Hence Mr Perronet infers, that a ſemicircle of 500 feet ſpan may be erected. It would no doubt be ſtronger that this arch, becauſe its greater horizontal thruſt would keep the ſtones firmer together. The ſinking of the arches at Mantz was not quite ſo great, but every thing proceeded in the ſame way. It amounted in all to $20\frac{1}{2}$ inches, of which 12 inches were owing to the compreſſion and bending of the centering.

26 The foregoing obſervations exemplified.

In fig. 5. n° 1. may be obſerved an indication of this procedure of the maſonry. There may be noticed a horizontal line *a c*, and a diagonal *a b*. Theſe are ſuppoſed to be drawn on the maſonry as it would have ſtood had the frames not yielded during the building. The dotted line A *b′ c′* ſhews the ſhape which it took by the ſinking of the centering. The dotted line on the other ſide was actually drawn on the maſonry when the keyſtone was ſet; and the wavy black line on the ſame ſide ſhews the form which the dotted line took by the ſtriking of the centering. The undulated part of this line cuts its former poſition a little below the middle, going without it below, and falling within it above. This ſhews very diſtinctly the movement of the whole maſonry, diſtinguiſhing the parts that were forced out and the parts which ſunk inward.

We preſume that the practical reader will think this account of the internal movements of a ſtupendous arch very inſtructive and uſeful. As Mr Perronet obſerved it to be uniformly the ſame in ſeveral very large arches which he erected, we may conclude that it is the general proceſs of nature. We by no means have the confidence in the durability or ſolidity of his arches which he prudently profeſſes to have. We have converſed with ſome very experienced maſons, who have alſo erected very great arches, and in very difficult ſituations, which have given univerſal ſatisfaction; and we have found them uniformly of opinion, that an arch which has ſettled to ſuch a proportion of its curvature as to change the radius from 150 to 244 feet, is in a very hazardous ſituation. They think the hazard the greater, becauſe the ſpan of the arch is ſo great in proportion to its weight (as they expreſs it very emphatically) or its height. The weight, ſay they, of the haunches is too ſmall for forcing together the keyſtones, which have ſcarcely any wedgelike form to keep them from ſliding down. This is very good reaſoning, and expreſſes very familiar notions. The mechanician would ſay, that the horizontal thruſt at the crown is too ſmall. When we queſtioned them about the propriety of Mr Perronet's method of removing the centering, they unanimouſly approved of its general principle, but ſaid that it was very tickliſh indeed in the execution. The caſes which he narrates were new to them. They ſhould have almoſt deſpaired of ſucceſs with arches which had gone ſo much out of ſhape by the bending of the centres; becauſe, ſaid they, the ſlope of the centering, to a great diſtance from the crown, was ſo little, that the archſtones could not ſlide outwards along it, to cloſe even the under ſide of the joints which had opened above the haunches; ſo that *all* the archſtones were at too great a diſtance from each other; and a great and *general* ſubſiding of the whole was neceſſary for bringing them even to touch each other. They had *never* obſerved ſuch bendings of the centerings which they had employed, having never allowed themſelves to contract the feet of their truſſes into ſuch narrow ſpaces. They obſerved, that nothing but lighters with their maſts down can paſs under the truſſes, and that the ſides muſt be ſo protected by advanced works from the accidental ſhock of a loaded boat, that there cannot be left room for more than one. They added, that the bridges of communication, neceſſary for the expeditious conducting of the work, made all this ſuppoſed roomineſs uſeleſs: beſides, the buſineſs can hardly be ſo urgent and crowded any where, as to make the paſſage through every arch indiſpenſably neceſſary. Nor was the inconvenience of this obſtruction greatly complained of during the erection of Weſtminſter or Blackfriars bridges. Nothing ſhould come in competition with the *undoubted* ſolidity of the centering and the future arch; and all boaſting diſplay of talent and ingenuity by an engineer, in the exhibition of the wonders of his art, is miſplaced here.

Theſe appeared to us good reaſons for preferring the more cautious, and incomparably more ſecure, conſtruction of Mr Mylne, in which the breadth given to each baſe of the truſſes permitted a much more effective diſpoſition of the abutting timbers, and alſo enabled the engineer to make it incomparably ſtiffer; ſo that no change need be apprehended in the joints which have already cloſed, and in which the mortar has already taken its ſet, and commenced an union that never can be reſtored if it be once broken in the ſmalleſt degree, no not even by greater compreſſion.

27 The connection that is formed by mortar of lime, &c.

Here we beg leave to mention our notions of the connection that is formed by mortar compoſed of lime or gypſum. We conſider it as conſiſting chiefly, if not ſolely, in a cryſtallization of the lime or gypſum and water. As much water is taken up as is neceſſary for the formation of the cryſtals during their gradual converſion into mild calcareous earth or alabaſter, and the reſt evaporates. When the free acceſs of air is abſolutely prevented, the cryſtallization never proceeds to that ſtate, even although the mortar becomes extremely dry and hard. We had an opportunity of obſerving this accidentally, when paſſing through Maeſtricht in 1770, while they were cutting up a maſſy revetment of a part

Center.

a part of the fortifications more than 300 years old. The mortar between the bricks was harder than the bricks (which were Dutch clinkers, ſuch as are now uſed only for the greateſt loads); but when mixed with water it made it limewater, ſeemingly as ſtrong as if freſh lime had been uſed. We obſerved the ſame thing in one ſmall part of a huge maſs of ancient Roman work near Romney in Kent; but the reſt, and all the *very old* mortar that we have ſeen, was in a mild ſtate, and was generally much harder than what produced any lime water. Now when the mortar in the joints has begun its firſt cryſtallization, and is allowed to remain in perfect reſt, we are confident that the ſubſequent cryſtals, whether of lime, or of calcareous earth, or of gypſum, will be much larger and ſtronger than can ever be produced if they are once broken; and the farther that this cryſtallization has been carried, that is, the harder that the mortar has become, leſs of it remains to take any new cryſtallization. Why ſhould it be otherwiſe here than in every other cryſtallization that we are acquainted with?

28 Neceſſity of keeping the joints in their firſt ſtate.

We think therefore that it is of great conſequence to keep the joints in their *firſt* ſtate if poſſible; and that the ſtrength (as far as it depends on the mortar) is greatly diminiſhed by their opening; eſpecially when the mortar has acquired conſiderable hardneſs, which it will do in a month or ſix weeks, if it be good. The coheſion given by mortar is indeed a mere trifle, when oppoſed to a force which tends to open the joints, acting, as it generally does, with the tranſverſe force of a lever: but in ſituations where the overload on any particular archſtones tends to puſh them down through between their neighbours, like wedges, the coheſion of the mortar is then of very great conſequence.

We muſt make another obſervation. Mr Perronet's ingenious proceſs tended very effectually to cloſe the joints. In doing this, the forces which he brought into action had little to oppoſe them; but as ſoon as they were cloſed, the contact of the parts formerly open oppoſed an obſtruction incomparably greater, and immediately balanced a force which was but juſt able to turn the ſtone gently about the two edges in which it touched the adjoining ſtones. This is an important remark, though ſeemingly very trifling; and we wiſh the practitioner to have a very clear conception of it; but it would take a multitude of words to explain it. It is worth an experiment. Form a little arch of wooden blocks; and form one of theſe ſo, that when they are all reſting on the centering, it may be open at the outer joint—Remove the centering—Then preſs on the arch at ſome diſtance from the open joint.—You will find that a very ſmall preſſure will make the arch bend till that joint cloſes—Preſs a little harder, and the arch will bend more, and the next joint will open.—Thus you will find that, by preſſing alternately on each ſide of the open joint, that ſtone can eaſily be made to flap over to either ſide; and that immediately after this is done the reſiſtance increaſes greatly. This ſhews clearly, that a very moderate force, judiciouſly employed, will cloſe the joints, but will not preſs the parts ſtrongly together. The joints therefore are *cloſed*, but *no more than cloſed*, and are hanging only by the edges by which they were hanging while the joints were open. The arch, therefore, though apparently cloſe and firm, is but looſe and tottering. Mr Perronet ſays, that his arches were firm, becauſe hardly a ſtone was obſerved to chip or ſplinter off at the edges by the ſettlement. But he had done every thing to prevent this, by digging out the mortar from between the headers, to the depth of two inches, with ſaws made on purpoſe. But we are well informed, that before the year 1791 (twenty years after the erection) the arches at Neuilly had ſunk very ſenſibly, and that very large ſplinters had flown off in ſeveral places. It could not be otherwiſe. The original conſtruction was too bold; we may ſay needleſsly and oſtentatiouſly bold. A very gentle ſlope of the roadway, which would not have ſlackened the mad gallop of a ducal carriage, nor ſenſibly checked the laborious pull of a loaded waggon, and a proper difference in the ſize of the arches, would have made this wonderful bridge incomparable ſtronger, and alſo much more elegant and pleaſing to the eye. Indeed, it is far from being as handſome as it might have been. The ellipſe is a moſt pleaſing figure to every beholder; but this is concealed as much as poſſible, and it is attempted to give the whole the appearance of a tremendous lintel. It has the oppreſſive look of danger. It will not be of long duration. The bridge at Mantz is ſtill more exceptionable, becauſe its piers are tall and ſlender. If any one of the arches fails, the reſt muſt fall in a moment. An arch of Blackfriars Bridge might be blown up without diſturbing its neighbours.

29 Mr Perronet's conſtructions too bold.

30 A bad method of ſtriking the centre.

Mr Perronet mentions another mode of ſtriking the centering, which he ſays is very uſual in France. Every ſecond bridging is cut out. Some time after, every ſecond of the remainder; after this, every ſecond of the remainder; and ſo on till all are removed. This is never practiſed in this country, and is certainly a very bad method. It leaves the arch hanging by a number of diſtant points; and it is wonderful that any arch can bear this treatment.

31 The common method in Britain.

Our architects have generally proceeded with extreme caution. Wherever they could, they ſupported the centering by intermediate pillars, even when it was a truſſed centre, having a tie-beam reaching from ſide to ſide. The centre was made to reſt, not immediately on theſe pillars, but on pieces of timber formed like acute wedges, placed in pairs, one above the other, and having the point of the one on the thick end of the other. Theſe wedges were well ſoaped and rubbed with black lead, to make them ſlippery. When the centres are to be ſtruck, men are ſtationed at each pair of the wedges with heavy mauls. They are directed to ſtrike together on the oppoſite wedges. By this operation the whole centering deſcends together; or, when any part of the arch is obſerved to have opened its joints on the upper ſide, the wedges below that part are ſlackened. The framing may perhaps bend a little, and allow that part to ſubſide. If any part of the arch is obſerved to open its joints on the under ſide, the wedges below that part are allowed to ſtand after the reſt have been ſlackened. By this proceſs, the whole comes down gradually, and as ſlowly as we pleaſe, and the defects of every part of the arch may be attended to. Indeed the caution and moderation of our builders have commonly been ſuch, that few defects have been allowed to ſhew themſelves. We are but little acquainted with joints opening to the extent of two inches, and in ſuch a caſe would probably lift

Center. lift every stone of the arch again (B). We have not employed trussed centerings so much perhaps as we should have done; nor do we see their advantage (speaking as mere builders) over centres supported all over, and unchangeable in their form. Such centres must bend a little, and require loading on the middle to keep them in shape. Their compression and their elasticity are very troublesome in the striking of the centres in Mr Perronet's manner. The elasticity is indeed of use when the centres are struck in the way now described.

These observations on the management of the internal movements of a great arch, will enable the reader to appreciate all the merit of Mr Mylne's very ingenious construction. We proceed therefore to complete our description.

The gradual enlargement of the base of the piers of Blackfriars bridge enabled the architect to place a series of five posts *c*, *c*, *c*, *c*, *c*, one on each stap of the pier; the ingenious contexture of which made it like one solid block of stone (see ARCH, *Supplement*). These struts were gradually more and more oblique, till the outer one formed an obtuse angle with the lowest side of the interior polygon of the truss. On the top of these posts was laid a sloping SEAT or beam D of stout oak, the upper part of which was formed like a zig-zag scarfing. The posts were not perpendicular to the under side of the seat. The angles next the pier were somewhat obtuse. Short pieces of wood were placed between the heads of the posts (but not mortised into them), to prevent them from slipping back. Each face of the scarf was covered with a thick and smooth plate of copper. The feet of the truss were mortised into a similar piece F, which may be called the SOLE of the truss, having its lower side notched in the same manner with the upper side of D, and like it covered with copper. Between these two lay the STRIKING WEDGE E, the faces of which corresponded exactly with the slant faces of the seat and the sole. The wedge was so placed, that the corresponding faces touched each other for about half of their length. A block of wood was put in at the broad end or base of this wedge, to keep it from slipping back during the laying the archstones. Its outer end E was bound with iron, and had an iron bolt several inches long driven into it. The head of this bolt was broad enough to cover the whole wood of the wedge within the iron ferrule.

32 The excellence of Mr Mylne's method.

We presume that the reader, by this time, foresees the use of this wedge. It is to be driven in between the sole and the seat (having first taken out the block at the base of the wedge). As it advances into the wider spaces, the whole truss must descend, and be freed from the arch; but it will require prodigious blows to drive it back. Mr Mylne did not think so, founding his expectation on what he saw in the launching of great ships, which slide very easily on a slope of 10 or 12 degrees. He rather feared, that taking out the block behind would allow the wedge to be pushed back at once, so that the descent of the truss would be too rapid. However, to be certain of the operation, he had prepared an abundant force in a very ingenious manner. A heavy beam of oak, armed at the end with iron, was suspended from two points of the centre like a battering ram, to be used in the same manner. Nothing could be more simple in its structure, more powerful in its operation, or more easy in its management. Accordingly the success was to his wish. The wedge did not slip back of itself; and very moderate blows of the ram drove it back with the greatest ease. The whole operation was over in a very few minutes. The spectators had suspected, that the space allowed for the recess of the wedge was not sufficient for the settlement of the arch; but the architect trusted to the precautions he had taken in its construction. The reader, by turning to the article ARCH in this *Supplement*, will see, that there was only the arch LY which could be expected to settle: accordingly, the recess of the wedge was found to be much more than was necessary. However, had this not been the case, it was only necessary to take out the pieces between the posts below the seat, and then to drive back the heads of the struts; but this was not needed (we believe) in any of the arches. We are well assured that none of the arches sunk an inch and a half. The great arch of 100 feet span did not sink one inch at the crown. It could hardly be perceived whether the arch quitted the centering gradually or not, so small had been the changes of shape.

33 The great superiority of the centering used by him.

We have no hesitation in saying, that (if we except some waste of great timber by uncommon joggling) the whole of this performance is the most perfect of any that has come to our knowledge. We doubt not but that several have equalled it, or may have excelled it; but we do not know of them: and we think, that the bringing forward such performances is no less serviceable to the public than it is honourable to the inventor. Nor do we suppose that any views of interest can be so powerful as to prevent an ingenious architect from communicating to the public such honourable specimens of his own talents. We should be happy to communicate more of this kind; for we consider it as a very important article of practical mechanics, and think that it is of consequence to the nation that it should be very generally understood. In every corner of the country bridges are to be built—we have everywhere good *masons*, who are fully able to execute any practicable project, but too little acquainted with principle to invent, or to accommodate even what they know to local circumstances, and are very apt to be duped by appearances of ingenuity, or misled by erroneous notions of the strains which are excited. We profess more science, and to treat the subject with the assistance of accurate principles: But while we are certain that every circumstance is susceptible of the most accurate determination, we must acknowledge that we have by no means attained an accurate knowledge of all the strains which are produced

(B) The writer of this article can only say, that, after much inquiry, he has no information of any arch being received from the builder as sufficient that had suffered half the change of shape mentioned by Mr Perronet. The arch of Dublin bridge, built by an excellent, but a very private, mason, Mr Steven, is 105 feet wide, with only 22 feet of rise. It was erected (but not on a trussed centering) without changing one full inch in its elevation; and when the centering was removed, it sunk only $1\frac{1}{4}$th inches, and about half an inch more when the parapets were added and the bridge completely finished.

produced and excited in a frame of carpentry, which is ſettling and changing its ſhape, even though it be not very complicated; far leſs are we poſſeſſed of a clear view of what happens in a maſs of maſonry in ſimilar conditions. Therefore, though we ſpeak with the ſtrong belief of our being right, we ſpeak with a ſenſe of our fallibility, and with great deference to the judgment of eminent and experienced architects and engineers. We ſhould conſider their free and candid criticiſms as the higheſt favour; and we even ſolicit them, with aſſurances of thanks, and that we will take ſome opportunity, before the cloſe of this work, to acknowledge and correct our miſtakes. We even preſume to hope, that the liberal minded artiſt will be pleaſed with this opportunity which we give him of increaſing the national ſtock of knowledge. Let mutual jealouſy and rivalſhip reign in the breaſts, and prompt the exertions, of our reſtleſs neighbours on the continent—let them think that the dignity of man conſiſts in perpetual warfare, in which every individual feels himſelf indebted only to himſelf, freed from all the ſweet ties of domeſtic partiality, of friendſhip, and of patriotic attachment. We hope that the hearts of Britons will long continue to be warmed and *fortified* by the thoughts of mutual aſſiſtance, mutual co-operation, mutual attachment, and a patriotic preference of their countrymen to all other men. While theſe ſentiments are regulated by unſhaken honeſty, by candour, and by Chriſtian charity, we ſhall be ſecured from the *errors* of partial attachments, and yet enjoy all the pleaſures of unſophiſticated nature. Families will ſtill be bound together by the affectionate ties of blood; and the whole frame of Britiſh ſociety will be in harmony with the bonds which connect the members of each family, by their endleſs croſſings and intermixings. In this ſtate, the ſtate of ſocial nature, the man of talents will not lock up all the fruits of his exertions in his own breaſt, but will feel a pleaſure in imparting them to a ſociety that is dear to him, and on which he depends for all his beſt enjoyments. Nothing will hold the good man back when this is in his power, but the virtuous uſe which he can make of his ſuperiority in the diſcharge of his own little circle of duties. This is all that is required of true patriotiſm; and it is not too much to be expected from Britons, who feel a pleaſure in viewing their country as the great ſchool of the arts, under the patronage of a ſovereign who has done more for their improvement than all the other princes of Europe, and who (we are well aſſured) is now meditating a plan which muſt be highly gratifying to every eminent profeſſor of the arts.

34 The ſubject of this article connected with the conſtruction of wooden bridges.

THE ſubject which we have been conſidering is very cloſely connected with the conſtruction of wooden bridges. Theſe are not always conſtructed on the ſole principles of equilibrium, by means of mutual abutment. They are ſtiff frames of carpentry, where, by a proper diſpoſition, beams are put into a ſtate of extenſion, as well as of compreſſion, ſo as to ſtand in place of ſolid bodies as big as the ſpaces which the beams incloſe; and thus we are enabled to couple two, three, or four of theſe together, and ſet them in abutment with each other like mighty archſtones. We ſhall cloſe this article, therefore, with two or three ſpecimens of wooden bridges, diſpoſed in a ſeries of progreſſive compoſition, ſo as to ſerve as a ſort of introduction to the art in general, and furniſh a principle which will enable the intelligent and cautious artiſt to puſh it with confidence as far as it can go.

The general problem is this. Suppoſe that a bridge is to be thrown over the ſpace AB (fig. 9.), and that this is too wide for the ſtrength of the ſize of timber which is at our command; how may this beam AB be ſupported with ſufficient effect? There are but two ways in which the middle point C (where the greateſt ſtrain is) can be ſupported: 1. It may be ſuſpended by two ropes, iron rods, or wooden ties, DC, EC, made faſt to two firm points D, E, above it; or it may reſt on the ridge of two rafters *d* C, *e* C, which reſt on two firm points *d*, *e* below it. 2. It may be ſupported by connecting it with a point ſo ſupported; and this connection may be formed either by ſuſpending it from this point, or by a poſt reſting on it. Thus it may hang, by means of a rod or a king-poſt FC, from the ridge F of two rafters AF, BF; or it may reſt on the ſtrut C *f*, whoſe lower extremity *f* is carried by the ropes, rods, or wooden ties A *f*, B *f*. Plate XVI.

Whichſoever of theſe methods we employ, it follows, from the principles of carpentry, that the ſupport given to the point C is ſo much the more powerful, as we make the angle DCE, or *d* C *e*, or the equivalent angles AFB, or A *f* B, more acute.

Each of theſe methods may be ſuppoſed equally ſtrong. Our choice will depend chiefly on the facility of finding the proper points of ſupport D, E, *d*, *e*: except in the ſecond caſe, where we require no fixed points but A and B. The ſimple forms of the firſt caſe require a great extent of figure. Very rarely can we ſuſpend it from points ſituated as D and E. It is even ſeldom that we have depth enough of bank to allow the ſupport of the rafters *d* C, *e* C; but we can always find room for the ſimple truſs AFB. This therefore is the moſt uſually practiſed. 35 The uſual and ſimpleſt method of conſtructing ſuch bridges.

In the conſtruction, we muſt follow the maxims and directions preſcribed in the article CARPENTRY of this volume, and the article ROOF of the *Encycl.* The beams FA, FB muſt be mortiſed into AB, in the firmeſt manner, and there ſecured with ſtraps and bolts; and the middle muſt hang by a ſtrap attached to the king poſt FC, or to the iron rod that is uſed for a king poſt. No mortiſing in the point C muſt be employed; it is unneceſſary, and it is hurtful, becauſe it weakens the beam, and becauſe it lodges water, and ſoon decays by rot. The beſt practice is not to ſuſpend the beam immediately by this ſtrap, but to let it reſt, as in fig. 10. on a beam C, which croſſes the bridge below, and has its other end ſupported in the ſame manner by the other truſs.

It is evident that the length of the king poſt has no effect on the ſupport of C. We may therefore contract every thing, and preſerve the ſame ſtrength of ſupport, by finding two points *a* and *b* (fig. 11.) in the banks, at a moderate diſtance below A and B, and ſetting up the rafters *a* F, *b* F, and ſuſpending C from the ſhortened king poſt. In this conſtruction, when the beam AB reſts on a croſs bearer, as is drawn here, the ſtruts *a* F, *b* F are kept clear of it. No connection between them is neceſſary, and it may be hurtful, by inducing croſs ſtrains on both. It will, however, greatly increaſe creafe the ftiffnefs of the whole. This conftruction may fafely be loaded with ten times the weight that AB can carry alone.

36 An improvement of that method.

Suppofe this done, and that the fcantling of AB is too weak for carrying the weight which may be brought on the parts AC, CB. We may now trufs up each half, as in fig. 12. and then the whole will form a handfome bridge, of the fimpleft conftruction poffible. The interfections of the fecondary braces with thofe of the main trufs will form a hand-rail of agreeable figure.

We are not confined to the employment of an entire piece AB, nor to a rectilineal form. We may frame the bridge as in fig. 13. and in this form we diffuade from allowing any connection with the middle points of the main braces. This conftruction alfo may be followed till each beam AC and CB is loaded to ten times what it can fafely bear without the fecondary truffing.

37 Another method.

There is another way by which a bridge of one beam may be fupported beyond the power of the firft and fimpleft conftruction. This is reprefented in fig. 14. and fig. 15. The trufs beam FG fhould occupy one-third of AB. The advantage of this conftruction is very confiderable. The great elevation of the braces (which is a principal element of the ftrength) is preferved, and the braces are greatly fhortened.

This method may be pufhed ftill further, as in fig. 16.

38 Thefe methods combined.

And all thefe methods may be combined, by joining the conftructions of fig. 14. and fig. 15. with that of fig. 16.

In all of them there is much room for the difplay of fkill, in the proper adjuftment of the fcantling of the timber, and the obliquity of the braces to the lengths of the different bearings. A very oblique ftrut, or a flender one, will fuffice for a fmall load, and may often given an opportunity to increafe the general ftrength; while the great timbers and upright fupports are referved for the main preffures. Nothing will improve the compofition fo much as reflecting progreffively, and in the order of thefe examples, on the whole. This alone can preferve the great principle in its fimplicity and full energy.

39 The elements of all that can be done in this art.

Thefe conftructions are the elements of all that can be done in the art of building wooden bridges, and are to be found more or lefs obvioufly and diftinctly in all attempts of this kind. We may affert, that the more obvioufly they appear, the more perfect the bridge will be. It is aftonifhing to what extent the principle may be carried. We have feen a bridge of 42 feet fpan formed of two oak truffes, the biggeft timber of which did not exceed fix inches fquare, bearing with perfect fteadinefs and fafety a waggon loaded with more than two tons, drawn by four ftout horfes. It was framed as fig. 16. nearly, with the addition of the dotted lines, and was near thirty years old; protected, however, from the weather by a wooden roof, as many bridges in Germany are.

We recollect another in the neighbourhood of Stettin, which feemed conftructed with great judgment and fpirit. It had a carriage road in the middle about 20 feet (we think) wide, and on each fide a foot way about five feet wide. The fpan was not lefs than 60 feet, and the greateft fcantling did not appear to exceed 10 inches by 6.

This bridge confifted of four truffes, two of which formed the outfide of the bridge, and the other two made the feparation between the carriage road and the two foot ways. We noticed the conftruction of the truffes very particularly, and found it fimilar to the laft, except in the middle divifion of the upper trufs, which, being very long, was double truffed, as in fig. 17.

The reader will find in that volume of Leupold's *Theatrum Machinarum*, which he calls *Theatrum Pontificum*, many fpecimens of wooden bridges, which are very frequent in the champain parts of Germany. They are not, in general, models of mechanic art; but the reflecting reader, who confiders them *carefully*, will pick up here and there fubordinate hints, which are ingenious, and may fometimes be ufeful.

What we have now exhibited are not to be confidered as models of conftruction, but as elementary examples and leffons, for leading the reader fyftematically into a thorough conception of the fubject.

40 A wonderful bridge in Switzerland.

We cannot quit the fubject without taking notice of a very wonderful bridge at Wittingen in Switzerland, flightly defcribed by Mr Coxe (*Travels*, vol. I. 132.) It is of a conftruction more fimple ftill than the bridges we have been defcribing. The fpan is 230 feet, and it rifes only 25. The fketch (fig. 18.) will make it fufficiently intelligible. ABC is one of two great arches, approaching to a Catenarean fhape, built up of feven courfes of folid logs of oak, in lengths of 12 or 14 feet, and 16 inches or more in thicknefs. Thefe are all picked of a natural fhape, fuited to the intended curve; fo that the wood is nowhere cut acrofs the grain to trim it into fhape. Thefe logs are laid above each other, fo that their abutting joints are alternate, like thofe of a brick wall; and it is indeed a wooden wall, fimply built up, by laying the pieces upon each other, taking care to make the abutting joints as clofe as poffible. They are not faftened together by pins or bolts, or by fcarfings of any kind. They are, however, held together by iron ftraps, which furround them, at the diftance of five feet from each other, where they are faftened by bolts and keys.

Thefe two arches having been erected (by the help, we prefume, of pillars, or a centering of fome kind), and well butted againft the rock on each fide, were freed from their fupports, and allowed to fettle. They are fo placed, that the intended road *a b c* interfects them about the middle of their height. The roadway is fupported by crofs joifts, which reft on a long horizontal fummer beam. This is connected with the arches on each fide by uprights bolted into them. The whole is covered with a roof, which projects over the arches on each fide to defend them from the weather. Three of the fpaces between thefe uprights have ftruts or braces, which give the upper work a fort of truffing in that part.

This conftruction is fimple and artlefs; and appears, by the attempt to trufs the ends, to be the performance of a perfon ignorant of principle, who has taken the whole notion from a ftone arch. It is, however, of a ftrength much more than adequate to any load that can be laid on it. Mr Coxe fays, but does not explain

how,

Center.

how, that it is so contrived that any part of it can be repaired independent of the rest. It was the last work of one Ulrich Grubenhamm of Tuffen, in the canton of Appenzel, a carpenter without education, but celebrated for several works of the same kind; particularly the bridge over the Rhine at Schafhausen, consisting of two arches, one of 172 and the other of 193 feet span, both resting on a small rock near the middle of the river.

41 Another in North America.

While writing this article, we got an account of a wooden bridge erected in North America, in which this simple notion of Grubenhamm's is mightily improved. The span of the arch was said to exceed 250 feet, and its rise exceedingly small. The description we got is very general, but sufficient, we think, to make it perfectly intelligible.

In fig. 19. DD, EE, FF, are supposed to be three beams of the arch. They consist of logs of timber of small lengths, suppose of 10 or 12 feet, such as can be found of a curvature suited to its place in the arch without trimming it across the grain. Each beam is double, consisting of two logs applied to each other, side to side, and *breaking joint*, as the workmen term it. They are kept together by wedges and keys driven through them at short intervals, as at K, L, &c.

The manner of joining and strongly binding the two side pieces of each beam is shewn in fig. 20. The mortise *a i c b* and *d c i o*, which is cut in each half beam, is considerably longer on the outside than on the inside, where the two mortises meet. Two keys, BB and CC, are formed, each with a notch *b c d*, or *a i o*, on its side; which notch fits one end of the mortise. The inner side of the key is straight, but so formed, that when both keys are in their places, they leave a space between them wider at one end than at the other. A wedge AA, having the same taper as the space just mentioned, is put into it and driven hard. It is evident that this must hold the two logs firmly together.

This is a way of uniting timber not mentioned in the article Carpentry; and it has some peculiarities worthy of notice. In the first place, it may be employed so as to produce a very strong lateral connection, and would then co-operate finely with the other artificial methods of scarfing and tabling that we described in the article referred to. But it requires nice attention to some circumstances of construction to secure this effect. If the joints are accurately formed to each other, as if the whole had been one piece divided by an infinitely thin saw, this manner of joining will *keep* them all in their places. But no driving of the wedge AA will make them firmer, or cause one piece to press hard on the other. If the abutment of two parts of the half beam is already close, it will remain so; but if open in the smallest degree, driving of the wedge will not make it tighter. In this respect, therefore, it is not so proper as the forms described in Carpentry.

In order that the method now described may have the effect of *drawing* the halves of the beams together, and of keeping them hard squeezed on each other, the joints must be made so as not to correspond exactly. The prominent angle *a i o* (fig. 21.), formed by the ends of the two half mortises, must be made a little more obtuse than the angle *a f o* of the notch of the key which this prominence is intended to fill up. Moreover, the opposite side *e t* of this key should not be quite straight, but a very little convex. With these precautions, it is easy to see that, by driving the wedge AA, we cause the notch *a f o* to take hold, first at the two points *a* and *o*, and then, by continuing to drive the wedge, the sides *a f*, *o f*, of the notch gradually compress the wood of the half beams, and press them on each other. By continuing to drive the wedge, the mutual compression of the key and the beam squeezes all together, and the space *a f o i* is completely filled up. We may see, from this process, that the mutual compression and drawing together of the timber will be greater in proportion as we make the angle *a i o* more prominent, and its corresponding angle *a f o* more deep; always taking care that the key shall be thick enough not to break in the narrow part.

Center.

This adjustment of the keys to the mortise is necessary on another account. Supposing the joints to fit each other exactly before driving the wedge, and that the whole shrinks a little by drying—by this the angle *a i o* will become more prominent, and the angle *a f o* will become more shallow; the joint will open at *a* and *o*, and the mutual compressure will be at an end.

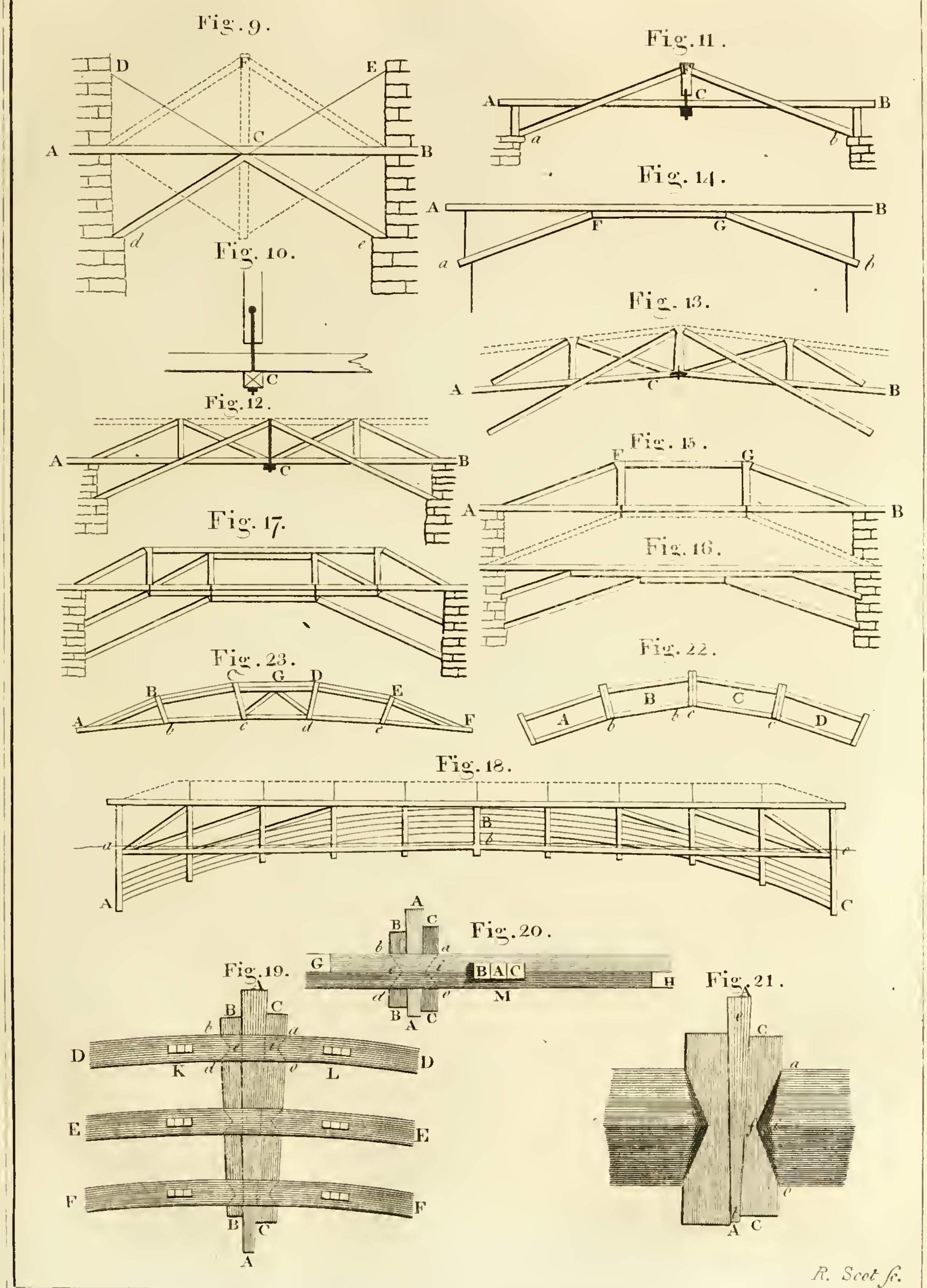
We may also observe, that this method will not give any additional firmness to the abutments of the different lengths employed to piece out the arch-beam; in which respect it differs materially from the other modes of joining timber.

Having shown how each beam is pieced together, we must now show how a number of them are united, so as to compose an arch of any thickness. This is done in the very same way. The beams have other mortises worked out of their inner sides, half out of each half of the beam. The ends of the mortises are formed in the same way with those already described. Long keys BB, CC, (fig. 19.) are made to fit them properly, the notches being placed so as to keep the beams at a proper distance from each other. It is now plain that driving in a long wedge AA will bind all together.

In this manner may an arch be extended to any span, and made of any thickness of arching. The bridge over Portsmouth river, in North America, was more than 250 feet in length, and consisted of several parallel arches of beams. The inventor (Mr Blodget) said that he found the strength so great, that he could with perfect confidence make one of four times the span.

We admire the ingenuity of this construction, and think it very effectual for bringing the timbers into firm and uniform abutment; but we imagine that it requires equilibration, because it is extremely flexible. There is nothing to keep it from bending, by an inequality of load, but the transverse strength of the beams. The keys and wedges can have very little power to prevent this bending. The distance between the beams will also contribute little or nothing to the stiffness; nay, we imagine that a great distance between them will make the frame more flexible. Could the beams be placed so near each other that they could be somehow joggled on each other, the whole would be stiffer; but at present they will bend like the plates of a coach-spring. But nothing hinders us from adding diagonal pieces to this construction, which will give it any degree of stiffness, and will enable it to bear any inequality of loading. When completed in this manner, we imagine that it will be at least equal to any construction

CENTRES. Plate XVII.



tion that has yet been thought of. One advantage it possesses that is very precious: Any piece that fails may be taken out, and replaced by another, without disturbing the rest, and without the smallest risk. On the whole, we think it a very valuable addition to British carpentry. The method here practised, both for joining the parts of one beam and for framing the different beams together, suggests the most firm and light constructions for dome-roofs that can be conceived; incomparably superior to any that have yet been erected. The whole may be framed, without a nail or a spike, into one net-like shell that cannot even be pulled in pieces. We may perhaps consider this in another article; at present we return to the consideration of trussed bridges.

42 Bridges combined by simple addition or by composition.

When the width of the river exceeds what is thought practicable by a single truss, we must then combine, either by simple addition, or by composition, different trusses together. We compose a bridge by simple addition when we make a frame of carpentry of an unchangeable and proper shape, to serve as one of the archstones of a bridge of masonry. This may easily be comprehended by looking at fig. 22. Each of the frames A, B, C, D, must be considered as a separate body, and all are supported by their mutual abutment. The nature of the thing is not changed, although we suppose that the rails of the frame B, instead of being mortised into an upright *b′ b′*, unconnected with the frame C, is mortised into the upright *c c* of that frame, the direction and intensity of the mutual pressures of the two frames are the same in both cases; accordingly this is a very common form of small wooden bridges. It is usual, indeed, to put diagonal battens into each: but we believe that this is more frequently done to please the eye than to produce an unalterable shape of each frame.

To an unskilful carpenter this bridge does not seem essentially different from the centering of Mr Hupeau for the bridge of Orleans; and indeed, in many cases, it requires reflection, and sometimes very minute reflection, to distinguish between a construction which is only an addition of frame to frame till the width be covered, from a construction where one frame works on the adjoining one transversely, pushing it in one part, and drawing it in another. The ready way for an unlettered artist to form a just notion of this point, is to examine whether he may saw through the connecting piece *b′ b′* from one end to the other, and make them two separate frames. Whenever this cannot be done without that part opening, it is a construction by composition. Some of the beams are on the stretch; and iron straps, extending along both pieces, are necessary for securing the joint. The bridge is no longer a piece of masonry, but a performance of pure carpentry, depending on principles peculiar to that art. Equilibration is necessary in the first construction; but, in the second, any inequality of loading is made ineffectual for hurting the edifice, by means of the stretch that is made to operate on some other piece. We are of opinion, that this most simple employment of the distinguishing principle of carpentry, by which the beams are made to act as ties, will give the most perfect construction of a wide bridge. One polygon alone should contain the whole of the abutments; and one other polygon should consist entirely of ties; and the beams which form the radii, connecting the angles of the two polygons, complete the whole. By confining the attention to these two simple objects, the abutments of the outer polygon, and the joints of the inner one, may be formed in the most simple and efficient manner, without any collateral connections and dependencies, which divide the attention, increase the complication, and commonly produce unexpected and hurtful strains. It was for this reason that we have so frequently recommended the centering of the bridge of Orleans. Its office will be completely performed by a truss of the form of fig. 23.; where the polygon ABCDEF, consisting of two layers of beams (if one is not sufficient), contains the whole abutments, and the other A *b c d e* F is nothing but an iron rod. In this construction, the obtuseness of the angles of the lower polygon is rather an advantage. The braces G *c*, G *d*, which are wanted for trussing the middle of the outer beams, will effectually secure the angles of the exterior polygon against all risk of change. The reader must perceive that we have now terminated in the construction of the Norman roof. We indeed think it the best general form, when some moderate declivity is not an insuperable objection. When this is the case, we recommend the general plan of the centering of the bridge of Orleans. We would make the bridge (we speak of a great bridge) consist of four trusses; two to serve as the outsides of the bridge, and two inner trusses, separating the carriage-way from the foot-paths. The road should follow the course of the lower polygon, and the main truss should form the rails. It might look strange; but we are here speaking of strength; and evident, but not unwieldy strength, when once it becomes familiar, is the surest source of beauty in all works of this kind.

43 How to distinguish bridges formed according to these different methods.

44 The best general form of a wooden bridge.

Centre of Friction, is that point in the base of a body on which it revolves; into which, if the whole surface of the base, and the mass of the body, were collected, and made to revolve about the centre of the base of the given body, the angular velocity destroyed by its friction would be equal to the angular velocity destroyed in the given body by its friction in the same time. See Friction in this Supplement.

Centre of Gyration, is that point in which, if the whole mass be collected, the same angular velocity will be generated in the same time, by a given force acting at any place, as in the body or system itself. This point differs from the centre of oscillation, in as much as in this latter case the motion of the body is produced by the gravity of its own particles; but, in the case of the centre of gyration, the body is put in motion by some other force acting at one place only.

Centre of Oscillation, is that point in the axis or line of suspension of a vibrating body, or system of bodies, in which, if the whole matter or weight be collected, the vibrations will still be performed in the same time, and with the same angular velocity, as before. Hence, in a compound pendulum, its distance from the point of suspension is equal to the length of a simple pendulum whose oscillations are isochronal with those of the compound one.

Centre of Pressure, of a fluid against a plane, is that point against which a force being applied equal and contrary to the whole pressure, it will just sustain it, so as that the body pressed on will not incline to either side.—This is the same as the centre of percussion, supposing the axis of motion to be at the intersection of this

this plane with the surface of the fluid; and the centre of pressure upon a plane parallel to the horizon, or upon any plane where the pressure is uniform, is the same as the centre of gravity of that plane.

CENTREVILLE, the chief town of Queen Ann's co. and on the E. side of Chesapeak bay in Maryland. It lies between the forks of Corsica creek, which runs into chester River and has been lately laid out; 18 miles S. of Chester; 34 S. E. by E. of Baltimore, and 95 S. W. by S. of Philadelphia. N. lat. 39. 6.—*Morse.*

CENTROBARICO, the same as centre of gravity.

CENTROBARIC METHOD, is a method of determining the quantity of a surface or solid, by means of the generating line or plane and its centre of gravity. The doctrine is chiefly comprised in this theorem:

Every figure, whether superficial or solid, generated by the motion of a line or plane, is equal to the product of the generating magnitude and the path of its centre of gravity, or the line which its centre of gravity describes.

CERUSE, or WHITE-LEAD, is a substance so much used in painting, and for other purposes, that numerous modes have been employed for the preparation of it. Of the most common of these, a sufficient account has been given in the Encyclopædia (see CERUSE, and the same word CHEMISTRY-*Index)*; but Lord Dundonald has discovered a more expeditious and facile method than any of them, which becomes the more useful, as the substance with which it is effected has been hitherto rejected by the chemical world as a *caput mortuum*.

His lordship directs common lead to be reduced to a calx, but not too fine, and to have a proportion of five-sixth parts thereof, intimately mixed with muriate, or solution of potass. In this state, he directs it to be frequently stirred, in order to have the new surfaces of the mixture exposed to the carbonic acid of atmospheric air; as his lordship observes, that the effects of the carbonic acid on the alkali existing in the present state of the mixture is essentially necessary, in order to effect the intended purpose. In this state, it is to be frequently sprinkled with water; and, after the calx has been long enough immersed with the muriate to be sufficiently operated upon, the muriate is to be levigated by common water from the calx, and to be concentrated by evaporation, in order to be made use of at a future period with other calx. The calx is to be afterwards ground, levigated, and dried for use.

For this discovery, his lordship obtained a patent on the 18th of August 1797; and the success which has attended the former patents of this scientific nobleman leads us to conclude, that the present discovery is entitled to the attention of the public.

CHACTAWS, or flat heads, are a powerful, hardy, subtile and intrepid race of Indians, who inhabit a very fine and extensive tract of hilly country, with large and fertile plains intervening, between the Alabama and Mississippi rivers, and in the western part of the state of Georgia. This nation had, not many years ago, 43 towns and villages, in three divisions, containing 12,123 souls, of which 4,041 were fighting men. They are called by the traders Flatheads, all the males having the fore and hind part of their skulls artificially flattened when young. These men, unlike the Muscogulges, are slovenly and negligent in every part of their dress, but otherwise are said to be ingenious, sensible, and virtuous men, bold and intrepid, yet quiet and peaceable. Some late travellers, however, have observed that they pay little attention to the most necessary rules of moral conduct, at least that unnatural crimes were too frequent among them. Different from most of the Indian nations bordering on the United States, they have large plantations or country farms, where they employ much of their time in agricultural improvements, after the manner of the white people. Although their territories are not ⅓th so large as those of the Muscogulge confederacy, the number of inhabitants is greater. The Chactaws and Creeks are inveterate enemies to each other.—*Morse.*

CHAGRE, a river and town in Terra Firma, S. America. The river opens to the N. Sea, and was formerly called Lagortas, from the number of alligators in it; has its source in the mountains near Cruces, and its mouth is in N. lat. 9. where there is a strong fort, built on a steep rock, on the E. side, near the sea shore. This fort has a commandant, and lieutenant, and the garrison is draughted from Panama, to which you go by this river, landing at Cruces, about 5 leagues from Panama, and thence one travels by land to that city. Opposite to fort Chagre is the royal custom-house. Here the river is broadest, being 120 toises over; whereas, at Cruces, where it begins to be navigable, it is only 20 toises wide; from the town of Chagre, to the mouth of the river, is 21 miles N. W. by W. but measuring by water is 43 miles. There is at Cruces an alcalde, who lives at the custom-house, and takes an account of all goods on the river. Chagre fort was taken by admiral Vernon, in 1740.—*ib.*

CHAMBERS (Sir William), the celebrated architect, was descended of the ancient family of Chalmers in Scotland, barons of Tartas, in France. His grandfather suffered considerably in his fortune by supplying Charles XII. of Sweden with money, &c. which that monarch repaid in base coin. Sir William's father resided several years in Sweden to recover his claims; and there Sir William was born, and, at eighteen years of age, appointed supercargo to the Swedish East India company. From a voyage which he made to China, he brought home the Asiatic style of ornament, in tents, temples, mosques, and pagodas. These ornaments (through the interest of lord Bute) he was enabled to apply in the gardens at Kew. Patronised by the princess dowager and the king, Mr Chambers had much of the fashionable business of the day. Under Burke's reform, he was appointed surveyor-general of the board of works. Somerset-house was worth to him at least £.2000 a year. His *Chef d'œuvres* are his staircases, particularly those at Lord Besborough's, Lord Gower's, and the Royal and Antiquarian Societies. The terrace behind Somerset house is a bold effort of conception. His designs for interior arrangements were excellent. His Treatise on Civil Architecture alone will immortalize his name. In private life, Sir William was hospitable, kind, and amiable. His son married Miss Rodney; Mr Cotton, Mr Innis, and Mr Harward, married his beautiful daughters. Having been abstemious in his youth, Sir William's constitution did not begin to break till he was seventy years of age. For the last three years, he was kept alive by wine and oxygenated air; and died on the 5th of March 1796. His celebrity will be lasting in the works which he has left; and, as he was equally skilled in the theory and practice of the arts which he professed, his precepts are as valuable as his works. At his death, he was fellow of the Royal and Antiquarian Societies, treasurer of the Royal Academy, surveyor-general of the board of works, and knight of the Swedish order of the Polar Star.

CHAMBERSBURG, a post town, in Pennsylvania, and the chief of Franklin co. It is situated on the eastern branch of Conogocheague creek, a water of Potowmac River in a rich and highly cultivated country, and healthy situation.—Here are about 200 houses, 2 Presbyterian churches, a stone gaol, a handsome court-house, built of brick, a paper and merchant mill. It is 58 miles E. by S. of Bedford, 11 N. W. of Shippensburg, and 157 W. of Philadelphia. N. lat. 39. 53. W. long. 77. 30.—*Morse*.

CHAMBLEE *River* or *Sorell*, a water of the St Lawrence, issuing from lake Champlain, 300 yards wide when lowest. It is shoal in dry seasons; but of sufficient breadth for rafting lumber, &c. spring and fall. It was called both Sorell and Richlieu when the French held Canada.—*ib*.

Chamblee *Fort*, is handsome and well built, on the margin of the river of the same name, about 12 or 15 miles S. W. from Montreal, and N. of St John's fort. It was taken by the Americans, Oct. 20, 1775, and retaken by the British, Jan. 18, 1776. N. lat. 45. 45.—*ib*.

CHAMFER, or Chamferet, an ornament, in architecture, consisting of half a scotia; being a kind of small furrow or gutter on a column.

CHAMPLAIN, a lake next in size to lake Ontario, and lies E. N. E. from it, forming a part of the dividing line between the states of New-York and Vermont. It took its name from a French governor, who was drowned in it. It was before called Corlaer's Lake. Reckoning its length from Fairhaven to St John's, a course nearly N. it is about 200 miles; its breadth is from 1 to 18 miles, being very different in different places; the mean width is about 5 miles; and it occupies about 500,000 acres. Its depth is sufficient for the largest vessels. There are in it above sixty islands of different sizes; the most considerable are North and South Hero, and Motte island. North Hero, or Grand Isle, is 24 miles long and from 2 to 4 wide. It receives at Ticonderoga the waters of Lake George from the S. S. W. which is said to be 100 feet higher than the waters of this lake. Half the rivers and streams which rise in Vermont fall into it. There are several which come to it from New-York state and some from Canada; to which last it sends its own waters, a N. course, through Soreil or Chamblee river, into the St Lawrence. This lake is well stored with fish; particularly salmon, salmon-trout, sturgeon and pickerel; and the land on its borders, and on the banks of its rivers, is good.

The rocks in several places appear to be marked, and stained, with the former surface of the lake, many feet higher than it has been since its discovery in 1608. The waters generally rise from about the 20th of April, to the 20th of June, from 4 to 6 feet; the greatest variation is not more than 8 feet. It is seldom entirely shut up with ice, until the middle of January. Between the 6th and 15th of April the ice generally goes off; and it is not uncommon for many square miles of it to disappear in one day.—*Morse*.

Champlain, a township the most northerly in Clinton co. New-York, which takes its name from the lake on which it lies. It was granted to some Canadian and Nova-Scotia refugees, who were either in the service of the United States, during the war, or fled to them for protection. The indigence or ill habits of these people occasioned the breaking up of the settlement; and a better set of inhabitants have now taken their place. The lands are fertile; and two rivers run through it, well stored with fish. It has 575 inhabitants, and 3 slaves. By the state census of 1796, 76 of the inhabitants are electors.—*ib*.

CHAPPE (Jean d'Auteroche), a French astronomer, was born at Mauriac, in Auvergne, March 2. 1728. A taste for drawing and mathematics appeared in him at a very tender age; and he owed to Dom Germain a knowledge of the first elements of mathematics and astronomy. M. Cassini, after assuring himself of the genius of this young man, undertook to improve it. He employed him upon the map of France, and the translation of Halley's tables, to which he made considerable additions. The king charged him in 1753 with drawing the plan of the county of Bitche, in Lorraine, all the elements of which he determined geographically. He occupied himself greatly with the two comets of 1760; and the fruit of his labour was his elementary treatise on the theory of those comets, enriched with observations on the zodiacal light, and on the aurora borealis. He soon after went to Tobolsk, in Siberia, to observe the transit of Venus over the sun; a journey which greatly impaired his health. After two years absence he returned to France in 1762, where he occupied himself for some time in putting in order the great quantity of observations he had made. M. Chappe also went to observe the next transit of Venus, viz. that of 1769, at California, on the west side of North America, where he died of a dangerous epidemic disease, the 1st of August 1769. He had been named adjunct astronomer to the academy the 17th of January 1759.

The published works of M. Chappe, are, 1. The Astronomical Tables of Dr Halley, with Observations and Additions, in 8vo, 1754. 2. Voyage to California, to Observe the Transit of Venus over the Sun, the 3d of June 1769; in 4to, 1772. 3. He had a considerable number of papers inserted in the Memoirs of the Academy, for the years 1760, 1761, 1764, 1765. 1766, 1767, and 1768; chiefly relating to astronomical matters.

CHAPPEL-HILL, a post town in Orange co. N. Carolina, situated on a branch of Newhope creek, which empties into the N. W. branch of Cape Fear River. This is the spot chosen for the seat of the University of North-Carolina. Few houses are as yet erected; but a part of the public buildings were in such forwardness, that students were admitted, and education commenced in Jan. 1796. The beautiful and elevated scite of this town commands a pleasing and extensive view of the surrounding country; 12 miles S. by E. of Hillsborough, and 472 S. W. of Philadelphia. N. lat. 35. 40. W. long. 79. 6.—*ib*.

Universal CHARACTERS, could they be introduced, Characters.

duced, would contribute ſo much to the diffuſion of uſeful knowledge, that every attempt to make ſuch a ſcheme ſimple and practicable is at leaſt entitled to notice. Accordingly, in the *Encyclopædia*, under the word CHARACTER, a ſhort account is given of the principal plans of univerſal characters which had then fallen under our obſervation; but ſince that article was publiſhed, a new method of writing, by which the various nations of the earth may communicate their ſentiments to each other, has been propoſed by *Thomas Northmore*, Eſq; of Queen-ſtreet, Mayfair. It bears ſome reſemblance to that which we have given from the *Journal Literaire*, 1720, but it is not the ſame; and of the two, Mr Northmore's is perhaps the moſt ingenious. The ground-work of the ſuperſtructure differs not indeed from that of the journaliſt, being this in both, "That if the ſame numerical *figure* be made to repreſent the *ſame word* in the various languages upon earth, an univerſal character is immediately obtained." The only objection which our author or his friends ſaw to ſuch a plan, originates in the diverſity of idioms; but, as he truly obſerves, every ſchoolboy has this difficulty to encounter as often as he conſtrues Terence.

Such then was Mr Northmore's original plan: but he ſoon perceived that it was capable of conſiderable improvement; for, inſtead of uſing a figure for *every* word, it will be neceſſary to apply one only to every *uſeful* word; and we all know how few words are abſolutely neceſſary to the communication of our thoughts. Even theſe may be much abbreviated by the adoption of certain *uniform fixed* ſigns (not amounting to above 20), for the various caſes, numbers, genders, degrees of compariſon, of nouns, tenſes, and moods, of verbs, &c. All words of negation, too, may be expreſſed by a prefixed ſign. A few inſtances will beſt explain the author's meaning.

Suppoſe the number	5	to repreſent the word	*ſee*,
	6	— —	*a man*,
	7	— —	*happy*,
	8	— —	*never*,
	9	— —	*I*.

"I would then (ſays he) expreſs the tenſes, genders, caſes, &c. *in all languages*, in ſome ſuch *uniform* manner as following:

(1)	5	=	*preſent tenſe*, —	ſee,
(2)	.5	=	*perfect tenſe*, —	ſaw,
(3)	:5	=	*perfect participle*, —	ſeen,
(4)	5:	=	*preſent participle*, —	ſeeing,
(5)	5·	=	*future*, — —	will ſee,
(6)	$\underline{5}$	=	*ſubſtantive*, —	ſight,
(7)	$\underline{\underline{5}}$	=	*perſonal ſubſtantive*, —	ſpectator,
(8)	$\dot{6}$	=	*nominative caſe*, —	a man,
(9)	$\ddot{6}$	=	*genitive*, — —	of a man,
(10)	$\dddot{6}$	=	*dative*, — —	to a man,
(11)	$\overset{\frown}{6}$	=	*feminine*, — —	a woman,
(12)	+6	=	*plural*, — —	men,
(13)	7	=	*poſitive*, — —	happy,
(14)	$\hat{7}$	=	*comparative*, —	happier,
(15)	$\hat{\hat{7}}$	=	*ſuperlative*, —	happieſt,
	$\underline{7}$	=	as above, N° 6. —	happineſs,
(16)	—7	=	*negation*, — —	unhappy,

"From the above ſpecimen, I ſhould find no difficulty in comprehending the following ſentence, though it were written in the language of the Hottentots: 9, 8, .5, —$\hat{7}$, $\overset{\frown}{6}$. *I never ſaw a more unhappy woman.*

"Thoſe languages which do not uſe the pronoun prefixed to the verb, as the Greek and Roman, &c. may apply it, in a ſmall character, ſimply to denominate the perſon; thus, inſtead of 9, 8, .5, *I never ſaw;* they may write, 8, $_{9}$.5, which will ſignify that the verb is in the firſt perſon, and will ſtill have the ſame meaning."

Our author ſeems confident that, according to this ſcheme of an univerſal character, about 20 ſigns, and leſs than 10,000 *choſen* words (ſynonyms being ſet aſide), would anſwer all the ends propoſed; and that foreigners, by referring to their numerical dictionary, would eaſily comprehend each other. He proceeds next to ſhew how appropriate ſounds may be given to his ſigns, and an univerſal *living language* formed from the univerſal *characters*.

To attain this end, he propoſes to diſtinguiſh the ten numerals by ten monoſyllabic names of eaſy pronunciation, and ſuch as may run without difficulty into one another. To illuſtrate his ſcheme, however, he calls them for the preſent, by their common Engliſh names; but would pronounce each number made uſe of by uttering ſeparately its component parts, after the manner of accountants. Thus let the number 6943 repreſent the word *horſe*, he would not, in the univerſal language, call a horſe *ſix thouſand nine hundred and forty three*, but *ſix, nine, four, three*, and ſo on for all the words of a ſentence, making the proper ſtop at the end of each. In the ſame manner, a diſtinct appellation muſt be appropriated to each of the prefixed ſigns, to be pronounced immediately after the numeral to which it is an appendage. Thus if *plu* be the appellation or the ſign of the plural number, *ſix, nine, four, three, plu* will be *horſes*.

"Thus (ſays our author), I hope, it is evident that about 30 or 40 diſtinct ſyllables are ſufficient for the above purpoſe; but I am much miſtaken if *eleven* only will not anſwer the ſame end. This is to be done by ſubſtituting the firſt 20 or 30 numerals for the ſigns, and ſaying, as in algebra, that a term is in the power of ſuch a number, which may be expreſſed by the ſimple word *under*. *Ex. gr.* Let 6943 repreſent the word *horſe;* and ſuppoſe 4 to be the ſign of the plural number, I would write the word thus, $\frac{4}{6943}$; and pronounce it, ſix, nine, four, three, in the power of or *under* four. By theſe means eleven diſtinct appellations would be ſufficient, and time and uſe would much abbreviate the pronunciation."

To refuſe the praiſe of ingenuity to this contrivance for an univerſal language would be very unjuſt; but elocution in this manner would be ſo very tedious, that ſurely the author himſelf, when he thinks more coolly on the ſubject, will perceive, that in the living ſpeech its defects would more than balance its advantages. A *pangraph*, as he calls his univerſal character, would indeed

deed be ufeful, and is certainly practicable; a *pavleg* (if we may form fuch a word) would not be very ufeful, unlefs it were much more perfect than it could be made according to the plan before us.

CHARLES *River* in Maffachufetts, called anciently *Quinobequin*, is a confiderable ftream, the principal branch of which rifes from a pond bordering on Hopkinton. It paffes through Hollifton and Bellingham, and divides Medway from Medfield, Wrentham, and Franklin, and thence into Dedham, where, by a curious bend, it forms a peninfula of 900 acres of land. A ftream called Mother Brook, runs out of this river in this town, and falls into Neponfit River, forming a natural canal, uniting the two rivers, and affording a number of excellent mill-feats. From Dedham the courfe of the river is northerly, dividing Newton from Needham, Wefton, and Waltham, paffing over romantic falls; it then bends to the N. E. and E. through Watertown and Cambridge, and paffing into Bofton harbor, mingles with the waters of Myftic River at the point of the peninfula of Charleftown. It is navigable for boats to Watertown, 7 miles. The moft remarkable bridges on this river are thofe which connect Bofton with Charleftown and Cambridge. There are 7 paper mills on this river, befides other mills. —*Morse.*

Charles *Co.* on the weftern fhore of Maryland, lies between Potowmack and Patuxent rivers. Its chief town is Port Tobacco, on the river of that name. Its extreme length is 28 miles, its breadth 24, and it contains 20,613 inhabitants, including 10,085 flaves. The country has few hills, is generally low and fandy, and produces tobacco, Indian corn, fweet potatoes, &c. —*ib.*

Charles City *Co.* in Virginia, lies between Chickahominy and James rivers. It contained formerly part of what now forms Prince George's co. It has 5588 inhabitants, including 3141 flaves.—*ib.*

Charles, a cape of Virginia, in about N. lat. 37. 15. It is on the N. fide of the mouth of Chefapeak bay, having Cape Henry oppofite to it.—*ib.*

Charles, a cape on the S. W. part of the ftrait entering into Hudfon Bay. N. lat. 62. 40. W. long. 75. 15.—*ib.*

CHARLESTON, a diftrict in the Lower country of S. Carolina, fubdivided into 14 parifhes. This large diftrict, of which the city of Charlefton is the chief town, lies between Santee and Combahee rivers. It pays £.21,473-14-6 fterling taxes. It fends to the ftate legiflature 48 reprefentatives and 13 fenators, and 1 member to Congrefs. It contains 66986 inhabitants, of whom, only 16352 are free.—*ib.*

Charleston, the metropolis of S. Carolina, is the moft confiderable town in the ftate; fituated in the diftrict of the fame name, and on the tongue of land formed by the confluent ftreams of Afhley and Cooper, which are fhort rivers, but large and navigable. Thefe waters unite immediately below the city, and form a fpacious and convenient harbor; which communicates with the ocean juft below Sullivan's Ifland; which it leaves on the N. 7 miles S. E. of Charlefton. In thefe rivers the tide rifes, in common, about 6½ feet; but uniformly rifes 10 or 12 inches more during a night-tide. The fact is certain; the caufe unknown. The continual agitation which the tides occafion in the waters which almoft furround Charlefton—the refrefhing fea-breezes which are regularly felt, and the fmoke arifing from fo many chimneys, render this city more healthy than any part of the low country in the fouthern ftates. On this account it is the refort of great numbers of gentlemen, invalids from the W. India iflands, and of the rich planters from the country, who come here to fpend the fickly months, as they are called, in queft of health and of the focial enjoyments which the city affords. And in no part of America are the focial bleffings enjoyed more rationally and liberally than here. Unaffected hofpitality—affability—eafe of manners and addrefs—and a difpofition to make their guefts welcome, eafy and pleafed with themfelves, are characteriftics of the refpectable people of Charlefton. In fpeaking of the capital, it ought to be obferved, for the honour of the people of Carolina in general, that when in common with the other colonies, in the conteft with Britain, they refolved againft the ufe of certain luxuries, and even neceffaries of life; thofe articles, which improve the mind, enlarge the underftanding, and correct the tafte, were excepted; the importation of books was permitted as formerly.

The land on which the town is built, is flat and low, and the water brackifh and unwholefome. The ftreets are pretty regularly cut, and open beautiful profpects, and have fubterranean drains to carry off filth and keep the city clean and healthy; but are too narrow for fo large a place and fo warm a climate. Their general breadth is from 35 to 66 feet. The houfes which have been lately built, are brick, with tiled roofs. The buildings in general are elegant, and moft of them are neat, airy and well furnifhed. The public buildings are, an exchange, a ftate-houfe, an armoury, a poor-houfe, and an orphan's houfe. Here are feveral refpectable academies. Part of the old barracks has been handfomely fitted up, and converted into a college, and there are a number of ftudents; but it can only be called as yet a refpectable academy. Here are two banks—a branch of the national bank, and the S. Carolina bank, eftablifhed in 1792. The houfes for public worfhip are two epifcopal churches, two for Independents, one for Scotch Prefbyterians, one for Baptifts, one for German Lutherans, two for Methodifts, one for French Proteftants, a meeting-houfe for Quakers, a Roman Catholic chapel, and a Jewifh fynagogue.

Little attention is paid to the public markets; a great proportion of the moft wealthy inhabitants having plantations from which they receive fupplies of almoft every article of living. The country abounds with poultry and wild ducks. Their beef, mutton and veal are not generally of the beft kind; and few fifh are found in the market.

In 1787, it was computed that there were 1600 houfes in this city, and 15,000 inhabitants, including 5,400 flaves; and what evinces the healthinefs of the place, upwards of 200 of the white inhabitants were above 60 years of age. In 1791, there were 16,359 inhabitants, of whom 7684 were flaves. This city has often fuffered much by fire, the laft and moft deftructive happened as late as June, 1796.

Charlefton was incorporated in 1783, and divided into three wards, which chofe as many wardens, from among whom the citizens elect an intendant of the city. The intendant and wardens form the city-council, who have power to make and enforce bye-laws for the regulation of the city.

The value of exports from this port, in the year ending Nov. 1787, amounted to £.505,279-19-5 sterling. The number of vessels cleared from the custom-house the same year, was 947, measuring 62,118 tons; 735 of these, measuring 41,531 tons, were American; the others belonged to Great-Britain, Ireland, Spain, France, and the United Netherlands. In the year 1794, the value of exports amounted to 3,846,392 dollars. It is 60 miles S. W. by S. of Georgetown; 150 E. by S. of Augusta; 497 S. by W. of Richmond; 630 S. W. by S. of Washington city; 763 S. W. by S. of Philadelphia; and 1110 S. W. of Boston. The light-house lies in N. lat. 32. 41. 52. White Point at the S. end of the town, N. lat. 32. 44. 30. W. long. 80. 39. 45.

Knoxville, the capital of the state of Tennessee, is much nearer to this than to any sea-port-town on the Atlantic Ocean. A waggon road of only 15 miles is wanted to open the communication; and the plan is about to be executed by the state.—*ib.*

CHARLESTOWN, a post-town in Cecil co. Maryland, near the head of Chesapeak bay; 6 miles E. N. E. from the mouth of Susquehannah River; 10 W. S. W. from Elkton, and 50 S. W. by W. from Philadelphia. Here are about 20 houses, chiefly inhabited by fishermen employed in the herring fishery. N. lat. 39. 34.—*ib.*

CHARLESTOWN, a township in Montgomery co. New-York, on the S. side of Mohawk river, about 32 miles W. of Schenectady. By the state census of 1796, 456 of the inhabitants are electors.—*ib.*

CHARLESTOWN, a township in Mason co. Kentucky; situated on the Ohio at the mouth of Lauren's creek. It contains but few houses, and is 6 miles N. of Washington, and 60 N. E. of Lexington. N. lat. 38. 43. —*ib.*

CHARLESTOWN, a township in Chester co. Pennsylvania.—*ib.*

CHARLESTOWN, a post-town in Cheshire co. New-Hampshire, on the E. side of Connecticut River 30 miles S. of Dartmouth College; upwards of 70 N. of Northampton, 116 N. of W. of Boston, 80 W. by N. of Portsmouth, and 341 N. N. E. of Philadelphia. It was incorporated in 1753, and contains 90 or 100 houses, a Congregational church, a court-house and an academy. The road from Boston to Quebec passes through this town. N. lat. 43. 16. W. long. 72. 19. A small internal trade is carried on here.—*ib.*

CHARLESTOWN, the principal town in Middlesex co. Massachusetts, called *Mishawun* by the aboriginal inhabitants, lies N. of Boston, with which it is connected by Charles-River Bridge. The town, properly so called, is built on a peninsula, formed by Mystic River on the E. and a bay, setting up from Charles-River, on the W. It is very advantageously situated for health, navigation, trade, and manufactures of almost all the various kinds. A dam across the mouth of the bay, which sets up from Charles-River, would afford a great number of mill-seats for manufactures. Bunker's, Breed's, and Cobble (now Barrell's) hills, are celebrated in the history of the American Revolution. The second hill has upon its summit a monument erected to the memory of major gen. Warren, near the spot where he fell, among the first sacrifices to American liberty. The brow of the hill begins to be ornamented with elegant houses. All these hills afford elegant and delightful prospects of Boston, and its charmingly variegated harbor, of Cambridge and its colleges, and of an extensive tract of highly cultivated country. It contains within the neck or parish about 250 houses, and about 2000 inhabitants. The only public buildings of consequence are a handsome Congregational church, with an elegant steeple and clock, and an alms-house, very commodious and pleasantly situated.

Before the destruction of this town by the British in 1775, several branches of manufactures were carried on to great advantage, some of which have been since revived; particularly the manufacture of pot and pearl ashes, ship-building, rum, leather in all its branches, silver, tin, brass, and pewter. Three rope-walks have lately been erected in this town, and the increase of its houses, population, trade, and navigation, have been very great within a few years past. This town is a port of entry in conjunction with Boston. At the head of the neck there is a bridge over Mystic River which connects Charlestown with Malden.—*ib.*

CHARLESTOWN, a village in Berkley co. Virginia, situated on the great road leading from Philadelphia to Winchester; 8 miles from Shepherdstown, and 20 from Winchester.

CHARLESTOWN, a township in Washington co. Rhode-Island state, having the Atlantic ocean on the southward, and separated from Richmond on the northward by Charles-river, a water of Pawcatuck. Some of its ponds empty into Pawcatuck River, others into the sea. It is 19 miles N. W. of Newport, and contains 2022 inhabitants, including 12 slaves.

A few years ago there were about 500 Indians in the state; the greater part of them resided in this township. They are peaceable and well disposed to government, and speak the English language.—*ib.*

CHARLESTOWN, the only town in the island of Nevis, one of the Caribbees, belonging to Great-Britain. In it are large houses and well furnished shops, and it is defended by Charles fort. In the parish of St John, on the S. side of the town, is a large spot of sulphureous ground, at the upper end of a deep chasm in the earth, commonly called Sulphur Gut, which is so hot as to be felt through the soles of one's shoes. A small hot river, called the Bath, is thought to proceed from the said gut; and after running half a mile, loses itself in the sands of the sea. Black-Rock pond, about a quarter of a mile N. from the town, is milk-warm, owing to the mixture of hot and cold springs, yet it yields excellent fish; particularly fine eels, silver fish, and slim-guts. A prodigious piece of Nevis mountain falling down in an earthquake, several years ago, left a large vacuity, which is still to be seen. The altitude of this mountain, taken by a quadrant from Charlestown bay, is said to be a mile and a half perpendicular; and from the said bay to the top, four miles. The declivity from this mountain to the town is very steep half way, but afterwards easy of ascent. N. lat. 16. 55. W. long. 62. 42.—*ib.*

CHARLESTOWN, or *Oftins*, one of the four principal towns in the island of Barbadoes.—*ib.*

CHARLETON *Island*, or *Charles Island*, is situated at the bottom of James's bay, in New South Wales, on on the coast of Labrador, and yields a beautiful prospect, in spring, to those who are near it, after a voyage of 3 or 4 months in the most uncomfortable seas on the globe, and that by the vast mountains of ice in Hudson bay and straits. The whole island, spread with trees and branches, exhibits, as it were, a beautiful green tuft. The air even at the bottom of the bay, though in 51 degrees, a latitude nearer the sun than London, is excessively cold for nine months, and very hot the other three, except on the blowing of a N. W. wind. The soil on the E. side, as well as the W. bears all kinds of grain; and some fruits, gooseberries, strawberries, and dewberries, grow about Rupert's bay. N. lat. 52. 30. W. long. 82.—*ib.*

Charleton, a township in Saratoga co. New-York. By the state census of 1796, 268 of its inhabitants were electors.—*ib.*

Charleton, a township in Worcester co. Massachusetts, incorporated in 1754, and until then, formed the westerly part of Oxford. It is 60 miles S. W. of Boston, 15 S. W. of Worcester, and contains 1965 inhabitants. Quincbaugh River forms some of its rich intervale lands, and furnishes excellent mill seats for this, and many adjacent towns.—*ib.*

CHARLOTTE *Fort*, in S. Carolina, is situated on the point of land where Tugeloo and Broad rivers, uniting their waters, form Savannah River. According to Bartram, it is one mile below Fort James, Dartmouth. N. lat. 34. W. long. 82. 35.—*ib.*

Charlotte *Haven*, lies at the mouth of Charlotte River in E. Florida; having Carlos bay on the S. and Rock Point on the northward. N. lat. 27. W. long. 82. 40. Charlotte River is fed by Spiritu Santo Lagoon, which communicates, by Delaware River with Chatham or Punjo bay, which is 90 miles S. E. from Charlotte Haven.—*ib.*

Charlotte, a considerable township on the E. side of Lake Champlain, and the S. westernmost in Chittenden co. Vermont. Shelburne on the N. separates this town from Burlington. It contains 635 inhabitants. Split Rock, in Lake Champlain, lies off this town.

Charlotte *Co.* in Virginia, lies S. W. of Richmond, on the head waters of Staunton River, and contains 10,078 inhabitants, including 4,816 slaves. The court-house is 21 miles S. S. W. of Prince Edward court-house, and 379, about the same course, from Philadelphia.—*ib.*

Charlotteburg, a town in Brunswick co. N. Carolina. It stands on an island, and has an inlet and sound of the same name, a little S. of it.—*ib.*

Charlotte, or *Charlottesville*, a post-town in Salisbury district, N. Carolina, and chief town of Mecklenburg co. situated on Steel creek, which joins the Sugaw, and falls into Catabaw River about 10 miles N. of the S. Carolina boundary, and 44 S. of Salisbury. Here are about 40 houses, a court-house and gaol. —*ib.*

Charlottesville, the capital of Albemarle co. in Virginia, lies on the post road from Richmond to Danville, in Kentucky, 86 miles W. N. W. of the former, and 557 eastward of the latter, and 40 S. E. by E. of Staunton. It contains about 45 houses, a court-house and a goal, situated about half a mile N. from a water of Rivanna river.—*ib.*

Charlotte *Town*, the capital of the island of St John's, in the gulf of St Lawrence. Also, the name of a town on the S. W. side of the island of Dominica, in the W. Indies; and situated on the S. side of a deep bay.—*ib.*

CHARLOTIA, a town on the E. shore of St John's River, East Florida, where that river is about half a mile wide. It was founded by Den. Rolle, Esq. and is situated on a high bluff, 15 or 20 feet perpendicular from the river; and is in length half a mile, or more. The aborigines of America had a very great town in this place, as appears from the great tumuli and conical mounts of earth and shells, and other traces of a settlement which yet remain. The river, for near 12 miles above Charlotia, is divided into many channels by a number of islands.—*ib.*

CHARTRES, a fort which was built by the French, on the eastern side of the Mississippi, 3 miles northerly of *La Praire du Rocher*, or the Rock Meadows, and 12 miles northerly of St Genevieve, on the western side of that river. It was abandoned in 1772, being untenable by the constant washings of the Mississippi in high floods. The village southward of the fort was very inconsiderable in 1778. A mile above this is a village settled by 170 warriors of the Piorias and Mitchigamias tribes of Illinois Indians, who are idle and debauched.—*ib.*

CHATHAM, a maritime township in Barnstable co. Massachusetts, situated on the exterior extremity of the elbow of Cape Cod, conveniently for the fishery; in which they have usually about 40 vessels employed. It has 1140 inhabitants, and lies 95 miles S. E. of Boston.—*ib.*

Chatham, a township in Grafton co. New-Hampshire. It was incorporated in 1767, and in 1790 contained 58 inhabitants.—*ib.*

Chatham, a flourishing township in Middlesex co. Connecticut, on the eastern bank of Connecticut River and opposite Middleton city. It was a part of the township of Middleton till 1767.—*ib.*

Chatham, a township in Essex co. N. Jersey, is situated on Passaic River, 13 miles W. of Elizabethtown, and nearly the same from Newark.—*ib.*

Chatham, a township in Columbia co. New-York. By the state census of 1796, 380 of its inhabitants were electors.—*ib.*

Chatham *Co.* in Hillsborough district, N. Carolina, about the centre of the state. It contains 9221 inhabitants, of whom 1632 are slaves. Chief town, Pittsburg. The court-house is a few miles W. of Raleigh, on a branch of Cape Fear river.—*ib.*

Chatham, a town of S. Carolina, in Cheraws district, situated in Chesterfield co. on the W. side of Great Pedee River. Its situation, in a highly cultivated and rich country, and at the head of a navigable river, bids fair to render it a place of great importance. At present it has only about 30 houses, lately built.—*ib.*

Chatham *Co.* in the lower district of Georgia, lies in the N. E. corner of the state, having the Atlantic ocean E. and Savannah river N. E. It contains 10,769 inhabitants, including 8,201 slaves. The chief town is Savannah, the former capital of the state.—*ib.*

Chatham, or *Punjo bay*, a large bay on the W. side of the S. end of the promontory of E. Florida. It receives North and Delaware rivers.—*ib.*

CHATHAM *Houfe*, in the territory of the Hudfon bay company, N. lat. 55. 23. 40. W. long. from Greenwich 98.—*ib.*

CHATA-HATCHI, or *Hatchi*, is the largeft river which falls into St Rofe's bay in W. Florida. It is alfo called Pea river, and runs from N. E. entering the bottom of the bay through feveral mouths; but fo fhoal that only a fmall boat or canoe can pafs them. Mr Hutchins afcended this river about 25 leagues, where there was a fmall fettlement of Couffac Indians. The foil and timber on the banks of the river refemble very much thofe of Efcambia.

CHATAUCHE, or *Chatahuthe*, a river in Georgia. The northern part of Appalachicola river bears this name. It is about 30 rods wide, very rapid, and full of fhoals. The lands on its banks are light and fandy, and the clay of a bright red. The Lower Creeks are fettled in fcattering clans and villages from the head to the mouth of this river. Their huts and cabins, from the high colour of the clay, refemble clufters of new-burned brick kilns. The diftance from this river to the Talapoofe River is about 70 miles, by the war-path, which croffes at the falls, juft above the town of the Tuckabatches.—*ib.*

CHATAUGHQUE *Lake*, in Ontario co. New-York, is about 18 miles long, and 3 broad. Conewango River which runs a S. S. E. courfe, connects it with Alleghany River. This lake is conveniently fituated for a communication between lake Erie and the Ohio; there being water enough for boats from fort Franklin on the Alleghany to the N. W. corner of this lake; from thence there is a portage of 9 miles to Chataughque harbor on lake Erie, over ground capable of being made a good waggon road. This communication was once ufed by the French.—*ib.*

CHAUMETTE (Pierre Gafparine), though a man of talents and an author, would hardly have deferved a place in this work, did not his life and the manner of his death hold out an awful warning againft thofe principles which produced the overthrow of focial order in France.

He was a native of the town of Nevers, in the Orleanois; and as he rofe to the office of recorder in Paris, few men excited more attention in France for a time, or had a more hateful tafk to perform, during the moft tragical part of the revolution, than Chaumette. He had been bred to the fea; but not relifhing that life, and failing to obtain expected preferment therein, he quitted it, and lived by the ufe of his pen, which he certainly knew how to manage more to his profit than the compafs. He could, however, fpeak better, and more fluently, than he could write. He had alfo been employed as a librarian and amanuenfis to a dignitary of the church, in the diocefe of Nivernois; but at the commencement of the troubles in France, he was actually a clerk to an attorney, and occafionally wrote for the newfpapers, as well as trifles for the ftage. He was one of the chief difciples of Camille Defmoulins, and among the firft who put the tri-coloured cockade in his hat juft before the taking of the Baftille. He greatly out-ran that apoftle in zeal for the new faith; for when Camille was compofing the firft number of his *Vieux Cordelier*, with the hope of tranquillifing the overheated imaginations of the leaders of that great event, and tempering the public rage againft the real or fuppofed enemies of the new order of things, Chaumette was ftill farther inflaming it, and directing it in vengeance againft particular individuals. It was Chaumette that inftigated the commune of Paris to demand the trial of the queen, and he was of the committee which prepared the charges and regulated the evidence againft that ill-fated woman. He was himfelf a witnefs too againft her at the revolutionary tribunal, and undertook to reprimand M. la Tour Dupin, lately war minifter to Louis XVI. for not expofing thofe parts of Antoinette's conduct, which, it was infifted on, he was privy to or acquainted with.

The moft infamous part of Chaumette's conduct on that occafion was his accufing the queen of an inceftuous connection with her fon. Even the horrid tribunal was fhocked at this infinuation, of which the author became inftantly the object of almoft univerfal abhorrence; and Robefpierre himfelf, under whofe aufpices Chaumette was believed to act, grew outrageous when he was told of a charge fo fcandaloufly abfurd. "The fool (exclaimed he) was it not enough that he had proved her a Meffalina, but he muft make her an Agrippina too!" Of proof indeed there was not much; and the fevereft enemy of the beautiful Antoinette, if his mind be not wholly warped by prejudice, will admit, that by thefe brethren in iniquity fhe was murdered under the form of a revolutionary trial.

Robefpierre had fenfe enough to fee that this abominable conduct of Chaumette would hurt the caufe in which they were both embarked; and for that reafon he never forgave him, though he allowed the zeal to continue to operate on inferior objects, till it whelmed the zealot himfelf in ruin. Chaumette had credit now with none but the very *fcum* of the revolution; and fuch recrementitious matter will always be thrown off in national ebullitions of this kind.

Robefpierre was at this time in the very zenith of his power, yet Chaumette moved fuch a propofition in the full commune, as gave reafon to many to believe that he would fet up as his rival in the city. This daring motion was for uniting all the heads of the 48 fections of Paris in one council; a meafure that would have fuperfeded the force of the legiflature itfelf, if not its authority. This was a project, conceived in common with the famous Hebert, Momora, and Mazuel, and would have been aided in its execution by the daring Roufin, who at that time commanded a body of the *armeé revolutionaire*.

How far Robefpierre was apprifed of or approved the fcheme, does not appear; many fhrewd obfervers of what was paffing, feemed fatisfied that it was to have been only a prelude "to the fwelling act" that was to follow, when the hero of the piece was to have been in full play. The majority of the convention faw through the veil which covered the workings of the plot, and anticipated their own danger, fhould it be carried into effect. They, therefore, without lofs of time, annulled the proceedings already had in it, and declared all to be rebels who fhould perfift therein. Chaumette appeared to put a good face on the correction. He told the commune, on its next meeting, that his propofition muft be relinquifhed; for that the convention, with a voice paternal, though fevere, had ftamped with nullity

nullity their former resolution, and that it became them, like dutiful children, to submit. Hebert, Momora, and Mazuel, were soon after accused as traitors, imprisoned, tried, and executed; but Chaumette survived a short time longer, as his enemies thought it safer to wear away by degrees the remaining popular partiality for him, before he should be struck at. He was taken up, however, on the 26th of March 1794, under a charge of conspiring, with the foregoing men, against the government, and guillotined on the 13th of April following, without the smallest effort on the part of Robespierre, to save him. Such is the gratitude and such the friendship of minds filled with universal philanthropy and the rights of man! That Chaumette and Robespierre were closely linked together, is known to all who are not strangers to the transactions of that time; but when the latter had risen to dictatorial power on the shoulders of the former, he kicked him, like an useless scaffold, from under his feet.

Chaumette said at the place of execution, that the revolution had inflamed his imagination, and at times intoxicated his brain, from the too free gratification of his vengeance for the personal injuries he had received. He said also, that three instances had come to light of his aristocratic and inveterate enemies attempting his life; and that a desire of reprisal, in which he conceived the safety of the commonwealth in a measure involved, made him seek all occasions for arrogating power; but that he never cherished an idea of possessing any permanent authority, not even of a secondary or subordinate nature. That the revolution intoxicated his brain, is doubtless true; but that he never aspired to permanent authority, is an infamous falsehood.

CHAUSETRAPPES. See *Crow's Feet*, Encycl.

CHEAT *River*, rises in Randolph co. Virginia, and after pursuing a N. N. W. course, joins Monongahela River, 3 or 4 miles within the Pennsylvania line. It is 200 yards wide at its mouth, and 100 yards at the Dunkards settlement, 50 miles higher, and is navigable for boats except in dry seasons. There is a portage of 37 miles from this River to the Potowmack at the mouth of Savage river.—*Morse*.

CHEGOMEGAN, a point of land about 60 miles in length, on the S. side of lake Superior. About 100 miles W. of this cape, a considerable River falls into the lake; upon its banks abundance of virgin copper is found.—*ib*.

CHELMSFORD, a township in Middlesex co. Massachusetts, situated on the S. side of Merrimack River 26 miles N. westerly from Boston, and contains 1144 inhabitants. There is an ingeniously constructed bridge over the River at Pawtucket Falls, which connects this town with Dracut. The route of the Middlesex canal, designed to connect the waters of Merrimack with those of Boston harbor, will be southerly through the E. part of Chelmsford.—*ib*.

CHELSEA, called by the ancient natives *Winnisimet*, a town in Suffolk co. Massachusetts, containing 472 inhabitants. Before its incorporation, in 1738, it was a ward of the town of Boston. It is situated northeasterly of the metropolis, and separated from it by the ferry across the harbor, called Winnisimet.—*ib*.

CHELSEA, a township in Orange co. Vermont, having 239 inhabitants.—*ib*.

CHELSEA, the name of a parish in the city of Norwich (Connecticut) called the Landing, situated at the head of the river Thames, 14 miles N. of New-London, on a point of land formed by the junction of Shetucket and Norwich, or Little rivers, whose united waters constitute the Thames. It is a busy, commercial, thriving, romantic, and agreeable place, of about 150 houses, ascending one above another in tiers, on artificial foundations, on the south point of a high, rocky hill.—*ib*.

CHEMIN DES RONDS, in fortification, the way of the rounds, or a space between the rampart and the low parapet under it, for the rounds to go about it.

CHEMISTRY,

1 Definition. IS a science, the object of which is to ascertain the ingredients that enter into the composition of bodies, to examine the nature of these ingredients, the manner in which they combine, and the properties resulting from their combination.

As an art, it has been in some measure coeval with the human race; for many of the most important branches of manufactures could not have been conducted without at least some knowledge of chemical combinations. As a science, it can hardly be dated farther back than the middle of the 17th century; but since that time it has advanced with a rapidity altogether unprecedented in the annals of philosophy. Newton laid its foundation; and since his days an almost incredible number of the most distinguished names in Europe have enlisted under its banners. So rapid has this progress been, that though the article CHEMISTRY in the *Encyclopædia* was written only about ten years ago, the language and reasoning of chemistry have been so greatly improved, and the number of facts have accumulated so much, that we find ourselves under the necessity of tracing over again the very elements of the science.

2 Importance of chemistry. Indeed, if we consider the importance of chemistry, we shall not be so much surprised at the ardour with which it has been cultivated. As a science, it is intimately connected with all the phenomena of nature; the causes of rain, snow, hail, dew, wind, earthquakes; even the changes of the seasons can never be explored with any chance of success while we are ignorant of chemistry; and the vegetation of plants, and some of the most important functions of animals, have received all their illustration from the same source. No study can give us more exalted ideas of the wisdom and goodness of the Great First Cause than this, which shews us everywhere the most astonishing effects produced by the most simple though adequate means, and displays to our view the great care which has every where been taken to secure the comfort and happiness of every living creature. As an art, it is intimately connected with

Oxygen. with all our manufactures: The glass-blower, the potter, the smith, and every other worker in metals, the tanner, the soap-maker, the dyer, the bleacher, are really practical chemists; and the most essential improvements have been introduced into all these arts by the progress which chemistry has made as a science. Agriculture can only be improved rationally, and certainly by calling in the assistance of chemistry; and the advantages which medicine has derived from the same source are too obvious to be pointed out.

3 Arrangement. It is evident from the definition of chemistry that it must consist in a history of the simple substances which enter into the composition of bodies, in an investigation of the manner in which these substances combine, and in a description of the properties of the compounds which they form. And this is the arrangement which we mean to pursue; reserving to ourselves, however, the liberty of deviating a little from it, whenever it may appear necessary for the sake of perspicuity. All our classifications are in fact artificial; nature does not know them, and will not submit to them. They are useful, however, as they enable us to learn a science sooner, and to remember it better; but if we mean to derive these advantages from them, we must renounce a rigid adherence to arbitrary definitions, which nature disclaims. Oxygen.

We shall begin by an account of the simplest bodies, and proceed gradually to those which are more compound. By *simple bodies*, we do not mean what the ancient philosophers called the *elements of bodies*, but merely substances, which have not yet been decompounded. Very possibly the bodies which we reckon simple may be real compounds; but till this has actually been proved, we have no right to suppose it. Were we acquainted with all the elements of bodies, and with all the combinations of which these elements are capable, the science of chemistry would be as perfect as possible; but at present this is very far from being the case.

We shall divide this article into four parts. The *first* part shall treat of those bodies which are at present considered as simple; the *second*, of those bodies which are formed by the union of two simple bodies, and which for want of a better word we shall call *compound bodies*; the *third*, of those bodies which are formed by the union of two compound bodies; and the *fourth*, of bodies such as they are presented to us by nature in the mineral, vegetable, and animal kingdoms.

PART I. OF SIMPLE BODIES. (1)

4 Classes of simple bodies. ALL the bodies which are at present reckoned simple, because they have never been decompounded, may be reduced into six classes.

1. Oxygen,	4. Earths,
2. Simple combustibles,	5. Caloric,
3. Metals,	6. Light.

These shall form the subjects of the six following chapters.

CHAP. I. *Of* OXYGEN.

Plate XVIII. TAKE a quantity of nitre, or saltpetre as it is also called, and put it into a gun barrel A (fig. 1.), the touch-hole of which has been previously closed up with

5 Method of procuring oxygen. metal. This barrel is to be bent in such a manner, that while the close end, in which the nitre lies, is put into the fire E, the open end may be plunged below the surface of the water, with which the vessel B is filled. At the same time, the glass jar, D, previously filled with water, is placed on the support C, lying at the bottom of the vessel of water B, so as to be exactly over the open end of the gun barrel A. As soon as the nitre becomes hot, it emits a quantity of air, which issuing from the end of the gun barrel, ascends to the top of the glass jar D, and gradually displaces all the water. The glass jar D then appears to be empty, but is in fact filled with air. It may then be removed in the following manner; Slide it away a little from the gun barrel and the support, and then dipping any flat dish into the water below it, raise it on it, and bear it away. The dish must be allowed to retain a quantity of water in it, (see fig. 2.) Another jar may then be filled with air in the same manner; and this process may be continued either till the nitre ceases to give out air, or till as many jarfuls have been obtained as are required. This method of obtaining and confining air was first invented by Dr Mayow, and afterwards much improved by Dr Hales. All the airs obtained by this or any other process, or, to speak more properly, all the airs differing from the air of the atmosphere, have, in order to distinguish them from it, been called *gases*, and this name we shall afterwards employ.

The gas which we have obtained by the above process was discovered by Dr Priestley on the 1st of August 1774, and called by him *dephlogisticated air*. Mr Scheele of Sweden discovered it in 1775, without any previous knowledge of what Dr Priestley had done: he gave it the name of *empyreal air*. Condorcet, so conspicuous during the French revolution, gave it first the name of *vital air*; and Mr Lavoisier afterwards called it *oxygen gas*; a name which is now generally received, and which we shall adopt. 6 Discovered by Priestley and Scheele.

Oxygen gas may be obtained likewise by the following process:

D (in fig. 3.) represents a wooden trough, the inside of which is lined with lead or tinned copper. AB is a shelf running along the inside of it, about three inches from the top. C is the cavity of the trough, which ought to be a foot deep. It is to be filled with water at least an inch above the shelf AB In the body of the trough, which may be called the cistern, the jars destined to hold gas are to be filled with water, and then to be lifted, and placed inverted upon the shelf at B, with 7 Another method.

(1) The writer of the notes signed T. P. S. considers himself responsible for no other errors contained in this system of chemistry than those contained in his own notes. From a number of circumstances he was under the necessity of reading this work so cursorily, that probably many deductions which on more mature consideration he might have objected to, may have passed unnoticed. T. P. S.

Oxygen. with their edges a little over it. This trough, which was invented by Dr Prieſtley, has been called by the French chemiſts the *pneumato chemical*, or ſimply *pneumatic* apparatus, and is extremely uſeful in all experiments in which gaſes are concerned. Into the glaſs veſſel E put a quantity of the black oxyd (A) of manganeſe in powder, and pour over it as much of that liquid which in commerce is called *oil of vitriol*, and in chemiſtry *ſulphuric acid*, as will ſomewhat more than cover it. Then inſert into the mouth of the veſſel the glaſs tube F, ſo cloſely that no air can eſcape except through the tube. This may be done by covering the joining with a paſte made of wheat flour and water, or any other *lute*, as ſubſtances uſed for ſimilar purpoſes are called. The end of the tube C is then to be plunged into the pneumatic apparatus D and the jar G, previouſly filled with water, to be placed over it on the ſhelf. The whole apparatus being fixed in that ſituation, the glaſs veſſel E is to be heated by means of a lamp or a candle. A great quantity of oxygen gas ruſhes along the tube F, and fills the jar G. As ſoon as the jar is filled, it may be ſlid to another part of the ſhelf, and other jars ſubſtituted in its place, till as much gas has been obtained as is wanted.

8 Properties of oxygen.

1. Oxygen gas is colourleſs, and inviſible like common air. Like it too, it is elaſtic, and capable of indefinite expanſion and compreſſion.

9 Supports flame,

2. If a lighted taper be let down into a jar of oxygen gas, it burns with ſuch ſplendor that the eye can ſcarcely bear the glare of light, and at the ſame time produces a much greater heat than when burning in common air. It is well known that a candle put into a well cloſed jar filled with common air is extinguiſhed in a few ſeconds. This is the caſe alſo with a candle incloſed in oxygen gas; but it burns much longer in an equal quantity of that gas than of common air.

10 And life.

3. It was proved long ago by Boyle, that animals cannot live without air, and by Mayow that they cannot breathe the ſame air for any length of time without ſuffocation. Dr Prieſtley and ſeveral other philoſophers have ſhewn us, that animals live much longer in the ſame quantity of oxygen gas than of common air. Count Morozzo placed a number of ſparrows, one after another, in a glaſs bell filled with common air, and inverted over water.

	H.	M.
The firſt ſparrow lived	3	0
The ſecond	0	3
The third	0	1

He filled the ſame glaſs with oxygen gas, and repeated the experiment.

	H.	M.
The firſt ſparrow lived	5	23
The ſecond	2	10
The third	1	30
The fourth	1	10
The fifth	0	30
The ſixth	0	47
The ſeventh	0	27
The eighth	0	30
The ninth	0	22
The tenth	0	21

He then put in two together; the one died in 20 minutes, but the other lived an hour longer.

11 Exiſts in the atmoſphere.

4. Atmoſpherical air contains about 27 parts in the hundred of oxygen gas. This was firſt diſcovered by Scheele. It has been proved by a great number of experiments, that no ſubſtance will burn in common air previouſly deprived of all the oxygen gas which it contained; but combuſtibles burn with great ſplendor in oxygen gas, or in other gaſes to which oxygen gas has been added. Oxygen gas, then, is abſolutely neceſſary for combuſtion.

5. It has been proved alſo, by many experiments, that no breathing animal can live for a moment in any air or gas which does not contain oxygen mixed with it. Oxygen gas then is abſolutely neceſſary for reſpiration.

6. When ſubſtances are burnt in oxygen gas, or in any other gas containing oxygen, if the air be examined after the combuſtion, a great part of the oxygen will be found to have diſappeared. If charcoal, for inſtance, be burnt in oxygen gas, there will be found, inſtead of part of the oxygen, another very different gas, known by the name of carbonic acid gas. Exactly the ſame thing takes place when air is reſpired by animals; part of the oxygen gas diſappears, and its place is occupied by ſubſtances poſſeſſed of very different properties. Oxygen gas then undergoes ſome change during combuſtion, as well as the bodies which have been burnt; and the ſame obſervation applies alſo to reſpiration (B).

12 Its ſpecific gravity.

7. The ſpecific gravity of oxygen gas, as determined by Mr Kirwan*, is 0,00135, that of water being 1,0000, as is always the caſe when ſpecific gravity is mentioned abſolutely. It is therefore 740 times lighter than the ſame bulk of water. Its weight to atmoſpherical air is as 1103 to 1000: 116 cubic inches of oxygen gas weigh 39,03 grains troy, 116 cubic inches of common air, 35,38 grains.

* On *Phlogiſton*, ſect. i.

13 *Affinity* explained.

8. Oxygen is capable of combining with a great number of bodies, and forming compounds. As the combination of bodies is of the utmoſt importance in chemiſtry,

(A) This ſubſtance ſhall be afterwards deſcribed. It is now very well known in Britain, as it is in common uſe with bleachers and ſeveral other manufacturers.

(B) Mayow had in the laſt century made conſiderable progreſs towards the diſcovery of oxygen gas. He knew that only a part of the air ſupported combuſtion: This part he called *particulæ igneo aereæ*. He knew that this part was contained in nitre: Pars nitri aerea nihil aliud quam particulæ ejus igneo-aereæ eſt." He adds, "At non eſt eſtimandum pabulum igneo-aereum ipſum aerem eſſe, ſed tantum partem ejus majus activam ſubtilemque. Quippe lucerna vitro incluſa expirat cum tamen copia aeris ſatis ampla in eodem continetur." He knew alſo that it was this part of the air which was uſeful in reſpiration. After mentioning ſeveral experiments to prove this, he adds, "Ex dictis certo conſtat animalia reſpirando particulas quaſdam vitales eaſque elaſticas ab aere haurire." See his *Tractatus quinque Medico-Phyſici*, p. 12. and 106.—He knew alſo that this part of the air was neceſſary to combuſtion: "Et tamen certo conſtat, particulas nitro-aereas non minus quam ſulphureas ad ignem conflandum neceſſareas eſſe." *Ibid.* p. 26.

Oxygen.

miſtry, before proceeding farther we ſhall attempt to explain it. When common ſalt is thrown into a veſſel of pure water, it melts, and very ſoon ſpreads itſelf through the whole of the liquid, as any one may convince himſelf by the taſte. In this caſe the ſalt is combined with the water, and cannot afterwards be ſeparated by filtration or any other method merely mechanical. It may, however, by a very ſimple proceſs: Pour into the ſolution a quantity of ſpirit of wine and the whole of the ſalt inſtantly falls to the bottom.

Why did the ſalt diſſolve in water, and why did it fall to the bottom on pouring in ſpirit of wine? Theſe queſtions were firſt anſwered by Sir Iſaac Newton. There is a certain attraction between the particles of common ſalt and thoſe of water, which cauſes them to unite together whenever they are preſented to one another. There is an attraction alſo between the particles of water and of ſpirit of wine, which equally diſpoſes them to unite, and this attraction is greater than that between the water and ſalt; the water therefore leaves the ſalt to unite with the ſpirit of wine, and the ſalt, being now unſupported, falls to the ground by its gravity. This power, which diſpoſes the particles of different bodies to unite, was called by Newton *attraction*, by Bergman, *elective attraction*, and by many of the German and French chemiſts, *affinity*; and this laſt term we ſhall employ, becauſe the other two are rather general. All ſubſtances which are capable of combining together are ſaid to have an *affinity for* (c) each other: thoſe ſubſtances, on the contrary, which do not unite, are ſaid to have *no affinity* for each other. Thus there is no affinity between water and oil. It appears from the inſtance of the common ſalt and ſpirit of wine, that ſubſtances differ in the degree of their affinity for other ſubſtances, ſince the ſpirit of wine diſplaced the ſalt and united with the water. Spirit of wine therefore has a ſtronger affinity for water than common ſalt has.

In 1719 Geoffroi invented a method of repreſenting the different degrees of affinities in tables, which he called *tables of affinity*. His method conſiſted in placing the ſubſtances whoſe affinities were to be aſcertained at the top of a column, and the ſubſtances with which it united below it, each in the order of its affinity; the ſubſtance which had the ſtrongeſt affinity next it, and that which had the weakeſt fartheſt diſtant, and ſo of the reſt. According to this method, the affinity of water for ſpirit of wine and common ſalt would be marked as follows:

Water,
Spirit of wine,
Common ſalt,

This method has been univerſally adopted, and has contributed very much to the rapid progreſs of chemiſtry.

14
Affinities of oxygen.

We ſhall proceed therefore to give a table of the affinities of oxygen.

Oxygen,
Carbon,
Zinc,
Iron,
Manganeſe,
Hydrogen,
Azot,
Sulphur,
Phoſphorus,
Cobalt,
Nickel,
Lead,
Tin,
Phoſphorous acid,
Copper,
Biſmuth,
Antimony,
Mercury,
Silver,
Arſenic,
Sulphurous acid,
Oil,
Nitrous gas,
Gold,
White oxyd of arſenic,
Muriatic acid,
Oxyd of tin,
White oxyd of lead?
Nitrous acid,
White oxyd of manganeſe,
Water.

The reaſon of this order will appear when we treat of theſe various ſubſtances.

Oxygen
Sulphur.

Chap. II. *Of* Simple Combustible Bodies.

15
Five ſimple combuſtibles.

By *combuſtibles*, we mean ſubſtances capable of combuſtion; and by *ſimple combuſtibles*, bodies of that nature which have not yet been decompounded.(2) Theſe are only five in number, Sulphur, Phosphorus, Carbon, Hydrogen, and Azot. Were we to adhere ſtrictly to our definition indeed, we ſhould add all the metals; for they are alſo combuſtible, and have not yet been decompounded: But for the reaſons formerly given, we ſhall venture to deviate a little from ſtrict logic, and conſider them afterwards as a diſtinct claſs of ſubſtances.

Sect. I. *Of Sulphur.*

Sulphur, diſtinguiſhed alſo in Engliſh by the name of *brimſtone*, was known in the earlieſt ages. As it is found native in many parts of the world, it could not fail very ſoon to attract the attention of mankind. It was uſed by the ancients in medicine, and its fumes were employed in bleaching wool.*

Sulphur

* *Pliny*, lib. xxxv. c. 15.

(c) We are not certain that the phraſe *affinity for* is warranted by claſſical authority; we have ventured, however, to uſe it, becauſe, as the word *affinity* in this article ſignifies a ſpecies of attraction, we thought it would be more perſpicuous to put after it the prepoſition *for*, which uſually follows the word *attraction*, than *to* or *with*, which come after *affinity* when uſed in its ordinary acceptation.

(2) A more correct definition of combuſtibles, according to our *preſent* knowledge relative to this claſs of bodies, would be, a ſubſtance which has a ſtronger affinity for oxygen than *light* and *caloric* have. T. P. S.

Sulphur.

16
Properties of sulphur.

Sulphur is a hard brittle ſubſtance, commonly of a yellow colour, without any ſmell, and of a weak though perceptible taſte.

It is a non-conductor of electricity, and of courſe becomes electric by friction.

If a conſiderable piece of ſulphur be expoſed to a ſudden though gentle heat, by holding it in the hand, for inſtance, it breaks to pieces with a crackling noiſe†.

† *Fourcroy.*

Its ſpecific gravity is 1,990.

When heated to the temperature of 185° of Fahrenheit, it melts and becomes very fluid. If the temperature be ſtill farther increaſed, the fluidity diminiſhes; but when the ſulphur is then carried from the fire and allowed to cool, it becomes as fluid as ever before it congeals‡.

‡ *Dr Black.*

When ſulphur is heated to the temperature of 170°, it riſes up in the form of a fine powder, which may be eaſily collected in a proper veſſel. This powder is called *flowers of ſulphur.* When ſubſtances fly off in this manner on the application of a moderate heat, they are called *vola'ile;* and the proceſs itſelf, by which they are raiſed, is called *volatilization.*

17
Flowers of ſulphur.

Sulphur undergoes no change by being allowed to remain expoſed to the open air.

When thrown into water, it does not melt, as common ſalt does, but falls to the bottom, and remains there unchanged; it is therefore *inſoluble* in water. If, however, it be poured, while in a ſtate of fuſion, into water, it aſſumes a red colour, and retains ſuch a degree of ſoftneſs, that it may be kneaded between the fingers; but it loſes this property in a few days*.

* *Fourcroy.*

18
Sulphur capable of cryſtallizing.

There are a great many bodies which, after being diſſolved in water or melted by heat, are capable of aſſuming certain regular figures. If a quantity of common ſalt, for inſtance, be diſſolved in water, and that fluid, by the application of a moderate heat, be made to fly off in the form of ſteam; or, in other words, if the water be ſlowly *evaporated,* the ſalt will fall to the bottom of the veſſel in cubes. Theſe regular figures are called *cryſtals.* Now ſulphur is capable of cryſtallizing. If it be melted, and as ſoon as its ſurface begins to congeal, the liquid ſulphur beneath be poured out, the internal cavity will exhibit long needle-ſhaped cryſtals of an octahedral figure. This method of cryſtallizing ſulphur was contrived by Rouelle.

19
Converted by combuſtion into an acid.

When ſulphur is heated to the temperature of 302° in the open air, it takes fire ſpontaneouſly, and burns with a pale blue flame, and at the ſame time emits a great quantity of fumes of a very ſtrong ſuffocating odour. When heated to the temperature of 570°, or a little higher, it burns with a bright white flame, and at the ſame time emits a vaſt quantity of fumes. If the heat be continued long enough, the ſulphur burns all away without leaving any aſhes or *reſiduum.* If the fumes be collected, they are found to conſiſt entirely of *ſulphuric acid.* By combuſtion, then, ſulphur is converted into an acid. This fact was known ſeveral centuries ago, but no intelligible explanation was given of it till the time of Stahl. That chemiſt undertook the taſk; and founded on his experiments a theory ſo exceedingly ingenious, and ſupported by ſuch a vaſt number of facts, that it was in a very ſhort time adopted with admiration by all the philoſophic world, and contributed not a little to raiſe chemiſtry to that rank among the ſciences from which the ridiculous pretenſions of the early chemiſts had excluded it.

20
Stahl's explanation of this

According to Stahl, there is only one ſubſtance in nature capable of combuſtion, which therefore he called Phlogiston; and all thoſe bodies which can be ſet on fire contain leſs or more of it. Combuſtion is merely the ſeparation of this ſubſtance. Thoſe bodies which contain none of it are of courſe incombuſtible. All combuſtibles, except thoſe which conſiſt of pure phlogiſton (if there be any ſuch), are compoſed of an incombuſtible body and phlogiſton united together. During combuſtion the phlogiſton flies off, and the incombuſtible body remains behind. Now when ſulphur is burnt, the ſubſtance which remains is ſulphuric acid, an incombuſtible body. Sulphur therefore is compoſed of ſulphuric acid and phlogiſton.

To eſtabliſh this theory completely, it was neceſſary to ſhew that ſulphur could be actually made by combining ſulphuric acid and phlogiſton; and this alſo Stahl undertook to perform. *Sulphat of potaſs* is a ſubſtance compoſed of ſulphuric acid and potaſs (D), and *charcoal* is a combuſtible body, and therefore, according to the theory of Stahl, contains phlogiſton: when burnt, it leaves a very inconſiderable reſiduum, and conſequently contains hardly any thing elſe than phlogiſton. He melted together in a crucible a mixture of *potaſs* and *ſulphat of potaſs,* ſtirred into it one-fourth part by weight of pounded charcoal, covered the crucible with another inverted over it, and applied a ſtrong heat to it. He then allowed it to cool, and examined its contents. The charcoal had diſappeared, and there only remained in the crucible a mixture of potaſs and ſulphur combined together, and of a darker colour than uſual, from the reſiduum of the charcoal. Now there were only three ſubſtances in the crucible at firſt, potaſs, ſulphuric acid, and charcoal: two of theſe have diſappeared, and *ſulphur* has been found in their place. Sulphur then muſt have been formed by the combination of theſe two. But charcoal conſiſts of phlogiſton and a very ſmall reſiduum, which is ſtill found in the crucible. The ſulphur then muſt have been formed by the combination of ſulphuric acid and phlogiſton. This ſimple and luminous explanation appeared ſo ſatisfactory, that the compoſition of ſulphur was long conſidered as one of the beſt demonſtrated truths in chemiſtry.

21
Unſatisfactory.

There are two facts, however, which Stahl either did not know or did not ſufficiently attend to, neither of which were accounted for by his theory. The firſt is, that ſulphur will not burn if air be completely excluded; the ſecond, that ſulphuric acid is heavier than the ſulphur from which it was produced.

To account for theſe, or facts ſimilar to theſe, ſucceeding chemiſts refined upon the theory of Stahl, deprived his phlogiſton of *gravity,* and even aſſigned it a principle of *levity.* Still, however, the neceſſity of the contact of air remained unexplained. At laſt Mr Lavoiſier, who had already diſtinguiſhed himſelf by the extenſiveneſs of his views, the accuracy of his experiments, and

(D) The nature of *potaſs* ſhall afterwards be explained. It is the *potaſh* well known in commerce in a ſtate of purity.

Sulphur.

and the precifion of his reafoning, undertook the examination of this fubject, and his experiments were publifhed in the Memoirs of the Academy of Sciences for 1777. He put a quantity of fulphur into a large glafs veffel filled with air, which he inverted into another veffel containing mercury, and then fet fire to the fulphur by means of a burning glafs. It emitted a blue flame, and gave out thick vapours, but was very foon extinguifhed, and could not be again kindled. There was, however, a little fulphuric acid formed, which was a good deal heavier than the fulphur which had difappeared; there was alfo a diminution in the air of the veffel proportional to this increafe of weight. The fulphur, therefore, during its converfion into an acid, muft have abforbed part of the air. He then put a quantity of fulphuret of iron, which confifts of fulphur and iron combined together, into a glafs veffel full of air, which he inverted over water (E). The quantity of air in the veffel continued diminifhing for eighteen days, as was evident from the afcent of the water to occupy the fpace which it had left; but after that period no farther diminution took place. On examining the fulphuret, it was found fomewhat heavier than when firft introduced into the veffel, and the air of the veffel wanted precifely the fame weight. Now this air had loft all its oxygen; all the oxygen of the air in the veffel muft therefore have entered into the fulphuret. Part of the fulphur was converted into fulphuric acid; and as all the reft of the fulphuret was unchanged, the whole of the increafe of weight muft have been owing to fomething which had entered into that part of the fulphur which was converted into acid. This fomething we know was oxygen. Sulphuric acid therefore muft be compofed of fulphur and oxygen; for as the original weight of the whole contents of the veffel remained exactly the fame, there was not the fmalleft reafon to fuppofe that any fubftance had left the fulphur.

22 Real explanation by Lavoifier.

It is impoffible, then, that fulphur can be compofed of fulphuric acid and phlogifton, as Stahl fuppofed; fince fulphur itfelf enters as a part into the compofition of that acid. There muft therefore have been fome want of accuracy in the experiment by which Stahl proved the compofition of fulphur, or at leaft fome fallacy in his reafonings; for it is impoffible that two contradictory facts can both be true. Upon examining the potafs and fulphur produced by Stahl's experiment, we find them to be confiderably lighter than the charcoal, fulphuric acid, and potafs originally employed. Something therefore has made its efcape during the application of the heat. And if the experiment be conducted in a clofe veffel, with a pneumatic apparatus attached to it, a quantity of gas will be obtained exactly equal to the weight which the fubftances operated on have loft; and this weight confiderably exceeds that of all the charcoal employed. This gas is *carbonic acid gas*, which is compofed of charcoal and oxygen, as will afterwards appear. We now perceive what paffes in this experiment: Charcoal has a ftronger affinity for oxygen at a high temperature than fulphur has. When charcoal therefore is prefented to fulphuric acid in that temperature, the oxygen of the acid combines with it, they fly off in the form of carbonic acid gas, and the fulphur is left behind.

Sulphur ‖ Phofphorus

The combuftion of fulphur, then, is nothing elfe than the act of its combination with oxygen; and, for any thing which we know to the contrary, it is a fimple fubftance.

23 Affinities of fulphur.

The affinities of fulphur, according to Bergman, are as follows:

Lead,
Tin,
Silver,
Mercury,
Arfenic,
Antimony,
Iron,
Fixed alkalies,
Ammonia,
Barytes,
Lime,
Magnefia,
Phofphorus?
Oils,
Ether,
Alcohol.

Sect. II. *Of Phofphorus.*

24 Production of phofphorus.

Let a quantity of bones be burnt, or, as it is termed in chemiftry, *calcined*, till they ceafe to fmoke, or to give out any odour, and let them afterwards be reduced to a fine powder. Put this powder into a glafs veffel, and pour fulphuric acid on it by little at a time, till farther additions do not caufe any extrication of air bubbles (F). Dilute the mixture with a good deal of water, agitate it well, and keep it hot for fome hours; then pafs it through a filtre. Evaporate the liquid flowly till a quantity of white powder falls to the bottom. This powder muft be feparated by filtration, and thrown away. The evaporation is then to be refumed; and whenever any white powder appears, the filtration muft be repeated in order to feparate it. During the whole procefs, what remains on the filtre muft be wafhed with pure water, and this water added to the liquor. The evaporation is to be continued till all the moifture difappears, and nothing but a dry mafs remains. Put this mafs into a crucible, and keep it melted in the fire till it ceafes to exhale fulphureous odours; then pour it out. When cold it affumes the appearance of a brittle glafs. Pound this glafs in a mortar, and mix it with one-third by weight of charcoal duft. Put this mixture into an earthen ware retort, and apply a receiver containing a little water. Put the retort into a fand bath, and increafe the fire till it becomes red hot. A fubftance then paffes into the receiver, which has the appearance of melted wax, and which congeals as it falls into the water of the receiver. This fubftance is *phofphorus*.

25 Its difcovery.

It was difcovered by Brandt, a chemift of Hamburgh, about the year 1667, while he was employed in attempting to extract from human urine, a liquid capable of converting filver into gold.*

* *Leibnitz, Melange de Berlin.*

Kunkel, another German chemift, hearing of the difcovery, was anxious to find out the procefs, and for that

(E) This experiment was firft made by Scheele, but with a different view.

(F) The copious emiffion of air bubbles is called in chemiftry *effervefcence*.

Phosphorus that purpose associated himself with a friend of his named Kraft. But the latter procured the secret from the discoverer; and expecting by means of it to acquire a fortune, refused to give any information to his associate. Vexed at this treachery, Kunkel resolved to attempt the discovery himself; and though he knew only that phosphorus was obtained from urine, prosecuted the inquiry with so much zeal, that he succeeded, and has been deservedly considered as one of the discoverers†.

† Stahl's Three Hundred Experiments.

Boyle likewise discovered phosphorus. Leibnitz indeed affirms that Kraft taught Boyle the whole process, and Kraft declared the same thing to Stahl. But surely the assertion of a dealer in secrets, and one who had deceived his own friend, on which the whole of this story is founded, cannot be put in competition with the affirmation of a man like Boyle, who was one of the honestest men, as well as greatest philosophers, of his age; and he positively assures us that he made the discovery, without being previously acquainted with the process‡.

‡ Boyle Abridged by Shaw, iii. 174.

Gahn, a Swedish chemist, discovered, in 1769, that phosphorus was contained in bones‖, and Scheele (G) very soon after invented a process for obtaining it from them. Phosphorus is now generally procured in that manner. The process described in the beginning of this section is that of the Dijon academicians: it differs from that of Scheele only in a single particular.

‖ Bergman's Notes on Scheffer.

26
Its properties.

Phosphorus, when pure, is of a clear, transparent, yellowish colour; but when kept some time in water, it becomes opaque, and then has a great resemblance to white wax. Its consistence is nearly that of wax: it may be cut with a knife, or twisted to pieces with the fingers. It is insoluble in water. Its specific gravity is 1,714.

It melts at the temperature of 99°*, and even at 67°* it gives out a white smoke, and is luminous in the dark; that is to say, it suffers a slow combustion: so that it can only be prevented from taking fire by keeping it in a very low temperature, or by allowing it to remain always plunged in water. If air be excluded, it evaporates at 219°, and boils at 554°†. When heated to 122° (H), it burns with a very bright flame, and gives out a great quantity of white smoke, which is luminous in the dark; at the same time it emits an odour which has some resemblance to that of garlic. It leaves no residuum; but when the white smoke is collected, it is found to be an *acid*. Stahl considered this acid as the muriatic (I). According to him, phosphorus was composed of muriatic acid and phlogiston, and the combustion of it was merely the separation of phlogiston. He even declared, that to make phosphorus, nothing more was necessary, than to combine muriatic acid and phlogiston; and that this composition was as easily accomplished as that of sulphur itself‡.

* Pelletier, Journal de Physique, xxxv. 380.

† Ibid. 381.

27
Converted by combustion

‡ Three Hundred Experiments.

These assertions gained implicit credit; and the composition and nature of phosphorus were considered as completely understood, till Margraf of Berlin published his experiments in the year 1743. That great man, one of those illustrious philosophers who have contributed so much to the rapid increase of the science, distinguished equally for the ingenuity of his experiments and the clearness of his reasoning, attempted to produce phosphorus by combining together phlogiston and muriatic acid; but though he varied his process a thousand ways, presented the acid in many different states, and employed a variety of substances to furnish phlogiston, all his attempts failed, and he was obliged to give up the combination as impracticable. On examining the acid produced during the combustion of phosphorus, he found that its properties were very different from those of muriatic acid. It was therefore a distinct substance. The name of *phosphoric acid* was given to it; and it was concluded that phosphorus was composed of this acid united to phlogiston.

28
Into phosphoric acid,

But it was observed in 1772 by Morveau*, that phosphoric acid was heavier than the phosphorus from which it was produced (K); and Boyle had long before shewn that phosphorus would not burn except when in contact with air. These facts were sufficient to prove the inaccuracy of the theory concerning the composition of phosphorus; but they remained themselves unaccounted for, till Lavoisier published those celebrated experiments, which threw so much light on the nature and composition of acids.

* Digress. Academ. p. 253.

He exhausted a glass globe of air by means of an air pump; and after weighing it accurately, he filled it with oxygen gas, and introduced into it 100 grains of phosphorus. The globe was furnished with a stop-cock, by which oxygen gas could be admitted at pleasure. He set fire to the phosphorus by means of a burning glass. The combustion was extremely rapid, accompanied by a bright flame and much heat. Large quantities of white flakes attached themselves to the inner surface of the globe, and rendered it opaque; and these at last became so abundant, that notwithstanding the constant supply of oxygen gas, the phosphorus was extinguished. The globe, after being allowed to cool, was again weighed before it was opened. The quantity of oxygen employed during the experiment was ascertained, and the phosphorus, which still remained unchanged, accurately weighed. The white flakes, which were nothing else than pure phosphoric acid, were found exactly equal to the weights of the phosphorus and oxygen which had disappeared during the process. Phosphoric acid therefore must have been formed by the combination of these two bodies; for the absolute weight of all the substances together was the same before and after the process*. It is impossible then that phosphorus can be composed of phosphoric acid and phlogiston,

29
Which is phosphorus combined with oxygen.

* Lavoisier's Chemistry, Part I. chap. v.

(G) Crell, in his life of Scheele, informs us, that Scheele was himself the discoverer of the fact. This, he says, clearly appears from a printed letter of Scheele to Gahn, who was before looked upon as the discoverer. See *Crell's Annals*, English Transf. I. 17.

(H) Morveau, *Enc. Method. Chimie*, art. *Affinité*—According to Nicholson at 160°. See his *Translation of Chaptal.*

(I) This acid shall be afterwards described.

(K) The same observation had been made by Margraf, but no attention was paid to it.

Phosphorus || Carbon.

phlogiston, as phosphorus itself enters into the composition of that acid(L).

Thus the combustion of phosphorus like that of sulphur, is nothing else than its combination with oxygen: for during the process no new substance appears except the acid, accompanied indeed with much heat and light.

30 Phosphorus combines with sulphur.

Phosphorus combines readily with sulphur, as Margraf discovered during his experiments on phosphorus. This combination was afterwards examined by Mr Pelletier. The two substances are capable of being mixed in different proportions. Seventy-two grains of phosphorus and nine of sulphur, when heated in about four ounces of water, melt with a gentle heat. The compound remains fluid till it be cooled down to 77°, and then becomes solid. These substances were combined in the same manner in the following proportions:

72 Phosphor. 18 Sulphur	congeals at	59°
72 Phosphor. 36 Sulphur	at	50°
72 Phosphor. 72 Sulphur	at	41°
72 Phosphor. 216 Sulphur	at	99°

Phosphorus and sulphur may be combined also by melting them together without any water; but the combination takes place so rapidly that they are apt to rush out of the vessel if the heat be not exceedingly moderate.†

† Pelletier, *Journ. de Phys.* xxxv. 382.

Phosphorus is capable of combining also with many other bodies: the compounds produced are called *phosphurets*.

The affinities of phosphorus have not yet been ascertained.

Sect. III. *Of Carbon.*

If a piece of wood be put into a crucible, well covered with sand, and kept red hot for some time, it is converted into a black shining brittle substance, without either taste or smell, well known under the name of *charcoal*. This substance contains always mixed with it several earthy and saline particles. When freed from these impurities it is called *carbon*.

31 Properties of carbon.

Charcoal is insoluble in water; it is not affected (provided that all air be excluded) by the most violent heat which can be applied, excepting only that it is rendered much harder.

New made charcoal absorbs moisture with avidity. When heated to a certain temperature, it absorbs air copiously. La Metherie plunged a piece of burning charcoal into mercury, in order to extinguish it, and introduced it immediately after into a glass vessel filled with common air. The charcoal absorbed four times its bulk of air. On plunging the charcoal in water, one-fifth of this air was disengaged. This air, on being examined, was found to contain a much smaller quantity of oxygen than atmospherical air does. He extinguished another piece of charcoal in the same manner, and then introduced it into a vessel filled with oxygen gas. The quantity of oxygen gas absorbed amounted to eight times the bulk of the charcoal; a fourth part of it was disengaged on plunging the charcoal into water*. It appears from the experiments of Sennebier, that charcoal, when exposed to the atmosphere absorbs oxygen gas in preference to *azot*†, as the other portion of common air is called.

* *Journ. de Phys.* xxx. 309.
† *Ann. de Chim.* iv. 261.

When heated to the temperature of 370°‡, it takes fire, and provided it has been previously freed from the earths and salts which it generally contains, it burns without leaving any residuum. If this combustion be performed in close vessels filled with oxygen gas instead of common air, part of the charcoal and oxygen disappear, and in their room is found a particular gas exactly equal to them in weight. This gas has the properties of an acid, and is therefore called *carbonic acid gas*. Mr Lavoisier, to whom we are indebted for this discovery, ascertained, by a number of very accurate experiments, that this gas was composed of about 28 parts of carbon and 72 of oxygen||.

‡ *Morveau, Encycl. Method.* art. *Affinité.*

32 Converted into an acid.

|| *Mem. Acad.* 1781, p. 448.

33 Susceptible of crystallization.

Carbon is susceptible of crystallization. In that state it is called *diamond*. The figure of the diamond varies considerably; but most commonly it is a hexagonal prism terminated by a six-sided pyramid. When pure it is colourless and transparent. Its specific gravity is from 3,44 to 3,55. It is one of the hardest substances in nature; and as it is not affected by a considerable heat, it was for many ages considered as incombustible. Sir Isaac Newton, observing that combustibles refracted light more powerfully than other bodies, and that the diamond possessed this property in great perfection, suspected, from that circumstance, that it was capable of combustion.(3) This singular conjecture was verified in 1694 by the Florentine academicians, in the presence of Cosmo III. grand duke of Tuscany. By means of a burning-glass, they destroyed several diamonds. Francis I. emperor of Germany, afterwards witnessed the destruction of several more in the heat of a furnace. These experiments were repeated by Rouelle, Macquer, and D'Arcet, who proved that the diamond was not merely evaporated, but actually burnt, and that if air was excluded it underwent no change.

No attempt, however, was made to ascertain the product, till Lavoisier undertook a series of experiments for that purpose in 1772. He obtained *carbonic acid gas*. It might be concluded from these experiments, that the diamond contains carbon; but it was reserved for Mr Tennant to show that it consisted entirely of that substance.

Into

(L) The quantity of phosphorus consumed was 45 grains
The quantity of oxygen gas - - - 69,375

Weight of the Phosphoric acid produced 114,375

Phosphoric acid therefore is composed of 100 parts phosphorus, and 154 oxygen.

(3) It were to be wished that some person provided with the proper apparatus would experiment on the *refractive* power of the gases, and ascertain if, according to Newton's theory, it bears any relation to their affinity for oxygen. T. P. S.

Carbon.

34 When it forms *diamond.*

Into a tube of gold, having one end cloſed and a glaſs tube adapted to the other to collect the product, that gentleman put $2\frac{1}{2}$ grains of diamonds and a quarter of an ounce of nitre (M). This tube was heated ſlowly; the conſequence of which was, that great part of the nitric acid paſſed off before the diamond took fire, and by that means almoſt the whole of the carbonic acid formed during the combuſtion of the diamond remained in the potaſs, for which it has a ſtrong affinity. To aſcertain the quantity of this carbonic acid, he diſſolved the potaſs in water, and added to the ſolution another ſalt compoſed of muriatic acid and lime. Muriatic acid has a ſtronger affinity for potaſs than for lime; it therefore combines with the potaſs, and at the ſame time the lime and carbonic acid unite and fall to the bottom of the veſſel, becauſe they are nearly inſoluble in water. He decanted off the liquor, and put the lime which contained the carbonic acid gas into a glaſs globe, having a tube annexed to it. This globe and tube he then filled with mercury, and inverted into a veſſel containing the ſame fluid. The lime by that means occupied the very top of the tube. It now remained to ſeparate the carbonic acid from the lime, which may be done by mixing it with any acid, as almoſt every other acid has a ſtronger affinity for lime than carbonic acid has. Accordingly on introducing muriatic acid, 10,3 ounce meaſures of carbonic acid gas, or nearly 9,166 grains, were ſeparated. But, according to the experiments of Lavoiſier, this gas is compoſed of 72 parts of oxygen and 28 of carbon; 9,166 grains therefore contain 2,56 grains of carbon, which is almoſt preciſely the weight of the diamond conſumed. It follows, therefore, that it was compoſed of pure carbon.* The difficulty of burning the diamond is owing entirely to its hardneſs. Meſſrs Morveau and Tennant rendered common charcoal ſo hard by expoſing it for ſome time to a violent fire in cloſe veſſels, that it loſt much of its natural tendency to combuſtion, and endured even a red heat without catching fire.†

* *Phil. Tranſ.* 1797, p. 123.

† *Encycl. Method. Chimie. art.* Acier.

Charcoal poſſeſſes a number of ſingular properties, which render it of conſiderable importance. It is incapable of putrefying or rotting like wood, and is not therefore liable to decay through age. This property has been long known. It was cuſtomary among the ancients to *char* the outſide of thoſe ſtakes which were to be driven into the ground or placed in water, in order to preſerve the wood from ſpoiling. New made charcoal, by being rolled up in cloths which have contracted a diſagreeable odour, effectually deſtroys it. It takes away the bad taint from meat beginning to putrefy, by being boiled along with it. It is perhaps the beſt teeth powder known. Mr Lowitz of Peterſburgh has ſhown, that it may be uſed with advantage to purify a great variety of ſubſtances.

35 Carburets.

Carbon unites with a number of bodies, and forms with them compounds known by the name of *carburets*. Its affinities have not yet been aſcertained.

Sect. IV. *Of Hydrogen.*

Hydrogen.

36 Method of procuring hydrogen.

Put into a glaſs veſſel furniſhed with two mouths a quantity of freſh iron filings, quite free from ruſt. Lute into one of theſe mouths the end of a crooked glaſs tube. Inſert the other end of this tube below a glaſs jar filled with water, and inverted into a pneumatic apparatus. Then pour upon the iron filings a quantity of ſulphuric acid, diluted with twice its own weight of water, and cloſe up the mouth of the veſſel. Immediately the iron filings and acid effervеſce with violence, a vaſt quantity of gas is produced, which ruſhes through the tube and fills the jar. This gas is called *hydrogen gas*.(N)

It was obtained by Dr. Mayow and by Dr Hales from various ſubſtances, and had been known long before in mines under the name of the *fire damp*. Mr Cavendiſh * was the firſt who examined its properties with attention. They were afterwards more fully inveſtigated by Prieſtley, Scheele, and Fontana.

* *Phil. Tran.* 1766.

37 Its properties.

Hydrogen, like *air*, is inviſible and elaſtic, and capable of indefinite compreſſion and dilatation.

Its ſpecific gravity differs according to its purity. Kirwan found it 0,00010†; Lavoiſier 0,000094‡, or about 12 times lighter than common air.

† *On Phlogiſton*, ſect. 1ſt.

‡ *Lavoiſier's Chemiſtry, Appendix.*

All burning ſubſtances are immediately extinguiſhed by being plunged into this gas. It is incapable therefore of ſupporting combuſtion.

Animals, when they are obliged to breathe it, die almoſt inſtantaneouſly. Scheele indeed found that he could breathe it for ſome time without inconvenience ‡; but Fontana, who repeated the experiment, diſcovered that this was owing to the quantity of common air contained in the lungs when he began to breathe; for on expiring as ſtrongly as poſſible before drawing in the hydrogen gas, he could only make three reſpirations, and even theſe three produced extreme feebleneſs and oppreſſion about the breaſt §.

‡ *Scheele on Fire.*

§ *Jour. de Phyſ.* xv. 99.

If a phial be filled with hydrogen gas, and a lighted candle be brought to its mouth, the gas will take fire, and burn gradually till it is all conſumed. If hydrogen and oxygen gas be mixed together and kindled, they burn inſtantaneouſly, and produce an exploſion like gunpowder. The ſame effect follows when a mixture of hydrogen gas and atmoſpherical air is kindled, but the exploſion is leſs violent. Hydrogen gas will not burn except in contact with oxygen gas, nor will it burn even in contact with oxygen gas, unleſs a red heat be applied to it. If 85 parts by weight of oxygen gas, and 15 of hydrogen gas, be mixed together, and ſet on fire in a cloſe veſſel, they diſappear, and in their place there is found a quantity of water exactly equal to them in weight. This water muſt be compoſed of theſe two gaſes; for it did not previouſly exiſt in the veſſel, and no other ſubſtance except the gaſes was introduced. Water then is compoſed of oxygen and hydrogen; and the combuſtion of hydrogen

38 Compoſition of water.

(M) Nitre is compoſed of potaſs and nitric acid; and nitric acid contains a great quantity of oxygen, which is eaſily ſeparated by heat. Diamond, when mixed with nitre, burns at a much lower heat than by any other proceſs.

(N) It was formerly called *inflammable air*, and by ſome chemiſts *phlogiſton*.

gen is nothing elſe but the act of its combination with oxygen (o).

It had been ſuppoſed, in conſequence of the experiments of Dr Prieſtley and ſeveral other philoſophers, that when hydrogen gas was allowed to remain in contact with water, it was gradually decompoſed, and converted into another gas; but Mr de Morveau,* Mr Haſſenfratz,† and Mr Libes,‡ have ſhewn, that it undergoes no change, provided ſufficient care be taken to exclude every other gas.

* *Encycl. Method. Chim.* i. 754
† *Ann. de Chim.* i. 92
‡ *Jour. de Phyſ.* xxxvi. 412.

Hydrogen gas diſſolves ſulphur, phoſphorus, and carbon. The compounds are called *ſulphurated*, *phoſphorated*, and *carbonated hydrogen gas*.

39 Compounds of hydrogen gas.

1. Sulphurated hydrogen gas was firſt examined with attention by Scheele, who, together with Bergman, diſcovered many of its properties. Mr Kirwan likewiſe publiſhed a very valuable paper on the ſame ſubject. If equal parts of ſulphur and potaſs be melted together in a covered crucible, they combine together, and form a compound known by the name of *ſulphuret of potaſs*, but formerly called, from its red colour, *hepar ſulphuris*, or *liver of ſulphur*. When this ſubſtance is moiſtened with water, it gives out a quantity of ſulphurated hydrogen gas; hence this gas was at firſt called *hepatic gas*.

40 Sulphurated hydrogen gas.

Mr Gengembre encloſed a bit of ſulphur in a glaſs veſſel filled with hydrogen gas, and melted the ſulphur by means of a burning glaſs. A quantity of it diſappeared, and the hydrogen aſſumed all the properties of *hepatic gas*. Hence it follows that this gas is merely ſulphur diſſolved in hydrogen gas.

The eaſieſt method of obtaining it is to pour an acid, the muriatic for inſtance, on a quantity of the ſulphuret reduced to powder. An effervеſcence takes place, the gas is extricated, and may be collected by means of a pneumatic apparatus. The theory of this emiſſion is obvious. The ſulphur is gradually converted into ſulphuric acid, by decompoſing the water, which is always united with acids, and ſeizing its oxygen: the hydrogen of the water is thus ſet at liberty; it aſſumes the gaſeous form, and at the ſame time diſſolves part of the remaining ſulphur, for which it has a conſiderable affinity.

The ſpecific gravity of ſulphurated hydrogen gas is 0,00135*; it is to common air as 1106 to 1000.

* *Kirwan on Phlogiſton* ſect. 1ſt.

It has a very fetid odour, preciſely ſimilar to that emitted by rotten eggs, which indeed is owing to the emiſſion of the very ſame gas.

It is not more reſpirable than hydrogen gas. When ſet on fire, in contact with oxygen gas, it burns with a light blue flame, without exploding, and at the ſame time a quantity of ſulphur is depoſited. The combuſtion of this gas, then, is merely the union of its hydrogen, and perhaps part of its ſulphur, with oxygen.

This gas turns ſyrup of violets to a green colour.* It does not ſeem capable of exiſting in atmoſpherical air without decompoſition; for the moment it comes into contact with oxygen gas, ſulphur is depoſited.†

* *Fourcroy's Chemiſtry, art.* Sulphur
† *Bergman.*

2. Phoſphorated hydrogen gas was diſcovered by Mr Gengembre in 1783, and by Mr Kirwan ſome time after, before he became acquainted with the experiments of that gentleman. It may be procured by mixing phoſphorus with potaſs diſſolved in water, and applying a boiling heat to the ſolution. The phoſphorus is gradually converted into an acid by decompoſing the water, and uniting with its oxygen. The hydrogen aſſumes the form of a gas, and flies off after diſſolving a little of the phoſphorus. This gas may be collected by means of a pneumatic apparatus.

41 Phoſphorated hydrogen gas.

Phoſphorated hydrogen gas has a ſmell reſembling that of putrid fiſh. When mixed with oxygen gas or common air, it becomes luminous; and on the application of the ſmalleſt heat, it burns with aſtoniſhing rapidity.‡ The products are water and phoſphoric acid. The combuſtion of this gas therefore is nothing elſe than the union of its phoſphorus and hydrogen with oxygen, attended by an emiſſion of heat and light.

‡ *Kirwan.*

Phoſphorated hydrogen gas may alſo be formed by introducing a bit of phoſphorus into a jar containing hydrogen gas; but care muſt be taken to make this gas as dry as poſſible; for its affinity with phoſphorus is weakened in proportion to its moiſture.‖

‖ *Brugnatelli, Nicholſon's Journal*, i. 445.

3. Carbonated hydrogen gas ariſes ſpontaneouſly in hot weather from marſhes, but always mixed with ſeveral other gaſes. Several ſpecies of it have been lately diſcovered by the aſſociated Dutch chemiſts Bondt, Dieman, Van Trooſtwyck, and Lauwerenberg.§ When 75 parts of ſulphuric acid and 25 of ſpirit of wine are mixed together, a gas is extricated which ſuffers no alteration from ſtanding over water. Its ſpecific gravity is 0,00111, or it is to common air as 909 to 1000. It has a fetid odour, and burns with a ſtrong compact flame. When paſſed through ſulphur it is converted into ſulphurated hydrogen gas, and at the ſame time a quantity of carbon is depoſited in the form of a fine powder; it muſt therefore be compoſed of carbon and hydrogen gas. When burnt, the product is carbonic acid

§ *Ann. de Chim.* xxxi. 48.

42 Carbonated hydrogen gas.

(o) The hiſtory of this great diſcovery, and the objections which have been made to it, we reſerve for the chapter which treats of *Water*, where they will be better underſtood than they could be at preſent. This ſubſtance was called *hydrogen* by the French chemiſts, becauſe it enters into the compoſition of water, from υδωρ *water*, and γινομαι *I am born*. Objections have been made to the propriety of the name, into which we ſhall not enter. It ought never to be forgotten, that Newton had long before, with a ſagacity almoſt greater than human, conjectured, from its great refracting power, that water *contained a combuſtible ſubſtance*. (4)

(4) That Newton *a-priori* from its refractive power ſhould have determined the *diamond* to be a *combuſtible* ſubſtance *may* reflect the higheſt credit on his genius. His determination of water containing an inflammable ſubſtance can however be conſidered but as a *lucky hit*. He aſcribed this inflammable principle to it on account of its great refractive power in proportion to its ſpecific gravity, the ſine of the angle of incidence being to the ſine of the angle of refraction in rock cryſtal 1.5620 to 1. and its gravity being 2.650 whereas in rain water whoſe ſpecific gravity is but 1. they bear the proportion of 1.3358 to 1. Had Newton applied this method of determining whether a ſubſtance contained an *inflammable principle* to other combinations of *oxygen* he would have fallen into groſs errors, in *ſulphuric acid*, for inſtance, whoſe ſpecific gravity is 2.125 the ſine of the angle of incidence is to that of refraction but as 1.4285 to 1. Hence he would have concluded that it contains *no inflammable* ſubſtance. T. P. S.

Hydrogen. * Ibid.

acid gas and water.* By making ether (P) pass thro' a red hot glass tube, another carbonated hydrogen gas was formed, the specific gravity of which was 0,00086. Spirit of wine, passed in the same manner, afforded a gas, the specific gravity of which was 0,00053, and which burned with a paler flame than the other two. These gases were found to contain from 80 to 74 parts of carbon, and from 20 to 26 of hydrogen. The first species was found to contain most carbon, and the last to contain least †.

† Ibid.

43 Affinities of these gases.

The affinity of hydrogen gas for these three combustibles is as follows:

Sulphur,
Carbon,
Phosphorus (Q).

Dr Austin found, that by repeatedly passing electric explosions through a small quantity of carbonated hydrogen gas, it was permanently dilated to more than twice its original bulk. He rightly concluded, that this remarkable expansion could only be owing to the evolution of hydrogen gas. On burning air thus expanded, he found that it required a greater quantity of oxygen than the same quantity of gas not dilated by electricity: An addition therefore had been made to the combustible matter; for the quantity of oxygen necessary to complete the combustion of any body, is always proportional to the quantity of that body. He concluded from these experiments, that he had decomposed the carbon which had been dissolved in the hydrogen gas; and that carbon was composed of hydrogen and azot (R), some of which was always found in the vessel after the dilated gas had been burnt by means of oxygen ‡. If this conclusion be fairly drawn, we must expunge *carbon* from the list of simple substances, and henceforth consider it as a compound.

44 Attempt to decompose carbon

‡ Phil. Transf. lxxx. 51.

45 Examined,

There was one circumstance which ought to have prevented Dr Austin from drawing this conclusion, at least till warranted by more decisive experiments. The quantity of combustible matter had been increased. Now, if the expansion of the carbonated hydrogen gas was owing merely to the decomposition of carbon, no such increase ought to have taken place, but rather the contrary; for the carbon, which was itself a combustible substance, was resolved into two ingredients, hydrogen and azot, only the first of which burnt on the addition of oxygen and the application of heat. Dr Austin's experiments have been lately repeated by Mr William Henry with a great deal of accuracy.* He found, that the dilatation which Dr Austin describes actually took place, but that it could not be carried beyond a certain degree, a little more than twice the original bulk of the gas. Upon burning separately by means of oxygen, two equal portions of carbonated hydrogen gas, one of which had been expanded by electricity to double its original bulk, the other not, he found that each of them produced precisely the same quantity of *carbonic acid gas*. Both therefore contained the same quantity of carbon; consequently no carbon had been decompounded by the electric shocks.

Azot. * Phil. Tran. 1797 part 2d.

46 And found unsuccessful.

Mr Henry then suspected that the dilatation was owing to the water which every gas contains in a larger or smaller quantity. To ascertain this, he endeavoured to deprive the carbonated hydrogen gas of as much water as possible, by making it pass over very dry potass, which attracts water with avidity. Gas treated in this manner could only be expanded one-sixth of its bulk; but on admitting a drop or two of water, the expansion went on as usual. The substance decompounded by the electricity, then, was not the carbon, but the water in the carbonated hydrogen gas. Nor is it difficult to see in what manner this decomposition is effected. Carbon at a high temperature has a greater affinity for oxygen than hydrogen has; for if the steam of water be made to pass over red hot charcoal, it is decomposed, and carbonic acid and hydrogen gas are formed. The electric explosion supplies the proper temperature; the carbon unites with the oxygen of the water, and forms carbonic acid; and the hydrogen, thus set at liberty, occasions the dilation. Carbonic acid gas is absorbed with avidity by water: and when water was admitted into 709 measures of gas thus dilated, 100 measures were absorbed; a proof that carbonic acid gas was actually present. As to the azot which Dr Austin found in his dilated gas, it evidently proceeded from the admission of some atmospheric air, about 73 parts of which in the 100 consist of this gas: for Dr Austin's gas had stood long over water; and Drs Priestley and Higgins have shewn that air in such a situation always becomes impregnated with azot. (5.)

The

(P) Ether is a very volatile and fragrant liquid, obtained by mixing spirit of wine and acids, and distilling. It shall be afterwards described.

(Q) Sulphur decomposes carbonated hydrogen gas; therefore its affinity is greater than that of carbon. The Dutch chemists melted phosphorus in carbonated hydrogen gas, but no change was produced; therefore the affinity of phosphorus is inferior to that of carbon.

(R) See next Section.—His theory was, that carbonated hydrogen gas was composed of hydrogen, and azot, and carbon of azot, and carbonated hydrogen gas, which comes nearly to the same thing with regard to the elements of carbon. It is singular enough, that though Dr Austin would not allow the presence of carbon in carbonated hydrogen gas, he actually decomposed it by melting sulphur in it: the sulphur combined with the hydrogen gas, and a quantity of carbon was precipitated. This experiment he relates without making any remarks upon it, and seems indeed not to have paid any attention to it.

(5) The decomposition of the water held in solution by the *carbonated hydrogen gas* by means of the carbon uniting to the oxygen, and forming *carbonic acid gas* while the hydrogen is set at liberty, perfectly accounts for its increased bulk. But I think it by no means accounts for the increased *consumption* of oxygen on firing it. It is true that there is an addition to the hydrogen in the reservoir; but then we must recollect all the oxygen with which it was united, is now in union with the carbon; that therefore this carbon on the *combustion* taking place will combine with just so much the less of the oxygen added, and the *additional hydrogen* will require no more oxygen to reconvert it into water than it parted with to the carbon. I cannot see then with what this extra quantity is to unite. Is it not possible Dr Austin may have been deceived in an experiment which requires so much accuracy? T. P. S.

Azot.

47 Affinities of hydrogen.

The affinities of hydrogen have not yet been afcertained, but perhaps they are as follows:

Oxygen,
Carbon,
Azot,

Sect. V. *Of Azot.*

48 Method of procuring azot.

If a quantity of iron filings and fulphur, mixed together and moiftened with water, be put into a glafs veffel full of air, it will abforb all the oxygen in the courfe of a few days; but a confiderable refiduum of air ftill remains incapable of any farther diminution. This refiduum has obtained the appellation of *azotic gas*.

49 Difcovery of azot.

It was difcovered in 1772 by Dr Rutherford, now profeffor of botany in the univerfity of Edinburgh (s). Scheele procured it by the above procefs as early as 1776, and proved that it was a diftinct fluid. Mr Lavoifier afterwards proved the fame thing, without any previous knowledge of Scheele's difcoveries.

The air of the atmofphere contains about ,73 parts of azotic gas; almoft all the reft is oxygen gas. The eafieft method of procuring azotic gas is to put fome fulphuret of potafs into a glafs veffel filled with air, and accurately clofed, and then to apply heat to the fulphuret. All the oxygen is abforbed almoft inftantly. This method was firft pointed out by Morveau.*

* *Nicholfon's Journal*, i. 268.

Mr Kirwan examined the fpecific gravity of azotic gas obtained by Scheele's procefs; it was 0,00120: it is therefore fomewhat lighter than the atmofpheric air, it is to atmofpheric air as 985 to 1000 ‖.

‖ *On Phlogifton*, § 1ft.

It tinges delicate blue colours flightly with green ‡.

50 Its properties.

It is exceedingly noxious to animals; if they are obliged to refpire it, they drop down dead almoft inftantly (T). No combuftible will burn in it. This is the reafon that a candle is extinguifhed in atmofpherical air as foon as the oxygen near it is confumed. Mr Goettling, indeed, publifhed, in 1794, that phofphorus fhone, and was converted into phofphoric acid, in pure azotic gas. Were this the cafe, it would not be true that no combuftible burns in this gas; for the converfion of phofphorus into an acid, and even its fhining, is an actual though flow combuftion. Mr Goettling's experiments were foon after repeated by Drs Scherer and Jaeger, who found, that phofphorus does not fhine in azotic gas when it is perfectly pure; and that therefore the gas on which Mr Goettling's experiments were made had contained a mixture of oxygen gas, owing principally to its having been only confined by water. Thefe refults were afterwards confirmed by Profeffor Lampadius and Profeffor Hildebrandt. It is therefore proved beyond a doubt, that phofphorus does not burn in azotic gas, and that whenever it appears to do fo, there is always fome oxygen gas prefent †.

‡ *Fourcroy, Ann. de Chim.* i. 45.

† *Nicholfon's Journal*, ii. 8.

Azotic gas is capable of diffolving phofphorus, as has been proved by the experiments of Fourcroy and Vauquelin.

It diffolves alfo a little carbon; for azotic gas obtained from animal fubftances, which contain a great deal of azot, when confined long in jars, depofits on the fides of them a black matter which has the properties of carbon ‖.

‖ *Fourcroy, Ann. de Chim.* i. 45.

Thefe two folutions the properties of which have not yet been accurately examined, are called *phofphorated and carbonated azotic gas*.

51 Production of nitric acid.

Azotic gas is capable of combuftion. Take a glafs tube, the diameter of which is about the fixth part of an inch; fhut one of its ends with a cork, through the middle of which paffes a fmall wire with a ball of metal at each end. Fill the tube with mercury, and then plunge its open end into a bafon of that fluid. Throw up into the tube as much of a mixture, compofed of 13 parts of azotic and 87 parts of oxygen gas, as will fill 3 inches. Through this gas make, by means of the wire in the cork, a number of electric explofions pafs. The volume of gas gradually diminifhes, and in its place there is found a quantity of *nitrous acid*. This acid, therefore, is compofed of azot and oxygen: and thefe two fubftances are capable of combining or, which is the fame thing, azotic gas is capable of combuftion in the temperature produced by electricity, which we know to be pretty high. The combuftibility of azotic gas, and the nature of the product, was firft difcovered by Mr Cavendifh, and communicated to the Royal Society on the 2d of June 1785 (U).

52 Attempts to decompofe azot.

The affinities of azot are ftill unknown. It has never yet been decompounded, and muft therefore, in the prefent ftate of our knowledge, be confidered as a fimple fubftance. Dr Prieftley, who obtained azotic gas at a very early period of his experiments, confidered it as a compound of oxygen gas and phlogifton, and for that reafon gave it the name of *phlogifticated air*. According to the theory of Stahl, which was then univerfally prevalent, he confidered combuftion as merely the feparation of phlogifton from the burning body. To this

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(s) See his thefis *De Aere Mephitico*, publifhed in 1772.—"Sed aer falubris et purus refpiratione animali non modo ex parte fit mephiticus fed et *aliam indolis fuæ mutationem inde patitur*. Poftquam enim omnis aer mephiticus (carbonic acid gas) ex eo, ope lixivii cauftici fecretus et abductus fuerit, *qui tamen reftat* nullo modo falubrior inde evadit; nam quamvis nullam ex aqua calcis præcipitationem faciat haud minus quam antea *et flammam et vitam extinguit*. Page 17.

"Aer qui per carbones ignitos folle adactus fuit, atque deinde ab omni aere mephitico *(carbonic acid gas)* expurgatus, malignus tamen adhuc reperitur et omnino fimilis eft ei qui refpiratione inquinatur. Immo ab experimentis patet, hanc folam effe aeris mutationem quæ inflammationi adfcribi poteft. Si enim accenditur materies quælibet quæ ex phlogifto et bafi fixa atque fimplici conftat, *aer inde natus ne minimam aeris mephitici quantitatem in fe continere videtur*. Sic aer in quo fulphur aut phofphorus urinæ combuftus fuit, licet maxime malignus, calcem tamen ex aqua minime præcipitat. Interdum quidem fi ex phofphoro natus fuerit, nubeculam aquæ calcis inducit fed tenuiffimam, nec aeri mephitico attribuendam, fed potius acido illi quod in phofphoro ineft, et quod, ut experimenta docuerunt, hoc fingulari dote pollet." Page 19.

(T) Hence the name *azot*, given it by the French chemifts, which fignifies *deftructive to life*, from α and ζωη.

(U) It is remarkable enough, that the acidity of nitric acid was afcribed by Mayow, in 1674, to the prefence of oxygen. *Indoles cauftica fpiritus nitri* (fays he) *a particulis ejus igneo-aereis provenit*. Tract. p. 19.

Azot. this theory he made the following addition: Phlogiston is separated during combustion by means of chemical affinity: *Air* (that is, *oxygen gas*) has a strong affinity for phlogiston: Its presence is necessary during combustion, because it combines with the phlogiston as it separates from the combustible; and it even contributes by its affinity to produce that separation: The moment the air has combined with as much phlogiston as it can receive, or, to use a chemical term, the moment it is *saturated* with phlogiston, combustion necessarily stops, because no more phlogiston can leave the combustible (v): Air saturated with phlogiston is azotic gas. This was a very ingenious theory, and when Dr Priestley published it, exceedingly plausible. A great number of the most eminent chemists accordingly embraced it: But it was soon after discovered, that during combustion the quantity of air, instead of increasing, as it ought to have done, had phlogiston been added to it, actually diminished both in volume and weight. There was no proof therefore, that during combustion, any substance whatever combined with air, but rather the contrary. It was discovered also, that a quantity of air combined with the burning substance during combustion, as we have seen was the case with sulphur, phosphorus, carbon, and hydrogen; and that this air had the properties of oxygen gas. These discoveries entirely overthrew the evidence on which Dr Priestley's theory was founded: accordingly, as no attempt to decompound azot has succeeded, it has been given up by almost every chemist except Dr Priestley himself. Atmospheric air, as Scheele first proved, is composed of about 27 parts of oxygen, and 73 of azotic gas. During combustion, the oxygen is abstracted and the azotic gas remains behind.

53
Unsuccessful.

La Metherie made an attempt to prove that azot was composed of oxygen and carbon (w). He took a bit of burning charcoal, extinguished it in mercury, and then plunged it while hot into oxygen gas. On being plunged into water, one-fourth of the gas was disengaged, and part of it was found to consist of azotic gas. From this he concluded that he had formed azotic gas by combining oxygen and carbon: But it was proved by Mr Lavoisier, beyond the possibility of doubt, that oxygen and carbon form carbonic acid gas. They cannot then certainly form azot; for two contradictory facts cannot both be true. There must then have been something overlooked in the experiment. Indeed the experiment itself does not warrant the conclusion which De La Metherie drew from it. He did not ascertain whether the weight of the charcoal was diminished; and besides, there was azot mixed with the oxygen gas which he employed, as he himself has informed us: And how was it possible for him to admit the charcoal into water without, at the same time, admitting some atmospherical air?

Azot || Metals.

We have now described all the combustibles which are at present reckoned simple, except the metals. We have found, that during combustion, all of them combine with oxygen; that no part of them is disengaged, no part of them lost: we have therefore concluded, that the combustion of these substances is nothing else but the act of their uniting with oxygen. We have seen, however, that none of them, except phosphorus, was capable of uniting with oxygen at the common temperature of the atmosphere; that, in order to produce the union, heat was necessary, and that the degree of this heat was different for each. Hydrogen required a red heat, and azot a still greater (6). We have seen, too, that during these combinations a quantity of heat and light escaped. Now why is heat necessary for these combinations? and whence come the heat and the light which we perceive during the combustion of these bodies? These questions are of the highest importance, and can only be answered by a particular investigation of the nature and properties of heat and light. This investigation we shall attempt as soon as we have described the *metals* and *earths*, which form the subject of the two following chapters.

CHAP. III. *Of* METALS.

54
Properties of metals.

METALS may be considered as the great instruments of all our improvements: Without them, many of the arts and sciences could hardly have existed. So sensible were the ancients of their great importance, that they raised those persons who first discovered the art of working them to the rank of deities. In chemistry, they have always filled a conspicuous station: at one period the whole science was confined to them; and it may be said to have owed its very existence to a rage for making and transmuting metals.

55
Lustre.

1. One of the most conspicuous properties of the metals is a particular brilliancy which they possess, and which has been called the *metallic lustre*. This proceeds from their reflecting much more light than any other body; a property which seems to depend partly on the closeness of their texture. This renders them peculiarly proper for mirrors, of which they always form the basis.

56
Opacity.

2. They are absolutely opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for instance, $\frac{1}{100000}$ of an inch thick, does not permit the smallest ray of light to pass through it. Gold, however, may be rendered transparent; for gold leaf, $\frac{1}{280000}$ of an inch thick, transmits light of a lively green colour*. And it is not improbable that all the other metals, as Sir Isaac Newton supposed, would become transparent, if they could be reduced to a sufficient degree of thinness. It is to this opacity that a part of the excellence of the metals, as mirrors, is owing; their brilliancy alone would not qualify them for that purpose.

* Nicholson's Notes on Fourcroy.

57
Fusibility.

3. They may be melted by the application of heat, and even then still retain their opacity. This property enables

(v) This ingenious theory was first conceived by Dr. Rutherford, as appears from the following passage of his thesis. "Ex iisdem etiam deducere licet quod aer ille malignus (azotic gas) componitur ex *aere atmosphaerico cum phlogisto unito et quasi saturato*. Atque idem confirmatur eo, quod aer qui metallorum calcinationi jam inservit, et phlogiston ab iis abripuit ejusdem plane sit indolis." *De aere Mephitico*, p. 20.

(w) Or rather of *hydrogen*, for he considered carbon itself as a compound.

(6) If this be *true*, from whence comes the nitric acid in those calcareous caves in which there is neither animal nor vegetable putrefaction, but in which nitre is formed?

Metals.

enables us to caſt them in moulds, and then to give them any ſhape we pleaſe. In this manner many elegant iron utenſils are formed.

58
Gravity.

4. Their ſpecific gravity is greater than that of any other body hitherto diſcovered.

5. They are better conductors of electricity than any other body.

59
Malleability.

6. But one of their moſt important properties is *malleability*, by which is meant the capacity of being extended and flattened when ſtruck with a hammer. This property enables us to give the metallic body any form we think proper, and thus renders it eaſy for us to convert them into the various inſtruments for which we have occaſion. All metals do not poſſeſs this property; but it is remarkable that almoſt all thoſe which were known to the ancients have it. Heat increaſes this property conſiderably.

60
Ductility.

7. Another property which is alſo wanting in many of the metals, is *ductility;* by which we mean the capacity of being drawn out into wire, by being forced through holes of various diameters. This property has by ſome been called *tenacity;* and it doubtleſs depends upon the tenacity of the various metals.

61
Calcination

8. When expoſed to the action of heat and air, moſt of the metals loſe their luſtre, and are converted into earthy-like powders of different colours and properties, according to the metal, and the degree of heat employed. Several of the metals even take fire when expoſed to a ſtrong enough heat; and after combuſtion the reſiduum is found to be the very ſame earthy-like ſubſtance. If any of theſe *calces*, as they are called, be mixed with charcoal-powder, and expoſed to a ſtrong heat in a proper veſſel, it is changed again to the metal from which it was produced. From theſe phenomena Stahl concluded that metals were compoſed of *earth* and *phlogiſton*. He was of opinion that there was only one primitive earth, which not only formed the baſis of all thoſe ſubſtances known by the name of earths, but the baſis alſo of all the metals. He found, however, that it was impoſſible to combine any mere earth with phlogiſton; and concluded, therefore, with Beccher, that there was another principle beſides earth and phlogiſton which entered into the compoſition of the metals. To this principle Beccher gave the name of *mercurial earth*, becauſe according to him, it exiſted moſt abundantly in *mercury*. This principle was ſuppoſed to be very volatile, and therefore to fly off during calcination: and ſome chemiſts even affirmed that it might be obtained in the ſoot of thoſe chimneys under which metals have been calcined.

62
Stahl's theory of the compoſition of metals

63
Defective.

A ſtriking defect was ſoon perceived in this theory. The original metal may be again produced by heating its calx along with ſome other ſubſtance which contains phlogiſton: now, if the mercurial earth flies off during combuſtion, it cannot be neceſſary for the formation of complete metals, for they may be produced without it: if, on the contrary, it adheres always to the calx, there is no proof of its exiſtence at all. Chemiſts, in conſequence of theſe obſervations, found themſelves obliged to diſcard the mercurial principle altogether, and to conclude that metals were compoſed of earth only, united to phlogiſton. But if this be really the caſe, how comes it that theſe two ſubſtances cannot be united by art? Henkel was the firſt who attempted to ſolve this difficulty. According to him, earth and phlogiſton are ſubſtances of ſo oppoſite a nature, that it is exceedingly difficult, or rather it has been hitherto impoſſible for us to commence their union; but after it has been once begun by nature, it is an eaſy matter to complete it. No calcination has hitherto deprived the metals of all their phlogiſton; ſome ſtill adheres to the calces. It is this remainder of phlogiſton which renders it ſo eaſy to reſtore them to their metallic ſtate. Were the calcination to be continued long enough to deprive them altogether of phlogiſton, they would be reduced to the ſtate of other earths; and then it would be equally difficult to convert them into metals, or, to uſe a chemical term, to *reduce* them. Accordingly we find, that the more completely a calx has been calcined, the more difficult is its reduction. This explanation was favourably received. But after the characteriſtic properties of the various *earths* had been aſcertained, and the calces of metals were accurately examined, it was perceived that the calces differed in many particulars from all the *earths*, and from one another. To call them all the ſame ſubſtance, then, was to go much farther than either experiment or obſervation would warrant, or, rather, it was to declare open war againſt both experiment and obſervation. It was concluded, therefore, that each of the metals was compoſed of a peculiar *earthy ſubſtance* combined with phlogiſton. For this great improvement in accuracy, chemiſtry is chiefly indebted to Bergman.

Metals.

64
Improved by Henkel.

65
Farther improved.

66
Still imperfect.

But there were ſeveral phenomena of calcination which had all this time been unaccountably overlooked. The calces are all conſiderably heavier than the metals from which they are obtained. Boyle had obſerved this circumſtance, and had aſcribed it to a quantity of *fire* which, according to him, became fixed in the metal during the proceſs‡. But ſucceeding chemiſts paid little attention to it, or to the action of air, till Mr Lavoiſier publiſhed his celebrated experiments on calcination, in the memoirs of the Paris Academy for 1774. He put eight ounces of *tin* into a large glaſs retort, the point of which was drawn out into a very ſlender tube to admit of eaſy fuſion. This retort was heated ſlowly till the tin began to melt, and then ſealed hermetically. This heat was applied to expel ſome of the air from the retort; without which precaution it would have expanded and burſt the veſſel. The retort, which was capable of containing 250 cubic inches, was then weighed accurately, and placed again upon the fire. The tin ſoon melted, and a pellicle formed on its top, which was gradually converted into a grey powder that ſunk by a little agitation, to the bottom of the liquid metal: in ſhort, the tin was partly converted into a *calx*. This proceſs went on for three hours; after which the calcination ſtopped, and no farther change could be produced on the metal. The retort was then taken from the fire, and found to be preciſely of the ſame weight as before the operation. It is evident, then, that no new ſubſtance had been introduced, and that therefore the increaſed weight of calces, cannot, as Boyle ſuppoſed, be owing to the fixation of fire (x).

‡ *Fire and flame weighed.*

67
Refuted by Lavoiſier.

When

(x) This experiment had been performed by Boyle with the ſame ſucceſs. He had drawn a wrong concluſion from not attending to the ſtate of the air of the veſſel. *Shaw's Boyle*, II. 394.

Metals. When the point of the retort was broken, the air rushed in with a hissing noise, and the weight of the retort was increased by ten grains. Ten grains of air, therefore, must have entered, and, consequently, precisely that quantity must have disappeared during the calcination. The metal and its calx being weighed, were found just ten grains heavier than before: therefore, the air which disappeared was absorbed by the metal: and as that part of the tin which remained in a metallic state was unchanged, it is evident that this air must have united with the calx. The increase of weight, then, which metals experience during calcination, is owing to their uniting with air (Y). But all the air in the vessel was not absorbed, and yet the calcination would not go on. It is not the whole, then, but some particular part of the air which unites with the calces of metals. By the subsequent discoveries of Priestley, Scheele, and Lavoisier himself, it was ascertained, that the residuum of the air, after calcination has been performed in it, is always pure azotic gas: It follows, therefore, that it is only the *oxygen* which combines with calces; and that a metallic calx is not a simple substance, but a compound. Mr Lavoisier observed, that the weight of the calx was always equal to that of the metal employed, together with that of the oxygen absorbed. It became a question, then, Whether metals, during calcination, lost any substance, and, consequently, whether they contained any phlogiston? Mr Lavoisier accordingly proposed this question; and he answered it himself by a number of accurate experiments and ingenious observations. Metals cannot be calcined, excepting in contact with oxygen, and in proportion as they combine with it. Consequently they not only absorb oxygen during their calcination, but that absorption is absolutely necessary to their assuming the form of a calx. If the calx of mercury be heated in a retort, to which a pneumatic apparatus is attached, to the temperature of 1200°, it is converted into pure mercury; and, at the same time, a quantity of oxygen separates from it in a gaseous form. As this process was performed in a close vessel, no new substance could enter: The calx of mercury, then, was reduced to a metallic state without phlogiston. The weights of the metal, and the oxygen gas, are together just equal to that of the calx; the calx of mercury, therefore, must be composed of mercury and oxygen; consequently, there is no reason whatever to suppose that mercury contains phlogiston. Its calcination is merely the act of uniting it with oxygen (Z). The calces of lead, silver, and gold, may be decomposed exactly in the same manner; and Mr Van Marum, by means of his great electrical machine, decomposed also those of tin, zinc, and antimony, and resolved them into their respective metals and oxygen‖. The same conclusions, therefore, must be drawn with respect to these metals. All the metallic calces may be decomposed by presenting to them substances which have a greater affinity for oxygen than they have. This is the reason that charcoal-powder is so efficacious in reducing them: and if they are mixed with it, and heated in a proper vessel, furnished with a pneumatic apparatus, it will be easy to discover what passes. During the reduction, a great deal of carbonic acid gas comes over, which, together with the metal, is equal to the weight of the calx and the charcoal: it must therefore contain all the ingredients; and we know that carbonic acid gas is composed of carbon and oxygen. During the process, then, the oxygen of the calx combined with the charcoal and the metal remained behind. It cannot be doubted, therefore, that all the metallic calces are composed of the entire metals combined with oxygen; and that calcination, like combustion, is merely the act of this combination. All metals, then, in the present state of chemistry, must be considered as simple substances; for they have never yet been decompounded.

‖ *Jour. de Phys.* 1785.

68 Oxyd and oxydation what.

The words *calx* and *calcination* are evidently improper, as they convey false ideas; we shall therefore afterwards employ, in stead of them, the words *oxyd* and *oxydation*, which were invented by the French chemists. A metallic *oxyd* signifies a metal united with oxygen; and *oxydation* implies the act of that union.

Metals are capable of uniting with oxygen in different proportions, and, consequently, of forming each of them different oxyds. These are distinguished from one another by their colour. One of the oxyds of iron, for instance, is of a green colour; it is therefore called the *green oxyd;* the other, which is brown, is called the *brown oxyd.*

69 Number of metals.

The metals at present amount to 21; only 11 of which were known before the year 1730. Their names are gold, silver, platinum, mercury, copper, iron, tin, lead, zinc, antimony, bismuth, arsenic, cobalt, nickel, manganese,

(Y) It is remarkable that John Rey, a physician of Perigord, had ascribed it to this very cause as far back as the year 1630: But his writings had excited little attention, and had sunk into oblivion, till after his opinion had been incontestibly proved by Lavoisier. Mayow also, in the year 1674, ascribed the increase of weight to the combination of metals with oxygen. *Quippe vix concipi potest* (says he), *unde augmentum illud antimonii (calcinati) nisi a particulis nitro-aereis igneisque inter calcinandum* FIXIS *procedat.* Tract. p. 28. *Plane ut antimonii fixatio non tam a sulphuris ejus externi assumptione, quam particulis nitro-aereis, quibus flamma nitri abundat,* EI INFIXIS *provenire videatur.* Ibid. p. 29.

(Z) This experiment was performed by Mr Bayen in 1774. This philosopher perceived, earlier than Lavoisier, that all metals did not contain phlogiston. "Ces experiences (says he) vont nous detromper. Je ne tiendrai plus le language des disciples de Stahl, qui seront forcés de restreindre la doctrine sur le phlogistique, ou d'avouer que les precipités mercurials, dont je parle, ne sont pas des chaux metalliques, ou enfin qu'il y a des chaux qui peuvent se reduire sans le concours du phlogistique. Les experiences que j'ai faites me force de conclure que dans la chaux mercuriale dont je parle, le mercure doit son *etat calcaire, non à la perte du phlogistique* qu'il nà pas essuyée, *mais a sa combinaison intime avec le fluide elastique,* dont le poids ajouté a celui du mercure est la seconde cause de l'augmentation de pesanteur qu'on observe dans les precipités que j'ai soumis a l'examen." *Jour. de Phys.* 1774, pages 288, 295. It was in consequence of hearing Bayen's paper read that Lavoisier was induced to turn his attention to the subject.

Gold.

manganefe, tungften, molybdenum, uranium, tellurium, titanium, chromum.

The firft eight of thefe were formerly called *metals* by way of eminence, becaufe they are poffeffed either of malleability or ductility, or of both properties together; the reft were called *femimetals*, becaufe they are brittle. But this diftinction is now pretty generally laid afide; and, as Bergman obferves, it ought to be fo altogether, as it is founded on a falfe hypothefis, and conveys very erroneous ideas to the mind. The firft four metals were formerly called *noble* or *perfect metals*, becaufe their oxyds are reducible by the mere application of heat; the next four were *imperfect metals*, becaufe their oxyds were thought not reducible without the addition of fome combuftible fubftance; but this diftinction alfo is now very properly exploded.

Sect. I. *Of Gold.*

70 Properties of gold.

Gold feems to have been known from the very beginning of the world. Its properties and its fcarcity have rendered it more valuable than any other metal.

It is of an orange red, or reddifh yellow colour, and has no perceptible tafte or fmell.

No other fubftance can be compared with it in ductility and malleability. It may be beaten out into leaves fo thin, that one grain of gold will cover $56\frac{3}{4}$ fquare inches. Thefe leaves are only $\frac{1}{282000}$ of an inch thick. But the gold leaf with which filver wire is covered has only $\frac{1}{12}$ of that thicknefs. An ounce of gold, upon filver wire, is capable of being extended more than 1300 miles in length.

Its tenacity is fuch, that a gold wire $\frac{1}{10}$ of an inch in diameter, is capable of fupporting a weight of 500 pounds without breaking‡.

‡ *Macquer's Dict.*

Its hardnefs is 6 (A); its fpecific gravity 19.3. It melts at 32° of Wedgewood's pyrometer (B). When melted, it affumes a bright bluifh green colour. It expands in the act of fufion, and confequently contracts while becoming folid more than moft metals; a circumftance which renders it lefs proper for cafting into moulds.

It requires a very violent heat to volatilize it; it is therefore, to ufe a chemical term, exceedingly *fixed*. Boyle and Kunkel kept it for fome months in a glafs-houfe furnace, and yet it underwent no change; nor did it lofe any perceptible weight, after being expofed for fome hours to the utmoft heat of Mr Parker's lens*. Mr Lavoifier, however, obferved, that a piece of filver, held over gold melted by a fire blown by oxygen gas, which produces a much greater heat than common air, was fenfibly *gilt*: Part of the metal, then, muft have been volatilized.

* *Kirwan's Miner.* i. 92.

After fufion, it is capable of affuming a cryftalline form. Tillet and Mongez obtained it in fhort quadrangular pyramidal cryftals.

71 Oxydation of gold.

It is capable of combining with oxygen, and forming an *oxyd of gold*. There are two methods of producing this combination, *the application of heat*, and *folution in acids*. When it is expofed to a very violent heat in contact with air, gold abforbs oxygen. But the temperature muft be very high; fo high, indeed, that hardly any certain method of oxydating gold by heat is known, except by electricity. When the electric explofion is tranfmitted through gold leaf placed between two plates of glafs, or when a ftrong charge is made to fall on a gilded furface—in both cafes the metal is oxydated, and affumes a purple colour. It has been faid alfo, that the fame effect has been produced by a very violent fire; but few of the inftances which have been adduced are well authenticated.

The other method of oxydating gold is much eafier. For this purpofe, equal parts of nitric and muriatic acids are mixed together (C), and poured upon gold; an effervefcence takes place, the gold is gradually diffolved, and the liquid affumes a yellow colour. It is eafy to fee in what manner this folution is produced. No metal is foluble in acids till it has been reduced to the ftate of an oxyd. There is a ftrong affinity between the oxyd of gold and muriatic acid. The nitric acid furnifhes oxygen to the gold, and the muriatic acid diffolves the oxyd as it forms (7). When nitric acid is deprived of the greater part of its oxygen, it affumes a gafeous form, and is then called *nitrous gas*. It is the emiffion of this gas which caufes the effervefcence. The oxyd of gold may be precipitated from the nitro-muriatic acid, by pouring in a little potafs diffolved in water, or, which is much better, a little lime, both of which have a ftronger affinity for muriatic acid

(A) We have borrowed from Mr Kirwan the method of denoting the different degrees of hardnefs by figures, which we think a great improvement. Thefe figures will be underftood by Mr Kirwan's own explanation, which we here fubjoin.

3, Denotes the hardnefs of chalk.
4, A fuperior hardnefs, but yet what yields to the nail.
5, What will not yield to the nail, but eafily, and without grittinefs, to the knife.
6, That which yields more difficultly to the knife.
7, That which fcarcely yields to the knife.
8, That which cannot be fcraped by a knife, but does not give fire with fteel.
9, That which gives a few feeble fparks with fteel.
10, That which gives plentiful lively fparks. *Kirwan's Mineralogy*, I. 38.

(B) According to the calculation of the Dijon academicians, it melts at 1298° Fahr.; according to Bergman, at 1301°.

(C) This mixture, from its property of diffolving gold, was formerly called *aqua regia* (for gold, among the alchymifts, was the king of metals); it is now called *nitro-muriatic acid*.

(7) I would rather, from the late experiments of the French chemifts, confider it as decompofition of the oxygenated muriatic acid which is formed on our mixing nitric and muriatic acids: part of its oxygen uniting to the gold, thus oxyding it, and the oxygenated acid paffing to the ftate of muriatic acid, which diffolves the oxyd of gold. T. P. S.

Gold. acid than the oxyd has. This oxyd is of a yellow colour.

It is probable that gold is capable of two different degrees of oxydation, and of forming two different oxyds, *the yellow* and *the purple*: But neither the quantity of oxygen contained in these oxyds, nor the differences between them, have been accurately ascertained. The oxyds of gold may be decompofed in close veffels by the application of heat. The gold remains fixed, and the oxygen affumes the gafeous form. They may be decompofed, too, by all the fubftances which have a ftronger affinity with oxygen than gold has. The affinities of the oxyds of gold, according to Bergman†, are as follows:

† *Bergman on Elective Attractions, Opufc.* t. 3.

Muriatic acid,
Nitro muriatic,
Nitric,
Sulphuric,
Arfenic,
Fluoric,
Tartarous,
Phofphoric,
Sebacic,
Pruffic,
Fixed alkali (D),
Ammonia,

Gold is not changed either by air or water. It does not feem capable of combining either with fulphur or carbon. Mr Pelletier combined it with phofphorus, by melting together in a crucible half an ounce of gold and an ounce of phofphoric glafs (E), furrounded with charcoal. The *phofphuret of gold* thus produced was brittle, whiter than gold, and had a cryftallized appearance. It was compofed of 23 parts of gold and one of phofphorus †. He formed the fame compound by dropping fmall pieces of phofphorus into gold in fufion ‡.

72 Phofphuret of gold.

† *Ann. de Chim.* i. 71.
‡ *Ibid.* xiii. 104.

Gold is alfo capable of combining with moft of the metals. Its affinities are placed, by Bergman, in the following order:

Mercury,
Copper,
Silver,
Lead,
Bifmuth,
Tin,
Antimony,
Iron,
Platinum,
Zinc,
Nickel,
Arfenic,
Cobalt,
Manganefe,
Phofphorus?
Sulphurets of alkalies.

Sect. II. *Of Silver.*

Silver.

73 Properties of filver.

Silver appears to have been known almoft as early as gold. It is a metal of a fhining white colour, without either tafte or fmell.

It is the moft malleable and ductile of all metals except gold, and perhaps platinum. It can be reduced to leaves about $\frac{1}{160000}$ of an inch thick, and drawn into wire much finer than a human hair.

Its tenacity is fuch, that a wire of filver, $\frac{1}{10}$ of an inch in diameter, is capable of fuftaining 270 pounds without breaking ||. || *Macquer's Dict.*

Its hardnefs is 6,5.* Its fpecific gravity, before hammering, is 10,474; after hammering, 10,510 ‡: for it is remarkable that the fpecific gravity of almoft all the metals is increafed by hammering.

* *Kirwan.*
‡ *Briffon.*

It continues melted at 28° Wedgewood (F), but requires a greater heat to bring it to fufion †. † *Kirwan's Mineral.* ii. 107.

The experiments of the French academicians have proved that it may be volatilized, but that it requires a very violent heat.

When cooled flowly, it affumes a cryftalline form. Tillet and Mongez obtained it in quadrangular pyramidal cryftals, both infulated and in groups.

74 Oxyds of filver.

Silver may be combined with oxygen, and converted into an oxyd by expofure to a very violent heat. By this method Junker partly converted it into a *glafs*; and Macquer, by expofing it 20 times fucceffively to the heat of a porcelain furnace, obtained a *glafs* (G) of an olive green colour ‡. The oxyd of filver may alfo be formed by diffolving the metal in an acid, and precipitating it from its folution by potafs, lime, &c: for, during its folution, the metal becomes oxydated. Little is known at prefent concerning the oxyds of filver, nor whether there be more than two, the *black* and the *blue*. From the experiments of Wenzel and Bergman, it follows, that one oxyd of filver is compofed of about 90 parts of metal and 10 of oxygen ||. The affinities of the oxyds, according to Bergman, are as follows:

‡ *Macquer's Dict.*
|| *Kirwan's Miner.* ii. 493.

Muriatic acid,
Sebacic,
Oxalic,
Sulphuric,
Saccholactic,
Phofphoric,
Sulphurous,
Nitric,
Arfenic,
Fluoric,
Tartaric,
Citric,
Formic,
Lactic,
Acetous,
Succinic,
Pruffic,

Carbonic,

(D) Have the alkalis any affinity for the yellow oxyd? Is not their affinity confined to the purple oxyd alone? And does not this oxyd act as an acid?

(E) Phofphoric acid evaporated to drynefs and then fufed.

(F) According to the Dijon academicians, it melts at 1044° Fahr.; according to Bergman, at 1000°.

(G) Metallic oxyds, after fufion, are called *glafs*, becaufe they acquire a good deal of refemblance, in fome particulars, to common glafs.

Silver.

Carbonic,
Ammonia.

75 Sulphuret of silver.

When silver is melted with sulphur in a low red heat, it combines with it and forms *sulphuret of silver*. It is very difficult to determine the proportion of the ingredients which enter into the composition of this substance, because there is an affinity between silver and its sulphuret, which disposes them to combine together. The greatest quantity of sulphur which a given quantity of silver is capable of taking up is, according to Wenzel, $\frac{15}{100}$.* Sulphuret of silver is of a black or very deep violet colour, brittle and much more fusible than silver. If sufficient heat be applied, the sulphur is volatilized, and the metal remains behind in a state of purity.

* Ibid. 492.

76 Phosphuret of silver.

If one ounce of silver, one ounce of phosphoric glass, and two drams of charcoal, be mixed together, and heated in a crucible, *phosphuret of silver* is formed. It is of a white colour, and appears granulated, or as it were crystallized. It breaks under the hammer, but may be cut with a knife. It is composed of four parts of silver and one of phosphorus. Heat decomposes it by separating the phosphorus †. Pelletier has observed, that silver in fusion is capable of combining with more phosphorus than solid silver: for when phosphuret of silver is formed by projecting phosphorus into melted silver, after the crucible is taken from the fire a quantity of phosphorus is emitted the moment the metal congeals ‡.

† Pelletier, Ann. de Chim. i. 73.

‡ Ibid. xiii. 110.

Silver does not seem capable of combining with carbon.

77 Alloys of silver.

Silver is capable of combining with gold, and forming an *alloy* (H) composed of one part of silver and five of gold. That this is the proportion of the ingredients, was discovered by Homberg. He kept equal parts of gold and silver in gentle fusion for a quarter of an hour, and found, on breaking the crucible, two masses, the uppermost of which was pure silver, the undermost the whole gold combined with $\frac{1}{5}$ of silver. Silver, however, may be mixed with gold in almost any proportion. But there is a great difference between the mixture of two substances and their chemical combination. Metals which melt nearly at the same temperature, may be mixed from that very circumstance in any proportion; but substances can combine chemically only in one proportion. This observation, which is certainly of importance, was first made, as far as we know, by Mr Keir ‖. The alloy of silver and gold is of a greenish colour, but its properties have not yet been accurately examined.

Silver ‖ Platinum.

‖ Translation of Macquer's Dict. art. Allay.

78 Becomes tarnished by exposure.

Silver is not affected by water, nor by exposure to the air; but Mr Proust has remarked, that when long exposed in places frequented by men, as in churches, theatres, &c. it acquires a covering of a violet colour, which deprives it of its lustre and malleability. This covering, which forms a thin layer, can only be detached from the silver by bending it, or breaking it in pieces with a hammer. It was examined by Mr Proust, and found to be *sulphuret of silver*. He accounts for this transition of the silver into a *sulphuret*, by supposing that a quantity of sulphur is constantly formed and exhaled by living bodies.*

* Ann. de Chim. i. 142.

79 Its affinities.

The affinities of silver, according to Bergman, are as follows:

Lead,
Copper,
Mercury,
Bismuth,
Tin,
Gold,
Antimony,
Iron,
Manganese,
Zinc,
Arsenic,
Nickel,
Platinum,
Sulphurets of alkalies,
Sulphur,
Phosphorus.

Sect. III. *Of Platinum.*

The metals hitherto described have been known to mankind from the earliest ages, and have been always in high estimation on account of their beauty, scarcity, ductility, and indestructibility. But platinum, though perhaps inferior to them in none of these qualities, and certainly far superior in others, was unknown, as a distinct metal, before the year 1752 (I).

80 Discovery of platinum.

It has been found only in America, in Choco in Peru,

(H) Metals combined together are called *alloys* or *allays*.

(I) Father Cortinovis, indeed, has attempted to prove, that this metal was the *electrum* of the ancients. See the *Chemical Annals of Brugnatelli*, 1790. That the electrum of the ancients was a metal, and a very valuable one, is evident from many of the ancient writers, particularly Homer. The following lines of Claudian are alone sufficient to prove it:

Atria cinxit ebur, trabibus solidatur ahenis
Culmen et in celsas surgunt electra *columnas*. L. I. v. 164.

Pliny gives us an account of it in his Natural History. He informs us that it was a composition of silver and gold; and that by candle-light it shone with more splendor than silver. The ancients made cups, statues, and columns of it. Now, had it been our platinum, is it not rather extraordinary that no traces of a metal, which must have been pretty abundant, should be perceptible in any part of the old continent?

As the passage of Pliny contains the fullest account of electrum to be found in any ancient author, we shall give it in his own words, that every one may have it in his power to judge whether or not the description will apply to the platinum of the moderns.

" Omni auro inest argentum vario pondere.—Ubicunque quinta argenti portio est, *electrum* vocatur. Scrobes eæ reperiuntur in Canaliensi. Fit et cura electrum argento addito. Quod si quintam portionem excessit, incudibus

Platinum. Peru, and in the mine of Santa Fe, near Carthagena. The workmen of theſe mines muſt no doubt have been early acquainted with it; but they ſeem to have paid very little attention to it. It was unknown in Europe till Mr Wood brought ſome of it from Jamaica in 1741. Soon after it was noticed by Don Antonio de Ulloa, a Spaniſh mathematician, who had accompanied the French academicians to Peru in their voyage to meaſure a degree of the meridian. In the year 1752, it was examined by Scheffer of Sweden, and diſcovered by him to be a new metal, approaching very much to the nature of gold, and therefore called by him *aurum album, white gold.* Soon after it was examined by Lewis, Margraf, Macquer and Beaumé, Morveau, Bergman, and many other illuſtrious chemiſts.

81 Its properties.

Platinum, when pure, is of a white colour like ſilver, but not ſo bright (κ). It has no taſte nor ſmell.

It is both ductile and malleable; but the preciſe degree has not yet been aſcertained. It has been drawn into a wire of $\frac{1}{1940}$ of an inch in diameter. This wire admitted of being flattened, and had more ſtrength than a wire of ſilver or gold of the ſame ſize‡.

‡ *Withering.*

It is exceedingly difficult to fuſe it. Macquer and Beaumé ſucceeded by means of a powerful burning-glaſs. It melts more eaſily when mixed with other ſubſtances. Its fixity is ſtill greater than its infuſibility. If the ſtrongeſt fires cannot melt it, much leſs can they volatilize it.

Its hardneſs is 7,5‖. Its ſpecific gravity, after being hammered, is 23,000; ſo that it is by far the heavieſt body known.

‖ *Kirwan's Miner.* ii. 103.

Some of the experiments which have been made on platinum ſeem to prove that it may be oxydated by the application of a violent heat. The oxyd of this metal may be eaſily formed by diſſolving platinum in nitro-muriatic acid, and precipitating it by means of an earth or potaſs. The various oxyds of platinum have never yet been examined with accuracy. The one at preſent beſt known poſſeſſes, as Mr Berthollet has proved, the properties of an acid.

82 Phoſphuret of platinum.

The *ſulphuret of platinum* is unknown.

By mixing together an ounce of platinum, an ounce of phoſphoric glaſs, and a dram of powdered charcoal, and applying a heat of about 32° Wedgewood, Mr Pelletier formed a *phoſphuret of platinum* weighing more than an ounce. It was partly in the form of a button, and partly in cubic cryſtals. It was covered above by a blackiſh glaſs. It was of a ſilver white colour, very brittle, and hard enough to ſtrike fire with ſteel. When expoſed to a fire ſtrong enough to melt it, the phoſphorus was diſengaged, and burnt on the ſurface†.

† *Ann. de Chim.* i. 71.

He found alſo, that when phoſphorus was projected on red hot platinum, the metal inſtantly fuſed, and formed a phoſphuret. As heat expels the phoſphorus, Mr Pelletier has propoſed this as an eaſy method of purifying platinum*.

* *Ibid.* xiii. 105.

Platinum does not ſeem capable of combining with carbon.

Platinum ‖ Mercury.

It is not in the leaſt affected by the action of water or air.

83 Alloys of platinum.

1. When gold and Platinum are expoſed to a ſtrong heat, they combine, and form an alloy of a much whiter colour, but nearly as ductile as gold. The proportions of the ingredients are not known. When $\frac{1}{47}$ only of the alloy is platinum, the gold is ſcarcely altered in colour.

2. Whether ſilver and platinum combine chemically has not yet been properly aſcertained. When fuſed together (for which a very ſtrong heat is neceſſary), they form a mixture not ſo ductile as ſilver, but harder and leſs white. The two metals are ſeparated by keeping them for ſome time in the ſtate of fuſion; the platinum ſinking to the bottom from its weight. This circumſtance would induce one to ſuppoſe that there is very little affinity between them.

Sect. IV. *Of Mercury.*

Mercury, called alſo *quickſilver*, was known to the ancients, and ſeems to have been employed by them in gilding.

84 Properties of mercury.

It is of a white colour, exactly like that of poliſhed ſilver. It has no taſte, but acquires a ſlight odour when rubbed between the hands.

Its ſpecific gravity is 13,568†.

† *Briſſon.*

It differs from all other metals in always exiſting, at the common temperature of the atmoſphere, in a ſtate of fluidity. It freezes at 39°*; or, which is the ſame thing, it ceaſes to be a ſolid, and melts whenever it is placed in a temperature above 39°. It boils at the temperature of 600°.

* See *Macnab's Experiments Phil. Tranſ.*

From the experiments made on frozen mercury in Ruſſia, Hudſon's Bay, and Britain, we know that this metal, when ſolid, is malleable; but the extreme difficulty of examining it in that ſtate on account of the lowneſs of the temperature, has rendered it hitherto impoſſible to aſcertain the preciſe degree either of its malleability, ductility, or hardneſs.

85 It forms three oxyds:

Mercury is capable of combining with oxygen, and of forming *oxyds*, differing from each other in the quantity of oxygen which they contain. The oxyds of mercury, at preſent known, are the *black*, the *yellow*, and the *red*.

86 The black oxyd,

1. When mercury is agitated for ſome time in contact with oxygen gas, or atmoſpheric air, it is partly converted into a greyiſh-black powder, and at the ſame time part of the oxygen diſappears. This is the *black* oxyd of mercury. It is not known how much oxygen it contains, nor even whether the whole of the mercury which compoſes it be actually combined with oxygen.

87 Yellow oxyd,

2. The beſt way of forming the yellow oxyd is to diſſolve mercury, either in boiling ſulphuric acid or in cold nitric acid. During its ſolution, it deprives theſe acids of juſt as much oxygen as is neceſſary to convert it

bus non reſtitit. Et electro auctoritas, Homero teſte, qui Menelai regiam auro, electro, argento, ebore fulgere tradit. Minervæ templum habet Lindos inſulæ Rhodiorum in quo Helena ſacravit calicem ex electro.—Electri natura eſt ad lucernarum lumina clarius argento ſplendere. Quod eſt nativum, et venena deprehendit. Namque diſcurrunt in calicibus arcus cœleſtibus ſimiles cum igneo ſtridore, et gemina ratione prædicunt."—*Lib.* xxxiii. *cap.* iv.

(κ) To this colour it owes its name. *Plata*, in Spaniſh, is *ſilver*; and *platina*, *little ſilver*, was the name firſt given to the metal. Bergman changed that name into *platinum*, that the Latin names of all the metals might have the ſame termination and gender. It was, however, firſt called *platinum* by Linnæus.

Mercury.

it into a yellow oxyd; and if potass or lime be afterwards added to the solution, it precipitates, and may be obtained pure by washing it with water. It is a bright yellow coloured powder, which acts very powerfully as an emetic. From the observations of Bergman, it appears that it is composed of about 96,8 parts of mercury, and 3,2 of oxygen*.

* Kirwan's Miner. ii. 489.

88 And red oxyd.

3. The *red oxyd* of mercury may be prepared, either by distilling nitric acid off the metal repeatedly, or by keeping mercury for a long time exposed to a heat sufficient to evaporate it while it is in contact with air. When formed by the first process it was formerly called *red precipitate*; when by the last, *precipitate per se*. It is a beautiful red powder, or rather small red crystals, which have some escharotic qualities. When prepared by the second process, the heat must not be much below 600°, nor much above 800°, otherwise no union would take place; and it must be continued for some weeks. From the experiments of Mr Kirwan, it appears to contain 92,6 parts of mercury, and 7,4 of oxygen*.

† Kirwan's Miner. ii. 489.

These oxyds may be decomposed by the application of a heat amounting to 1200°. The oxygen flies off in the form of gas, and running mercury remains behind.

89 Their affinities.

The affinities of the oxyds of mercury, according to Bergman, are as follows:

Sebacic acid,
Muriatic,
Oxalic,
Succinic,
Arsenic,
Phosphoric,
Sulphuric,
Benzoic(L)?
Saccholactic,
Tartarous,
Citric,
Sulphurous,
Nitric,
Fluoric,
Zoonic(M)?
Acetous,
Boracic,
Prussic,
Carbonic.

90 Black sulphuret of mercury.

When two parts of mercury and three parts of flowers of sulphur are triturated for some time together, or when equal parts of mercury and melted sulphur are mixed together, they combine, and form a black powder, formerly called *ethiops mineral*, and now *black sulphuret of mercury*.

91 Red sulphuret.

When 300 grains of mercury, and 68 of sulphur, with a few drops of solution of potass to moisten them, are triturated for some time in a porcelain cup, by means of a glass pestle, black oxyd of mercury is produced. Add to this 160 grains of potass, dissolved in as much water. Heat the vessel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, so that the oxyd may be constantly covered to the depth of near an inch. The trituration must be continued about two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which usually happens when a large part of the fluid is evaporated. It then passes very rapidly to a red. No more water is to be added; but the trituration is to be continued without interruption. When the mass has acquired the consistence of a jelly, the red colour becomes more and more bright, with an incredible degree of quickness. The instant the colour has acquired its utmost beauty, the heat must be withdrawn, otherwise the red passes to a dirty brown. This red powder is the red sulphuret of mercury, called formerly *cinnabar*, and, when reduced to a fine powder, *vermilion*(N). The process above described, has been lately discovered by Mr Kirchoff, and is by far the simplest and cheapest mode of forming red sulphuret with which we are acquainted*. Count De Moussin Pouschin has discovered, that its passing to a brown colour may be prevented by taking it from the fire as soon as it has acquired a red colour, and placing it for two or three days in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. During this exposure, the red colour gradually improves, and at last becomes excellent. He discovered also, that when this sulphuret is exposed to a strong heat, it becomes instantly brown, and then passes into a dark violet; when taken from the fire, it passes instantly to a beautiful carmine red†.

* Nicholson's Journ. ii. 1.

† Ibid. p. 7.

The difference between these two sulphurets has never yet been ascertained. One would be apt to suspect at first that the black sulphuret consists of the real sulphuret of mercury combined with sulphur; the red, of the sulphuret of mercury combined with mercury, and that the real sulphuret of mercury was not yet accurately known. But it cannot be doubted that, during the formation of the *red sulphuret*, according to Kirchoff's process, there is an absorption of oxygen. The phenomena above described point out *that* almost incontestibly; and we observed, on attempting to repeat the experiment, that the black sulphuret, during its trituration, emitted sulphurated hydrogen gas. Perhaps, then, the mercury may be oxydated. We suspected at first that part of the sulphur might be converted into an acid; but on attempting an alteration of the process in consequence of that supposition, we could not succeed.

The red sulphuret of mercury is found naturally in several parts of the world. It used to be prepared by forming a black sulphuret with three parts of sulphur and one of mercury, and then setting fire to it. Part of the sulphur is burnt, and there remains behind a violet coloured body, which is powdered and put into a glass vessel, to the bottom of which a red heat is applied. A reddish

(L) Benzoat of mercury is decomposed by sulphuric acid. *Trommsdorf Ann. de Chim.* xi. 316.

(M) Zoonic acid decomposes the acetite of mercury. *Berthollet.*

(N) The word *vermilion*, is derived from the French word *vermeil*, which comes from *vermiculus* or *vermiculum*, names given in the middle ages to the *kermes*, or *cocus ilicis*, well known as a red dye. *Vermilion* originally signified the red dye of the kermes. See *Beckmann's Hist. of Discoveries*, II. 180.

Mercury.

A reddiſh brown ſubſtance ſublimes, which is red *ſulphuret of mercury*; but its colour is not nearly equal to that which is prepared by Kerchoff's proceſs.

92 Phoſphuret of mercury.

Mr Pelletier, after ſeveral unſucceſsful attempts to form phoſphuret of mercury, at laſt ſucceeded by diſtilling a mixture of red oxyd of mercury and phoſphorus. Part of the phoſphorus combined with the oxygen of the oxyd, and was converted into an acid; the reſt combined with the mercury.

Phoſphuret of mercury is of a black colour, of a pretty ſolid conſiſtence, and capable of being cut with a knife. When expoſed to the air, it exhaled vapours of phoſphorus||.

|| *Ann. de Chim.* xiii. 122.

Mercury does not ſeem capable of combining with carbon.

93 Its amalgams.

The combinations of mercury with the other metals are called *amalgams*.

1. The amalgam of gold forms very readily, becauſe there is a very ſtrong affinity between the two metals. If a bit of gold be dipped into mercury, its ſurface, by combining with mercury, becomes as white as ſilver. The eaſieſt way of forming this amalgam is to throw ſmall pieces of red hot gold into mercury. The proportions of the ingredients are not eaſily determined, becauſe the amalgam has an affinity both for the gold and the mercury; in conſequence of which they appear to combine in any proportion. Moſt probably it is compoſed of two parts of gold and one of mercury. The combination is formed moſt readily in theſe proportions; and if too much mercury be added, it may be ſeparated by filtration. The amalgam is of a white colour, and of the conſiſtence of butter†. This amalgam cryſtallizes in quadrangular priſms; which cryſtals, according to the Dijon academicians, are compoſed of ſix parts of mercury and one of gold. It is much uſed in gilding.

† *Keir's Notes on Macquer's Dict.* art. *Amalgam.*

2. The amalgam of ſilver is made in the ſame manner. It forms dendritical cryſtals, which, according to the Dijon academicians, contain eight parts of mercury and one of ſilver. Gellert was the firſt who remarked that its ſpecific gravity was greater than that of mercury, though that of ſilver be leſs.

3. Dr Lewis attempted to form an amalgam of platinum, but hardly ſucceeded, after a labour which laſted for ſeveral weeks. Mr Morveau ſucceeded by means of heat†. But a much more expeditious method has been lately diſcovered by Count Mouſſin Pouſchin. He took a dram of the orange-coloured ſalt, compoſed of *oxyd of platinum and ammonia* (O), and triturated it with an equal weight of mercury in a mortar of chalcedony. In a few minutes the ſalt became brown, and afterwards acquired a greeniſh ſhade. The matter was reduced to a very fine powder. Another dram of mercury was added, and the trituration continued: The matter became grey. A third dram of mercury began to form an amalgam; and ſix drams made the amalgam perfect. The whole operation ſcarce laſted 20 minutes. Mercury was added till it amounted to nine times the weight of the ſalt, and yet the amalgam continued very tenacious. It was eaſily ſpread out under the peſtle; it received the impreſſion of the moſt delicate ſeals, and had a very cloſe and brilliant grain. This amalgam is decompoſed, and the mercury paſſes to the ſtate of black oxyd by the ſimple contact of ſeveral of the metals and a great number of animal matters. This effect even takes place on rubbing it between the fingers*.

† *Ann. de Chim.* xxiv. 205.

Copper.

* *Ibid.*

94 Affinities.

The affinities of mercury, as aſcertained by the experiments of Morveau (P), are as follows:

Gold,
Silver,
Tin,
Lead,
Biſmuth,
Zinc,
Copper,
Antimony,
Arſenic (Q),
Iron.

Sect. V. *Of Copper.*

Except gold and ſilver, copper ſeems to have been more early known than any other metal. In the firſt ages of the world, before the method of working iron was diſcovered, copper was a principal ingredient in all domeſtic utenſils and inſtruments of war. Even during the Trojan war, as we learn from Homer, the combatants had no other armour but what was made of bronze, which is a mixture of *copper and tin*. The word *copper* is derived from the iſland of Cyprus, where it was firſt diſcovered, or at leaſt wrought to any extent, by the Greeks.

95 Properties of copper.

Copper is of a pale red colour with a ſhade of yellow. Its taſte is ſtyptic and nauſeous; and when rubbed it emits a diſagreeable ſmell. It poſſeſſes a conſiderable degree of malleability, though leſs than ſilver. Its tenacity is ſuch, that a wire of $\frac{1}{10}$ of an inch in diameter can ſuſtain a weight of $299\frac{1}{4}$ pounds without breaking†.

† *Macquer's Dict.*

Its hardneſs is 8 ‡. Its ſpecific gravity, when not hammered, is 7,788; when wire-drawn, 8,878||. The ſpecific gravity of Japan copper is 9,000*; that of Swediſh copper, 9,3243†.

‡ *Kirwan's Miner.* ii. 127.

|| *Briſſon.*

It melts at 27° Wedgewood; according to the calculation of the Dijon academicians, at 1449° Fahrenheit. When allowed to cool ſlowly, it aſſumes a cryſtalline form. The Abbé Mongez, to whom we owe many valuable experiments on the cryſtallization of metals, informs us, that theſe cryſtals are quadrangular pyramids, frequently inſerted into one another.

* *Keir's Notes on Macquer's Dict.*

† *Bergman,* ii. 263.

96 Brown oxyd of copper.

When copper is heated red hot in contact with air, it is ſoon covered with a brown earthy cruſt, which may be eaſily ſeparated by hammering or by plunging the metal into water. If the heat be continued, another ſcale of the ſame kind ſoon forms; and by continuing the proceſs the whole metal may be converted into an earthy-like cruſt, which is merely a combination of copper and oxygen, and is therefore called *brown oxyd of copper*. It is compoſed of about 84 parts of copper and 16 of oxygen‡.

‡ *Kirwan's Miner.* ii. 487.

97 Blue and green oxyds.

When copper is diſſolved in ſulphuric acid, and precipitated by means of lime, it falls in the form of a blue-coloured powder, which is the *blue oxyd of copper*. If this

(O) Ammonia is an alkali hereafter to be deſcribed. It is often called, in Engliſh, *hartſhorn*.

(P) We ſhall have occaſion to conſider theſe celebrated experiments afterwards.

(Q) Theſe two are added from Bergman. Bergman places *lead* before tin, and zinc before biſmuth.

Copper. this oxyd of copper be dried in the open air, it aſſumes a green colour, and is then called the *green oxyd of copper*. This laſt oxyd may alſo be produced by diſtilling a ſufficient quantity of nitric acid off copper. Little ſatisfactory is yet known with reſpect to theſe oxyds; it has not even been aſcertained whether the blue and green be really two different oxyds, or whether the difference in colour be owing to ſome other cauſe. It is probable, however, that the *green* oxyd contains more oxygen than the blue; becauſe the blue oxyd aſſumes a green colour when expoſed for ſome time to the open air, during which it may be ſuppoſed to abſorb oxygen. An experiment of Fourcroy proves inconteſtibly, that the *brown* oxyd contains leſs oxygen than the green. He converted the green oxyd into the brown by applying heat; and during the diſtillation obtained oxygen gas‖.

‖ *Fourcroy*, iii. 101.

98 Their affinities.

The affinities of the oxyds of copper, according to Bergman, are as follows:

Pyromucous acid*,
Oxalic,
Tartarous,
Muriatic,
Sulphuric,
Saccholactic,
Nitric,
Sebacic,
Arſenic,
Phoſphoric,
Succinic,
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Fixed alkalies,
Ammonia,
Fixed oils.

* *Schrickel.*

When copper is long expoſed to the air, its ſurface becomes covered over with a green cruſt, which is *green oxyd of copper*. This oxydation never penetrates beyond the ſurface.

Copper is not attacked by water at the boiling temperature; but if cold water be allowed to remain long on its ſurface, the metal becomes partly oxydated.

99 Sulphuret of copper.

Sulphur mixes readily with copper. The combination may be formed by mixing the ingredients together and applying a pretty ſtrong heat. *Sulphuret of copper* is brittle, ſofter than copper, of a black colour externally, and within of a leaden grey. It is compoſed, according to Kirwan's experiments, of 81 parts of copper and 19 of ſulphur*.

* *Kirwan's Miner.* ii. 508.

100 Phoſphuret of copper.

Mr Pelletier formed *phoſphuret of copper* by melting together one ounce of copper, one ounce of phoſphoric glaſs, and one dram of charcoal. It was of a white colour. On expoſure to the air, it loſt its luſtre and became blackiſh‡. Margraf was the firſt perſon that formed this phoſphuret. His method was to diſtil phoſphorus and brown oxyd of copper together. It is formed moſt eaſily by projecting phoſphorus into red hot copper. According to Pelletier, it contains 20 parts of phoſphorus and 80 of copper*. This phoſphuret is harder than iron: It is not ductile, and yet cannot eaſily be pulveriſed. Its ſpecific gravity is 7,1220. It cryſtallizes in tetrahedral priſms‡.

‡ *Ann. de Chim.* i. 74.

* *Ibid.* xiii. 3.

‡ *Sage, Journ. de Phyſ.* xxxviii. 468.

Copper ‖ Iron.

101 Alloys of copper.

1. Copper combines readily with gold when the two metals are melted together. The compound is of a reddiſh colour, more fuſible than gold, but leſs ductile. The proportions of the ingredients which form this alloy are not known; nor would it be eaſy to aſcertain them, as the two metals are almoſt equally fuſible. The current gold of this country is compoſed of 11 parts of gold and one part of copper.

2. The alloy of copper and ſilver is made as eaſily as that of gold, and the properties are equally unknown. It is harder and more ſonorous than ſilver. The current ſilver coin of Britain is compoſed of 15 parts of ſilver and one of copper.

3. Platinum combines readily with copper. The alloy is much more fuſible than platinum; it is ductile, hard, takes a fine poliſh, and is not liable to tarniſh. This alloy has been employed with advantage for compoſing the mirrors of reflecting teleſcopes.

4. The amalgam of copper cannot be formed by ſimply mixing that metal with mercury, nor even by the application of heat; becauſe the heat neceſſary to melt copper ſublimes mercury. Dr Lewis has given us ſeveral proceſſes for forming this amalgam. One of the ſimpleſt is to triturate mercury with a quantity of common ſalt and verdigriſe; a ſubſtance compoſed of oxyd of copper and vinegar. The theory of this proceſs is not very obvious.

102 Its affinities.

The affinities of copper are, according to Bergman, as follows:

Gold,
Silver,
Arſenic,
Iron,
Manganeſe,
Zinc,
Antimony,
Platinum,
Tin,
Lead,
Nickel,
Biſmuth,
Cobalt,
Mercury,
Sulphuret of alkali,
Sulphur,
Phoſphorus.

Sect. VI. *Of Iron.*

103 Diſcovery of iron.

Iron, the moſt abundant and moſt uſeful of all the metals, was neither known ſo early, nor wrought ſo eaſily, as gold, ſilver, and copper. For its diſcovery we muſt have recourſe to the nations of the eaſt, among whom, indeed, almoſt all the arts and ſciences firſt ſprung up. The writings of Moſes (who was born about 1635 years before Chriſt) furniſh us with the ampleſt proof at how early a period it was known in Egypt and Phœnicia. He mentions furnaces for working iron‡, ores from which it was extracted*; and tells us, that ſwords‖, knives¶, axes†, and tools for cutting ſtones§, were then made of that metal. How many ages before the birth of Moſes iron muſt have been diſcovered in theſe countries, we may perhaps conceive, if we reflect, that the knowledge of iron was brought

‡ Deut. iv. 20.
* *Ibid.* viii. 9.
‖ Numb. xxxv. 16.
¶ Levit. i. 17.
† Deut. xviii. 5.
§ *Ibid.* xxvii. 5.

Iron.

brought over from Phrygia to Greece by the Dactyli*, who settled in Crete during the reign of Minos I. about 1431 years before Christ; yet during the Trojan war, which happened 200 years after that period, iron was in such high estimation, that Achilles proposed a ball of it as one of his prizes during the games which he celebrated in honour of Patroclus (R). At that period none of their weapons were formed of iron. Now if the Greeks in 200 years had made so little progress in an art which they learned from others, how long must it have taken the Egyptians, Phrygians, Chalybes, or whatever nation first discovered the art of working iron, to have made that progress in it which we find they had done in the days of Moses?

* *Hesiod*, as quoted by *Pliny*, lib. vii. c. 57.

104 Its properties.

Iron, when fresh broken, is of a bluish grey colour. It has a styptic taste, and emits a smell when rubbed.

It is malleable and ductile in every temperature; and its malleability is increased in proportion as the temperature augments. Its tenacity is such, that an iron wire $\frac{1}{10}$ of an inch in diameter sustains a weight of 450 pounds without breaking.*

* *Macquer's Dict.*

Its hardness is such, that it may be easily reduced to powder by the application of a file. Its specific gravity is 7,788. It is infusible in the strongest heats hitherto produced.

It is attracted by the magnet or loadstone, and is itself capable of becoming magnetic; but it retains this property only for a very short time.

It is not hardened by being plunged into liquids while hot, nor softened by being cooled slowly.

Iron combines with oxygen very readily. When kindled in oxygen gas, it burns with great rapidity and splendor, and is in this manner converted into an oxyd. It is converted into an oxyd also when surrounded by moist air, or when plunged in water; because it has a stronger affinity for oxygen than hydrogen has, and is therefore capable of decomposing water.

105 Forms two oxyds.

Mr Proust has lately proved, that there are only two oxyds of iron, the *green*, and the *brown* or *red*, and that all the other supposed oxyds are merely mixtures of these two in various proportions†.

† *Ann. de Chim.* xxiii. 85. and *Nicholson's Journal*, i. 453.

The *green oxyd* may be obtained by dissolving iron in sulphuric acid, and then precipitating it by potass. It is a light, green-coloured, earthy-like substance, composed, as Mr Lavoisier has shewn, of 27 parts of oxygen, and 73 of iron‡. When this oxyd is exposed to the air, it quickly absorbs more oxygen, and is converted into a brown powder, which is the *brown oxyd*. Mr Proust has proved that it contains 52 parts of iron and 48 of oxygen. This oxyd is well known under the name of *rust of iron*, which is generally, however, or perhaps always, combined with carbonic acid gas.

‡ *Mem. Acad. Par.* 1782.

106 Their affinities.

The affinities of these oxyds, according to Bergman, are as follows:

Gallic acid?
Oxalic acid,
Tartarous,
Camphoric,*
Sulphuric,
Saccholactic,
Muriatic,
Pyromucous‡,
Nitric,
Sebacic,
Phosphoric,
Arsenic,
Fluoric,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic.

* *La Grange.*

‡ *Schrickel.*

107 Sulphuret,

Iron unites readily with sulphur. Sulphuret of iron, formerly called *pyrites*, is found ready formed in many parts of the world. It is not easy to determine the proportions of its ingredients, because it is capable of combining both with iron and sulphur, and consequently, if there happens to be any excess of either during its formation, it takes it up. Perhaps the proportions are not far from equal parts of sulphur and of iron. It is of a pale yellow or brownish colour, and is capable of assuming a crystalline form. Its specific gravity is about 4,000. When placed upon the fire, it precipitates; and at a red heat loses its yellow colour, and becomes of an iron grey, excepting its surface, which is of a bright red. It melts at 102° Wedgewood in a covered crucible into a bluish slag, somewhat porous internally.‡ When exposed to air and moisture, the sulphur, as happens in all sulphurets, gradually absorbs oxygen, and is converted into an acid.

‡ *Kirwan's Miner.* ii. 76.

If iron filings and sulphur be mixed together, and formed into a paste with water, the sulphur decomposes the water, and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under ground. This phenomenon was first discovered by Homberg; and it is considered as affording an explanation of the origin of volcanoes. The native sulphuret of iron has been observed more than once to take fire on being suddenly moistened with water.

208 Phosphuret,

Iron combines readily with phosphorus, and forms *phosphuret of iron*; to which Bergman, who first discovered it, gave the name of *siderum*.

There is a particular kind of iron, known by the name of *cold short iron*, because it is brittle when cold, though it be malleable when hot. Bergman was employed

(R) Αυταρ Πηλειδης θηκεν σολον αυτοχοωνον,
Ὁν πριν μεν ριπτασκε μεγα σθενος Ηετιωνος·
Αλλ' ητοι τον επεφνε ποδαρκης διος Αχιλλευς,
Τον δ' αγετ' εν νηεσσι συν αλλοισι κτεατεσσι.
Στη δ' ορθος, ϗ μυθον εν Αργειοισιν εειπεν·
Ορνυσθ', οἱ ϗ τουτου αεθλου πειρησεσθε·
Ει οἱ ϗ μαλα πολλον αποπροθι πιονες αγροι,
Ἑξει μιν ϗ πεντε περιπλομενους ενιαυτους
Χρεωμενος· ου μεν γαρ οἱ ατεμβομενος γε σιδηρου
Ποιμην ουδ' αροτηρ, εισ' ες πολιν, αλλα παρεξει. Iliad, xxiii. l. 826.

Iron.

ployed at Upsal in examining the cause of this property, while Meyer was occupied at Stetin with the same investigation; and both of them discovered, nearly at the same time, that, by means of sulphuric acid, a white powder could be separated from this kind of iron, which by the usual process they converted into a metal of a dark steel grey, exceedingly brittle, and not very soluble in acids. Its specific gravity was 6,700; it was not so fusible as copper; and when combined with iron rendered it *cold short*. Both of them concluded that this substance was a new metal; and Bergman gave it the name of *siderum*. But Klaproth soon after recollecting that the salt composed of phosphoric acid and iron bore a great resemblance to the white powder obtained from cold short iron, suspected the presence of phosphoric acid in this new metal. To decide the point, he combined phosphoric acid and iron, and obtained, by heating it in a crucible along with charcoal powder (s), a substance exactly resembling the new metal. Meyer, when Klaproth communicated to him this discovery, informed him that he had already satisfied himself, by a more accurate examination, that siderum contained phosphoric acid. Soon after this, Scheele actually decomposed the white powder obtained from cold short iron, and thereby demonstrated, that it was composed of phosphoric acid and iron. The siderum of Bergman, however, is composed of phosphorus and iron, the phosphoric acid being deprived of its oxygen during the *reduction*; or it is phosphuret of iron. It may be formed by fusing in a crucible an ounce of phosphoric glass, an ounce of iron, and half a dram of charcoal powder. It is very brittle, and appears white when broken. When exposed to a strong heat, it melts, and the phosphorus is dissipated.* It may be formed also by melting together equal parts of phosphoric glass and iron-filings. Part of the iron combines with the oxygen of the phosphoric glass, and is vitrified; the rest forms the phosphuret, which sinks to the bottom of the crucible. It may be formed also by dropping small bits of phosphorus into iron-filings heated red hot‡. The proportions of the ingredients of this phosphuret have not yet been determined.

* Pelletier, Ann. de Chim. i. 104.

‡ Id. Ann. de Chim. xiii. 113.

109 And carburet of iron.

Iron likewise combines with carbon, and forms a *carburet*. Carburet of iron has been long known and used in the arts under the names of *plumbago* and *black lead*. It is of a dark iron grey or blue colour, and has something of a metallic lustre. It has a greasy feel, and blackens the fingers, or any other substance to which it is applied. It is found in many parts of the world, especially in England, where it is manufactured into pencils. It is not affected by the most violent heat as long as air is excluded, nor is it in the least altered by simple exposure to the air, or to water. Its nature was first investigated by Scheele; who proved, by a very ingenious analysis, that it could be converted almost wholly into carbonic acid gas, and that the small residuum was iron. It follows from this analysis, that it is composed of carbon and iron; for the carbon during its combustion had been converted into carbonic acid gas. By the subsequent experiments of Pelletier and other French chemists, it has been shewn to consist nearly of nine parts of carbon to one of iron.

110 Varieties of iron.

There are a great many varieties of iron, which artists distinguish by particular names; but all of them may be reduced under one or other of the three following states: *Wrought iron* (or simply *iron*), *steel*, and *cast* or *raw iron*.

111 Wrought iron.

Wrought Iron is the substance which we have been hitherto describing. As it has never yet been decompounded, we consider it when pure as a simple body; but it has seldom or never been found without some small mixture of foreign substances. These substances are either some of the other metals, or oxygen, carbon, or phosphorus.

112 Steel.

Steel is distinguished from iron by the following properties.

It is so hard as to be unmalleable while cold, or at least it acquires this property by being immersed while ignited into a cold liquid: for this immersion, though it has no effect upon *iron*, adds greatly to the hardness of *steel*.

It is brittle, resists the file, cuts glass, affords sparks with flint, and retains the magnetic virtue for any length of time.

It loses this hardness by being ignited and cooled very slowly.

It melts at above 130° Wedgewood. It is malleable when red hot, but scarcely so when raised to a white heat.

It may be hammered out into much thinner plates than iron. It is more sonorous; and its specific gravity, when hammered, is greater than that of iron.

By being repeatedly ignited in an open vessel, and hammered, it becomes *wrought iron*†.

† Dr Pearson on Wootz, Phil. Transf.

113 Cast iron.

Cast Iron is distinguished by the following properties:

It is scarcely malleable at any temperature. It is generally so hard as to resist the file. It can neither be hardened nor softened as steel can by ignition and cooling. It is exceedingly brittle. It melts at 130° Wedgewood. It is more sonorous than steel.*

* Ibid.

Cast iron is converted into wrought iron by exposing it for a considerable time in a furnace to a heat sufficiently strong to melt it. During the process it is constantly stirred by a workman, that every part of it may be equally exposed to the air. In about an hour the hottest part of the mass begins to heave and swell, and to emit a lambent blue flame. This continues nearly an hour; and by that time the conversion is completed. The heaving is evidently produced by the emission of an elastic fluid‡.

‡ Beddoes, Phil. Transf. 1791.

Wrought iron may be converted into steel by being kept for some hours in a strong red heat, surrounded with charcoal powder in a covered crucible. By this process, which is called *cementation*, the iron gains some weight.

114 Cause of these varieties.

These different kinds of iron have been long known, and the converting of them into each other has been practised in very remote ages. Many attempts have been made to explain the manner in which this conversion is accomplished. According to Pliny, steel owes its peculiar properties chiefly to the water into which it is plunged in order to be cooled§. Becher supposed that fire was the only agent; that it entered into the iron, and converted it into steel. Reaumur was the first who attended accurately to the process; and his numerous experiments have certainly contributed to elucidate the subject. He supposed that iron was converted into

§ Pliny, l. xxxiv. 14.

(s) This process in chemistry is called *reduction*.

to steel by combining with saline and oily or sulphureous particles, and that these were introduced by the fire. But it was the analysis of Bergman, published in 1781, that first paved the way to the explanation of the nature of these different species of iron.

By dissolving in diluted sulphuric acid 100 parts of cast iron, he obtained 40 ounce measures of hydrogen; from 100 parts of steel he obtained 48 ounce measures; and from 100 parts of wrought iron, 50 ounce measures. Now as the hydrogen is produced by the property which iron has of decomposing water and uniting with its oxygen, it is evident that the greater the quantity of hydrogen obtained, with the more oxygen does the iron combine. But the quantities of iron were equal; they ought therefore to have combined with equal quantities of oxygen. But it is evident, from the quantities of hydrogen obtained, that the cast iron received less oxygen than either of the other two: cast iron therefore must contain already some oxygen, since it requires less than the other two species in order to be saturated. Here then is one difference between cast iron and the other two kinds; it contains oxygen. Steel, on the contrary, does not appear to contain any oxygen. The difference between the quantity of hydrogen produced during its solution and that of wrought iron, which contains no oxygen, is exceedingly small, and it has been found to diminish in proportion to the purity of the steel.

From 100 parts of cast iron Bergman obtained 2,2 of plumbago, or $\frac{1}{45}$; from 100 parts of steel, 0,5, or $\frac{1}{200}$; and from 100 parts of wrought iron, 0,12, or $\frac{1}{900}$. Now plumbago is composed of $\frac{9}{10}$ths of carbon; cast iron therefore contains a considerable quantity of carbon, steel a smaller quantity, and wrought iron a very minute portion, which diminishes according to its purity, and would vanish altogether if iron could be obtained perfectly pure. Mr Grignon, in his notes on this analysis, endeavoured to prove, that plumbago was not essentially a part of cast iron and steel, but that it was merely accidentally present. But Bergman, after considering his objections, wrote to Morveau on the 18th November 1783. "I will acknowledge my mistake whenever Mr Grignon sends me a single bit of cast iron or steel which does not contain plumbago; and I beg of you, my dear friend, to endeavour to discover some such, and to send them to me; for if I am wrong, I wish to be undeceived as soon as possible."* This was almost the last action of the illustrious Bergman. He died a few months after at the age of 49, leaving behind him a most brilliant reputation, which no man ever more deservedly acquired. His industry, his indefatigable, his astonishing industry, would alone have contributed much to establish his name; his extensive knowledge would alone have attracted the attention of philosophers; his ingenuity, penetration, and accurate judgment, would alone have secured the applause; and his candour and love of truth procured him the confidence and the esteem of the world—But all these qualities were united in Bergman, and conspired to form one of the greatest men and noblest characters that ever adorned human nature.

* *Morveau, Encycl. Method. Chimie* i. 448.

The experiments of Bergman were fully confirmed by those of Morveau, Vandermonde, Monge, and Berthollet, who have likewise thrown a great deal of additional light on the subject. From all these experiments the following deductions may be made.

Wrought iron is a simple substance, and if perfectly pure would contain nothing but *iron*.

Steel is iron combined with carbon. The proportion of this last ingredient has not yet been ascertained; Dr Pearson fixes it at $\frac{1}{300}$th part at a medium. Steel, in consequence of its composition, has been called by some chemists *carburet of iron*; but before assigning it that name, which has been also given to plumbago, it ought to be determined what are the proportions of carbon and iron which saturate each other. Is it the proportion in which these two substances exist in steel, or that which forms plumbago? In the first case, plumbago is carburet of iron combined with carbon; in the second, steel is carburet combined with iron. Or is it some intermediate proportion? Till these points be determined, perhaps it would be better to continue the old names than to risk the imposing of false ones.

Cast iron is iron contaminated with various foreign substances, the proportions of which vary according to circumstances. These substances are chiefly oxyd of iron and carbon, and sometimes silica (T).

Bergman found a quantity of manganese in the iron and steel which he examined; but it appears from the experiments of Vauquelin, that his method of determining the presence of that metal was not accurate.

115
Vauquelin's analysis of steel.

Mr Vauquelin* has lately analysed four kinds of steel with great care, and contrived his processes with much ingenuity. The result of his analysis is as follows:

* *Jour. de Mines.* See *Nicholson's Journal*, i. 200.

First steel, composed of	Carbon,	-	0,00789
	Silica,	-	0,00315
	Phosphorus,		0,00345
	Iron,	-	0,98551
			1
Second steel, composed of	Carbon,	-	0,00683
	Silica,	-	0,00273
	Phosphorus		0,00827
	Iron,	-	0,98217
			1
Third steel, composed of	Carbon,	-	0,00789
	Silica,	-	0,00315
	Phosphorus,		0,00791
	Iron	-	0,98105
			1
Fourth steel, composed of	Carbon,	-	0,00631
	Silica,	-	0,00252
	Phosphorus,		0,01520
	Iron,	-	0,97597
			1

It cannot be concluded from these experiments, that all steel contains phosphorus and silica; far less that these substances enter necessarily into the composition of steel. This *may* be the case, and former analyses may not have been nice enough to detect it; but before it can be admitted, it must be shewn that these substances are always present in steel, and that it loses its essential properties when deprived of them.

(T) An earth which shall be described in the next chapter.

116 Alloys of iron.

Iron combines with moft metals.

1. The alloy of gold and iron is very hard, and might, according to Dr Lewis who examined it, be employed with advantage in forming cutting inftruments.

2 That iron combines with filver is certain, but hardly any thing is known about the nature of the compound.

3. Platinum is ufually found alloyed with iron. Dr Lewis did not fucceed in his attempts to unite thefe metals by fufion, but he melted together caft iron and platinum. The alloy was exceffively hard, and poffeffed ductility.

4. There is very little affinity between iron and mercury; they cannot therefore be amalgamated by fimple mixture, even with the affiftance of heat. Vogel affirms that he has produced an amalgam of iron by the following procefs; Pound one part of iron filings and two parts of alum in a mortar to a fine powder; then pour in two or three parts of mercury, and triturate till the fubftances be thoroughly mixed. Pour on a little water, and continue the trituration for about an hour. If then no particles of iron can be diftinguifhed, pour on a little more water to wafh out the alum, and then dry the amalgam. If particles of iron be perceptible, the trituration muft be continued till they difappear.*

* *Ann. de Chim.* vi. 39.

5. Iron may be united to copper by fufion, but not without confiderable difficulty. The alloy has been applied to no ufe.

117 Its affinities.

The affinities of iron, according to Bergman, are as follows:

Nickel,
Cobalt,
Manganefe,
Arfenic,
Copper,
Gold,
Silver,
Tin,
Antimony,
Platinum,
Bifmuth,
[illegible],
Mercury,
Sulphuret of alkali,
Carbon?
Phofphorus?
Sulphur?

Sect. VII. *Of Tin.*

The Phenicians were the firft of thofe nations which make a figure in ancient hiftory that were acquainted with *tin*. They procured it from Spain* and from Britain, with which nations they carried on a very lucrative commerce. At how early a period they imported this metal we may eafily conceive, if we recollect that it was in common ufe in the time of Mofes †.

* *Pliny*, l. 4. c. 34. and l. 34. c. 47.

† *Numbers* xxxi. 22.

118 Properties of tin;

Tin is of a greyifh white colour; it has a ftrong difagreeable tafte, and emits a peculiar fmell when rubbed.

It is very malleable; tin leaf, or *tinfoil* as it is called, is about $\frac{1}{1000}$th part of an inch thick, and it might be beat out into leaves as thin again if fuch were wanted for the purpofes of art. Its ductility, however, is exceedingly imperfect; for a tin wire $\frac{1}{10}$th of an inch in diameter, is capable of fupporting only 49 pounds without breaking ‡. It is very flexible, and produces a crackling noife when bended.

Its hardnefs is 6+. Its fpecific gravity is 7,291 †; after hammering, 7,299 ||.

It melts at the temperature 410°, according to Dr Lewis; according to the Dijon academicians, at 419°. When heated red hot in clofe veffels it fublimes. It cryftallizes in the form of a rhomboidal prifm.*

‡ *Macquer's Dictionary.*

† *Kirwan's Miner.* ii. 195.

|| *Briffon.*

* *Pajot. Jour. de Phyf.* xxxviii. 52.

119 Oxyds,

Tin unites very readily with oxygen. When heated in contact with air, its furface foon becomes covered with a grey pellicle; when this is taken off, another appears foon after; and in this manner the whole metal may be converted into a dirty grey powder, which is the *grey oxyd of tin*. It is compofed, according to Fourcroy, of 90 parts of tin and 10 of oxygen.

When tin is heated red hot in contact with air, it takes fire †, and burns with a very lively white flame, and is gradually fublimed. If the fublimate be examined, it is found to confift of a white powder; it is the *white oxyd of tin*. The white oxyd is perhaps never obtained quite pure by this procefs; it feems always to contain a mixture of *grey oxyd*: but it may be obtained pure by pouring nitric acid upon tin, and then drying it. That metal having a much ftronger attraction for oxygen than azot has, decompofes the acid with the greateft rapidity, and affumes the appearance of a white powder, which is the *white oxyd*. This oxyd poffeffes many of the properties of an acid, and is therefore often called *ftannic acid*. It feems to confift of about 77 parts of tin and 23 of oxygen ‡.

† *Geoffroy.*

‡ *Kirwan's Miner.* ii. 488.

The affinities of the grey oxyd of tin, according to Bergman, are as follows:

Pyromucous acid,*
Sebacic acid,
Tartaric,
Muriatic,
Sulphuric,
Oxalic,
Arfenic,
Phofphoric,
Nitric,
Succinic,
Fluoric,
Saccholactic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruffic.

* *Schrickel.*

120 Sulphurets,

Tin combines readily with fulphur. This fulphuret may be formed by fufing the two ingredients together. It is brittle, heavier than tin, and not fo fufible. It is of a bluifh colour and lamellated ftructure, and is capable of cryftallizing. According to Bergman, it is compofed of 80 parts of tin and 20 of fulphur; according to Pelletier, of 85 parts of tin and 15 of fulphur.*

Sulphur likewife combines with the white oxyd of tin, by mixing them together, and applying a gentle heat.† This compound has been called *aurum mufivum*. It is a mafs confifting of beautiful gold coloured flakes, and is ufed as a paint. It is compofed of about 40 parts of fulphur and 60 of white oxyd of tin ‡. The procefs for making this fubftance was formerly very complicated. Pelletier firft demonftrated its real compofition, and

* *Ann. de Chim.* xiii. 287.

† *Pelletier. Ibid.* p. 297.

‡ *Ibid.* 293.

Tin.

and was hence enabled to make many important improvements in the manner of manufacturing it ‖.

‖ See his *Memoire, Ann. de Chim.* xiii. 280.

Phoſphorus is eaſily combined with tin, by melting in a crucible equal parts of filings of tin and phoſphoric glaſs. Tin has a greater affinity for oxygen than phoſphorus has. Part of the metal therefore combines with

121 Phoſphuret,

the oxygen of the glaſs during the fuſion, and flies off in the ſtate of an oxyd, and the reſt of the tin combines with the phoſphorus. The phoſphuret of tin may be cut with a knife; it extends under the hammer, but ſeparates in laminæ. When newly cut it has the colour of ſilver; its filings reſemble thoſe of lead. When theſe filings are thrown on burning coals, the phoſphorus takes fire. This phoſphuret may likewiſe be formed by dropping phoſphorus gradually into melted tin. According to Pelletier, to whoſe experiments we are indebted for the knowledge of all the phoſphurets, it is compoſed of about 85 parts of tin, and 15 of phoſphorus*. Margraf alſo formed this phoſphuret, but he was ignorant of its compoſition.

* *Ann. de Chim.* xiii. 116.

122 Alloys,

Tin does not ſeem capable of combining with carbon. It is capable of combining with moſt of the metals.

1. It mixes readily with gold by fuſion; but the proportions in which theſe metals combine chemically are ſtill unknown. When one part of tin, and twelve of gold are melted together, the alloy is brittle, hard, and bad coloured. Twenty-four parts of gold and one of tin, produce a pale coloured alloy, harder than gold, but poſſeſſed of conſiderable ductility. Gold alloyed with no more than $\frac{1}{17}$th of tin is ſcarcely altered in its properties, according to Mr Alchorne†; but Mr Tillet, who has lately examined this alloy, found that whenever it was heated, it broke into a number of pieces.

† *Alchorne, Phil. Tranſ.*

2. The alloy of ſilver and tin is hardly known. According to Gellert and ſucceeding chemiſts, it is exceedingly brittle.

3. The alloy of platinum and tin is very fuſible and brittle, at leaſt when theſe metals are mixed in equal proportions‡.

‡ *Dr Lewis.*

4. Mercury diſſolves tin very readily, by being poured on it when melted. This amalgam cryſtallizes in the form of cubes, according to Daubenton; but according to Sage, in grey brilliant ſquare plates, thin towards the edges, and attached to each other ſo that the cavities between them are polygonal. It is compoſed of three parts of mercury and one of tin. The amalgam of tin is uſed to ſilver the backs of glaſs mirrors.

5. Tin unites very readily with copper, and forms alloys known by the names of *bronze* and *bell-metal*. The proportions of the ingredients cannot eaſily be aſſigned, perhaps becauſe the alloy has an affinity both for copper and tin. The ſpecific gravity of the alloy in all proportions is greater than the mean ſpecific gravity of the two metals ſeparately. When the quantity of tin is ſmall compared to that of the copper, $\frac{1}{10}$th for inſtance, the alloy is called *bronze*: it is brittle, yellow, and much heavier than copper; much more fuſible, and leſs liable to be altered by expoſure to the air. It was this alloy which the ancients uſed for ſharp edged inſtruments before the method of working iron was brought to perfection. The χαλκος of the Greeks, and perhaps the *æs* of the Romans, was nothing elſe. Even their copper coins contain a mixture of tin*.

* See *Dizé's Analyſis, Jour. de Phyſ.* 1790.

6. Tin ſeems capable of being united to iron by fuſion. That there is an affinity between theſe metals is evident from their adheſion when iron is dipt into melted tin. This is the method of making *tinplate*.

Tin ‖ Lead.

123 And affinities of tin.

The affinities of tin, according to Bergman, are as follows:

Zinc,
Mercury,
Copper,
Antimony,
Gold,
Silver,
Lead,
Iron,
Manganeſe,
Nickel,
Arſenic,
Platinum,
Biſmuth,
Cobalt,
Sulphuret of alkali,
Oxygen?
Sulphur?
Phoſphorus?

SECT. VIII. *Of Lead.*

LEAD appears to have been very early known. It is mentioned ſeveral times by Moſes. The ancients ſeem to have conſidered it as nearly related to tin.

124 Properties of lead.

Lead is of a bluiſh white colour, ſomewhat darker than tin. When newly melted it is very bright, but ſoon becomes tarniſhed by expoſure to the air. It has ſcarcely any taſte, but emits on friction a peculiar ſmell.

It is very malleable, and may be reduced to thin plates by the hammer; but its ductility is very imperfect: a wire of lead $\frac{1}{10}$th of an inch in diameter is only capable of ſupporting a weight of 29¼ pounds.*.

Its hardneſs is 5†; its ſpecific gravity is 11,3523‡ Its ſpecific gravity is not increaſed by hammering, neither does it become harder, as is the caſe with other metals: a proof that the hardneſs which metals aſſume under the hammer is in conſequence of an increaſe of denſity.

* *Macquer's Dictionary.*
† *Kirwan's Miner.* ii. 202.
‡ *Briſſon.*

It melts, according to Dr Lewis, at 540° Farenheit; according to the Dijon academicians, at 549°. When expoſed to a violent heat, it evaporates completely.

When cooled ſlowly, after being fuſed, it cryſtallizes. The Abbé Mongez obtained it in quadrangular pyramids lying on one of their ſides. Each pyramid was compoſed as it were of three layers. Pajot obtained it in the form of a polyhedron with 32 ſides, formed by the concourſe of ſix quadrangular pyramids†.

† *Jour. Phyſ.* xxxviii. 53.

Lead ſtains paper or the fingers of a bluiſh black colour.

125 Its oxyds.

There is a ſtrong affinity between this metal and oxygen. When nitric acid is poured upon it, an effervеſcence enſues, owing to the decompoſition of the acid; the lead ſeizes oxygen from it, and is converted into a white powder, which may be obtained pure by evaporating it to dryneſs, and then waſhing it in pure water. This is the *white oxyd of lead*. It is compoſed of about 95 parts of lead, and five of oxygen‡. The affinities of this oxyd are, according to Bergman, as follows:

‡ *Kirwan's Miner.* ii. 499.

Sulphuric acid,
Sebacic,
Saccholactic,
Oxalic,

Arſenic,

Lead.

Arſenic,
Tartarous,
Phoſphoric,
Muriatic,
Benzoic (u)?
Sulphurous,
Suberic ?} (v)
Zoonic ? }
Nitric,
Pyromucous (v)?
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Fixed alkali.

When lead is expoſed to heat in contact with air, its ſurface is ſoon covered with a grey pellicle; when this is taken off, another ſoon forms: and in this manner, the whole lead may ſoon be converted into a dirty grey powder, which ſeems to be the white oxyd mixed with a little lead. When this powder is heated red hot, it aſſumes a deep yellow colour. This is the *yellow oxyd* of lead, formerly called *maſſicot*. If the heat be continued, the colour is gradually changed to a beautiful red. This is the *red oxyd of lead*, formerly called *minium*. It is compoſed, as Lavoiſier has ſhewn, of 88 parts of lead and 12 of oxygen*.

* *Mem. Par.* 1781.

The manner in which theſe changes are brought about is evident; the metal gradually abſorbs oxygen from the atmoſphere. This has been actually proved by experiment. Theſe oxyds (if they really differ in the proportion of oxygen) reſemble acids in ſeveral of their properties. They are very eaſily converted into glaſs by fuſion. Scheele has ſhewn that there is alſo a *brown oxyd of lead*, which contains more oxygen than any of the others.

126 Sulphuret,

Sulphur unites eaſily to lead by fuſion. The ſulphuret of lead is brittle, of a deep grey colour, and much leſs fuſible than lead. Theſe two ſubſtances are often found naturally combined; the compound is then called *galena*. Sulphuret of lead is compoſed, according to the experiments of Wenzel, of 868 parts of lead, and 132 of ſulphur†.

† *Kirwan's Miner.* ii. 492.

127 Phoſphuret,

Phoſphuret of lead may be formed by mixing together equal parts of filings of lead and phoſphoric glaſs, and fuſing them in a crucible. It may be cut with a knife, but ſeparates into plates when hammered. It is of a ſilver white colour with a ſhade of blue, but it ſoon tarniſhes when expoſed to the air. This phoſphuret may alſo be formed by dropping phoſphorus into melted lead. It is compoſed of about 12 parts of phoſphorus and 88 of lead‡.

‡ *Pelletier, Ann. de Chim.* xiii. 114.

Lead combines with moſt of the other metals.

128 Alloys, and

1. Little is known concerning the alloy of lead and gold. It is ſaid to be brittle.

2. The alloy of ſilver and lead is very fuſible, and neither elaſtic nor ſonorous.

3. Platinum and lead unite in a ſtrong heat: the alloy is brittle, of a purpliſh colour, and ſoon changes on expoſure to the air§.

§ *Fourcroy.*

4. Mercury, when poured upon melted lead, diſſolves it readily. The amalgam is white and brilliant, and aſſumes a ſolid form. It is capable of cryſtallizing. The cryſtals are compoſed of one part of lead and one and a half of mercury.‖

‖ *Dijon Academicians.*

5. Copper and lead combine eaſily by fuſion; but the alloy has not been applied to any uſe.

6. Iron does not unite with lead.

7. Lead and tin may be combined by fuſion. The alloy in the proportion of two parts of lead, and one of tin, is more ſoluble than either of the metals ſeparately. It is accordingly uſed by plumbers as a ſolder.

129 Affinities.

Lead, when taken internally, acts as a poiſon. Its affinities, according to Bergman, are as follows:

Gold,
Silver,
Copper,
Mercury,
Biſmuth,
Tin,
Antimony,
Platinum,
Arſenic,
Zinc,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phoſphorus?

130 Names and marks given to the metals by the ancients.

The ancients gave to the ſeven metals laſt deſcribed (omitting *platinum*, which they did not know) the names of the planets, and denoted each of them by particular marks, which repreſented both the planet and the metal.

Gold was the	Sun, and repreſented by	☉.
Silver the	Moon,	☾.
Mercury	Mercury,	☿.
Copper	Venus,	♀.
Iron	Mars,	♂.
Tin	Jupiter,	♃.
Lead	Saturn,	♄.

It ſeems moſt probable that theſe names were firſt given to the planets; and that the ſeven metals, the only ones then known, were ſuppoſed to have ſome relation to the planets or to the gods that inhabited them, as the number of both happened to be the ſame. It appears from a paſſage in Origen, that theſe names firſt aroſe among the Perſians (w). Why each particular metal

(u) Benzoat of lead is decompoſed by muriatic acid. *Trommſdorf, Ann. de Chim.* xi. 317.

(v) Suberic acid decompoſes nitrat of lead. See *Jameſon's Mineralogy*, p. 166. Zoonic acid produces the ſame effect, as Berthollet has obſerved.

(v) Schrikel places it after the three mineral acids.

(w) *Contra Celſum*, lib. vi. 22.—" Celſus de quibuſdam Perſarum myſteriis ſermonem facit. Harum rerum, inquit, aliquod reperitur in Perſarum doctrina Mithraciſque eorum myſteriis veſtigium. In illis enim duæ cœleſtes converſiones, alia ſtellarum fixarum, errantium alia, et animæ per eas tranſitus quodam ſymbolo repræſentantur, quod

Lead. metal was denominated by a particular planet it is not easy to see. Many conjectures have been made, but scarcely any of them are satisfactory.

131 Origin of these marks according to the astrologers;

As to the characters by which these metals were expressed, astrologers seem to have considered them as the attributes of the deities of the same name. The circle in the earliest periods among the Egyptians was the symbol of divinity and perfection; and seems with great propriety to have been chosen by them as the character of the sun, especially as, when surrounded by small strokes projecting from its circumference, it may form some representation of the emission of rays. The semicircle is, in like manner, the image of the moon; the only one of the heavenly bodies that appears under that form to the naked eye. The character ♄ is supposed to represent the scythe of Saturn; ♃ the thunderbolts of Jupiter; ♂ the lance of Mars, together with his shield; ♀ the looking-glass of Venus; and ☿ the caduceus or wand of Mercury.

132 According to the alchemists.

The alchemists, however, give a very different account of these symbols. Gold was the most perfect metal, and was therefore denoted by a circle. Silver approached nearest it; but as it was inferior, it was denoted only by a semicircle. In the character ☿ the adepts discovered gold with a silver colour. The cross at the bottom expressed the presence of a mysterious something, without which mercury would be silver or gold. This something is combined also with copper; the possible change of which into gold is expressed by the character ♀. The character ♂ declares the like honourable affinity also; though the semicircle is applied in a more concealed manner: for, according to the properest mode of writing, the point is wanting at the top, or the upright line ought only to touch the horizontal, and not to interfect it. Philosophical gold is concealed in steel; and on this account it produces such valuable medicines. Of tin, one half is silver, and the other consists of the unknown something; for this reason the cross with the half moon appears in ♃. In lead this something is predominant, and a similitude is observed in it to silver. Hence in its character ♄ the cross stands at the top, and the silver character is only suspended on the right hand behind it.

133 Their real origin.

The fact, however, according to Professor Beckmann, from whom most of the above remarks have been taken, seems to be, that these characters are mere abbreviations of the old names of the planets. "The character of Mars (he observes*), according to the oldest mode of representing it, is evidently an abbreviation of the word Θουρος, under which the Greek mathematicians understood that deity; or, in other words, the first letter Θ, with the last letter ς placed above it. The character of Jupiter was originally the initial letter of Ζευς; and in the oldest manuscripts of the mathematical and astrological works of Julius Firmicus, the capital Z only is used, to which the last letter ς was afterwards added at the bottom, to render the abbreviation more distinct. The supposed looking-glass of Venus is nothing else than the initial letter distorted a little of the word Φωσφορος, which was the name of that goddess. The imaginary scythe of Saturn has been gradually formed from the two first letters of his name Κρονος, which transcribers, for the sake of dispatch, made always more convenient for use, but at the same time less perceptible. To discover in the pretended caduceus of Mercury the initial letter of his Greek name Στιλβων, one needs only look at the abbreviations in the oldest manuscripts, where they will find that the Σ was once written as C; they will remark also that transcribers, to distinguish this abbreviation from the rest still more, placed the C thus ◡, and added under it the next letter τ. If those to whom this deduction appears improbable will only take the trouble to look at other Greek abbreviations, they will find many that differ still farther from the original letters they express than the present character ☿ from the C and τ united. It is possible also that later transcribers, to whom the origin of this abbreviation was not known, may have endeavoured to give it a greater resemblance to the caduceus of Mercury. In short, it cannot be denied that many other astronomical characters are real symbols, or a kind of proper hieroglyphics, that represent certain attributes or circumstances, like the characters of Aries, Leo, and others quoted by Saumise."

* *History of Inventions, English translation*, iii. 67.

Sect. IX. *Of Zinc.*

Zinc. The ancients were acquainted with a mineral to which they gave the name of *Cadmea*, from Cadmus, who first taught the Greeks to use it. They knew that when melted with copper it formed brass; and that when burnt, a white spongy kind of ashes was volatilised, which they used in medicine*. This mineral contained a good deal of zinc; and yet there is no proof remaining that the ancients were acquainted with that metal (x). It is first mentioned in the writings of Albertus Magnus, who died in 1280; but whether he had seen it is not so clear, as he gives it the name of *marcasite of gold*, which implies,

134 Discovery of zinc.

* *Pliny*, l. 34. c. 2. and 10.

quod hujusmodi est. Scala altas portas habens, in summa autem octava porta. Prima portarum plumbea, altera stannea, tertia ex ære, quarta ferrea, quinta ex ære mixto, sexta argentea, septima ex auro. κλιμαξ ὑψιπυλος, επι δ' αιτῃ πυλη ογδοη. Ἡ πρωτη των πυλων μολιβδου, ἡ δευτερα κασσιτερου, ἡ τριτη χαλκου, ἡ τεταρτη σιδηρου, ἡ πεμπτη καρασου νομισματος, ἡ εκτη αργυρου, χρυσου δ' ἡ ἑβδομη. Primum assignant Saturno tarditatem illius sideris plumbo indicantes: alteram Veneri, quam referunt, ut ipsi quidem putant stanni splendor et mollities; tertiam Jovi, aheneam illam quidem et solidam: quartam Mercurio, quia Mercurius et ferrum, uterque operum omnium tolerantes, ad mercaturam utiles, laborum patientissimi. Marti quintam, inæqualem illam et variam propter mixturam. Sextam, quæ argentea est, lunæ; septimam auream soli tribuunt, quia solis et lunæ colores hæc duo metalla referunt."

Borrichius suspects, with a good deal of probability, that the names of the gods in this passage have been transposed by transcribers, either through ignorance or design. He arranges them as follows: "Secundam portam faciunt Jovis, comparantes ei stanni splendorem et mollitiem; tertiam Veneris æratam et solidam; quartam Martis, est enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter misturam inæqualem ac variam, et quia negotiator est; sextam Lunæ argenteam; septimam Solis auream." *Ol. Borrichius de ortu et progressu chemiæ.* Hafniæ, 1668, 4to. p. 29.

(x) Grignon indeed says, that something like it was discovered in the ruins of an ancient Roman city in Champagne; but the substance which he took for it was not examined with any accuracy. It is impossible therefore to draw any inference whatever from his assertion. *Bulletin des fouilles d'une ville Romaine.* p. 11.

Zinc.

implies, one would think, that it had a yellow colour (Y). The word *zinc* occurs first in the writings of Paracelsus, who died in 1541. He informs us very gravely, that it is a metal, and not a metal, and that it consists chiefly of the ashes of copper†. This metal has also been called *spelter*.

† See *Vol.* 6. *of his Works in* 4to.

Zinc has never been found in Europe in a state of purity, and it was long before a method was discovered of extracting it from its ore (Z). Henkel pointed out one in 1721, and Von Swab obtained it by distillation in 1742, and Margraf published a process in the Berlin Memoirs in 1746‡.

‡ *Bergman*, ii. 309.

135
Properties of zinc.

It is of a bluish white colour, somewhat lighter than lead. It has neither taste nor smell.

It has some degree of malleability; for by compression it may be reduced into thin plates§; but it cannot be drawn out into wire. It is more brittle when hot than when cold.

§ *Sage*.

Its hardness is 6*. Its specific gravity, when compressed, is 7,1908†; in its usual state, 6,862‡. It melts at about 699° Fahrenheit§.

* *Kirwan's Miner.* ii. 232.
† *Brisson.*
‡ *Kirwan, ibid.*
§ *Bergman.*

When allowed to cool slowly, it crystallizes in small bundles of quadrangular prisms, disposed in all directions. If they are exposed to the air while hot, they assume a blue changeable colour*.

* *Mongez.*

136
Its oxyds,

When zinc is kept melted in contact with air, it becomes covered with a grey pellicle, which gradually assumes a yellowish tint. By removing this pellicle from time to time, the whole of the metal may be reduced into a grey powder. This is the *grey oxyd of zinc*. This oxyd is probably composed of about 85 parts of zinc and 15 of oxygen†. When zinc is violently heated, it burns with a bright white flame, and at the same time a quantity of very light white flakes are sublimed. These flakes are the *white oxyd of zinc*, which contains a good deal more oxygen than the grey oxyd (A).

† *Morveau, Kirwan's Miner.* ii. 489.

Zinc may also be oxydated by solution in acids, particularly the nitric acid. Whether the oxyd obtained by precipitating zinc from its solution in that acid, or by distilling that acid off zinc, be really different from the white oxyd, has not yet been properly ascertained; but one would be apt to suspect, from the experiments mentioned by Mr Kirwan, that it contained a good deal more oxygen‖.

‖ *Mineral* ii. 499.

The affinities of the oxyds, or rather of the white oxyd of zinc, are, according to Bergman, as follows:

Oxalic acid,
Sulphuric,
Pyromucous*,
Muriatic,
Saccholactic,
Nitric,
Sebacic,
Tartaric,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic,
Ammonia.

* *Schrickel.*

137
Sulphuret,

There is an affinity between sulphur and zinc, as is evident from these two substances being often found united; but it is very difficult to form the sulphuret of zinc artificially, on account of the rapid oxydation and consequent volatilization of the zinc. Morveau, however, succeeded in forming it.

138
Phosphurets,

Zinc may be combined with phosphorus, by dropping small bits of phosphorus into it while in a state of fusion. Pelletier, to whom we are indebted for the experiment, added also a little resin, to prevent the oxydation of the zinc. Phosphuret of zinc is of a white colour, a metallic splendor, but resembles lead more than zinc. It is somewhat malleable. When hammered or filed, it emits the odour of phosphorus. When exposed to a strong heat, it burns like zinc*.

* *Ann. de Chim.* xiii, 129.

Phosphorus

(Y) The passages in which he mentions it are as follows:—*De Mineral.* lib. ii. cap. 11. "Marchasita, sive marchasida ut quidam dicunt, est lapis in substantia, et habet multas species, quare colorem accipit cujuslibet metalli, et sic dicitur marchasita argentea et aurea, et sic dicitur aliis. Metallum tamen quod colorat eum non distillat ab ipso, sed evaporat in ignem, et sic relinquitur cinis inutilis, et hic lapis notus est apud alchimicos, et in multis locis veniuntur.

Lib. iii. chap. 10. "Æs autem invenitur in venis lapidis, et quod est apud locum qui dicitur Goselaria est purissimum et optimum, et toti substantiæ lapidis incorporatum, ita quod totus lapis est sicut marchasita aurea, et profundatum est melius ex eo quod purius.

Lib. v. cap. 5. "Dicimus igitur quod marchasita duplicem habet in sui creatione substantiam, argenti vivi scilicet mortificati, et ad fixionem approximantis, et sulphuris adurentis. Ipsam habere sulphureitatem comperimus manifesta experientia. Nam cum sublimatur, ex illa emanat substantia sulphurea manifesta comburens. Et sine sublimatione similiter perpenditur illius sulphureitas.

"Nam si ponatur ad ignitionem, non suscipit illam priusquam inflammatione sulphuris inflammetur, et ardeat. Ipsam vero argenti vivi substantiam manifestatur habere sensibiliter. Nam albedinem præstat Veneri meri argenti, quemadmodum et ipsum argentum vivum, et colorem in ipsius sublimatione cælestium præstare, et luciditatem manifestam metallicam habere videmus, quæ certum reddunt artificem Alchimiæ, illam has substantias continere in radice sua."

(Z) The real discoverer of this method appears to have been Dr Isaac Lawson. See *Pott*, III. diss. 7. and *Watson's Chemical Essays*.

(A) Pott observed, that it was $\frac{1}{10}$th heavier than the zinc from which it was obtained; and Mr Boyle had long before ascertained the same fact.—*Shaw's Boyle*, II. 391, 394.

This oxyd of zinc was well known to the ancients. Dioscorides describes the method of preparing it. The ancients called it *pompholyx*, the early chemists gave it the name of *lana philosophica*. Dioscorides compares it to wool, εριων τολυπαις αφομοιουνται, v. 85. p. 352.

Zinc.

Phosphorus combines also with the oxyd of zinc, a compound which Margraf had obtained during his experiments on phosphorus. When 12 parts of oxyd of zinc, 12 parts of phosphoric glass, and two parts of charcoal powder, are distilled in an earthen ware retort, and a strong heat applied, a metallic substance sublimes of a silver-white colour, which when broken has a vitreous appearance. This, according to Pelletier, is phosphuret of oxyd of zinc. When heated by the blowpipe, the phosphorus burns, and leaves behind a glass transparent while in fusion, but opaque after cooling †.

† Pelletier, ibid. 128.

139 Carburet,

Zinc also combines with carbon, and forms carburet of zinc. The French chemists have shewn that zinc generally contains some carbon.

140 Alloys,

Zinc combines with most of the metals:

1. It mixes with gold in any proportion. The alloy is the whiter and the more brittle the greater quantity of zinc it contains. An alloy, consisting of equal parts of these metals, is very hard and white, receives a fine polish, and does not tarnish readily. It has therefore been proposed by Mr Malouin ‡ as very proper for the specula of telescopes. One part of zinc is said to destroy the ductility of 100 parts of gold ‖.

‡ Mem. Acad. Par. 1742.

‖ Keir's Macquer's Dictionary.

2. The alloy of silver and zinc is easily produced by fusion. It is brittle.

3. Platinum combines very readily with zinc. The alloy is brittle, pretty hard, very fusible, of a bluish white colour, not so clear as that of zinc.*

* Dr Lewis.

4. Zinc may be combined with mercury by fusion. The amalgam is solid. It crystallizes when melted and cooled slowly into lamellated hexagonal figures, with cavities between them. They are composed of one part of zinc and two and a half of mercury †. It is used to rub on electrical machines, in order to excite electricity.

† Elemens de Chim. Dijon, t. 3.

5. Zinc combines very readily with copper. This alloy, which is called *brass*, was known to the ancients. They used an ore of zinc to form it which they called *cadmia*. This alloy was very much valued by the ancients. Dr Watson has proved that it was to brass which they gave the name of *orichalcum*.* Their *æs* was copper or rather bronze (B). Brass is composed of about three parts of copper and one of zinc. It is of a beautiful yellow colour, more fusible than copper, and not so apt to tarnish. It is malleable, and so ductile that it may be drawn out into wire. When the alloy contains three parts of zinc and four of copper, it assumes a colour nearly the same with gold, but it is not so malleable as brass. It is then called *pinchbeck*, *prince's metal* or *Prince Rupert's metal*.

* Manchester Transf. vol. ii.

6. The alloy of iron and zinc has scarcely been examined: but Malouin has shewn that zinc may be used instead of tin to cover iron plates; a proof that there is an affinity between the two metals ‡.

Antimony.

‡ Mem. Par. 1742.

7. Tin and zinc combine easily. The alloy is harder than tin. This alloy is often the principal ingredient in the compound called *pewter*.

8. Mr Gmelin has succeeded in forming an alloy of zinc and lead by fusion. He put some suet into the mixture, and covered the crucible, in order to prevent the evaporation of the zinc. When the zinc exceeded the lead very much, the alloy was malleable, and much harder than lead. A mixture of two parts of zinc and one of lead formed an alloy more ductile and harder than the last. A mixture of equal parts of zinc and lead formed an alloy differing little in ductility and colour from lead; but it was harder, and more susceptible of polish, and much more sonorous. When the mixture contained a smaller quantity of zinc, it still approached nearer the ductility and colour of lead, but it continued harder, more sonorous, and susceptible of polish, till the proportions approached to one of zinc and 16 of lead, when the alloy differed from the last metal only in being somewhat harder.*

* Ann. de Chim. ix. 95.

141 And affinities.

The affinities of zinc, according to Bergman, are as follows:

Copper,
Antimony,
Tin,
Mercury,
Silver,
Gold,
Cobalt,
Arsenic,
Platinum,
Bismuth,
Lead,
Nickel,
Iron.

Sect. X. *Of Antimony.*

The ancients were acquainted with an oxyd of antimony to which they gave the names of στιμμι and *stibium*. Pliny* informs us, that it was found in silver ore; and we know that at present there are silver ores † in which it is contained. It was used as an external application to sore eyes; and Pliny gives us the method of preparing it ‡. Galen supposes that the τετραγωνον of Hippocrates was a preparation of antimony; but this wants proof. It does not appear, however, that the ancients considered this substance as a metal, or that they knew antimony in a state of purity (C). Who first extracted it from its ore we do not know; but Basil Valentine, a chemist of the 16th century, is the first who describes

* Pliny, l. xxxiii. c. 6.

† Kirwan's Miner. ii. 110.

‡ Pliny, ibid.

142 Discovery of antimony.

(B) The ancients do not seem to have known accurately the difference between copper, brass, and bronze. Hence the confusion observable in their names. They considered brass as only a more valuable kind of copper, and therefore often used the word *æs* indifferently to denote either. It was not till a late period that mineralogists began to make the distinction. They called copper *æs cyprium*, and afterwards only *cyprium*, which in process of time was converted into *cuprum*. When these changes took place is not known accurately. Pliny uses *cyprium*, lib. xxxvi. c. 26. The word *cuprum* occurs first in Spartian, who lived about the year 290. He says in his life of Caracalla, *cancelli ex ære vel cupro*.

(C) Mr Roux indeed, who at the request of Count Caylus analysed an ancient mirror, found it composed of copper, lead and antimony. This would go far to convince us that the ancients knew this metal, provided it could be proved that the mirror was *really* an ancient one; but this point appears to be extremely doubtful.

Antimony. describes the process. To him indeed we are indebted for our acquaintance with many of the properties of this metal.

Antimony is of a white colour, with a shade of grey. It has a sensible taste, but no smell ‖.

‖ *Fourcroy.*

143 Properties of antimony.

It is neither malleable nor ductile, but exceedingly brittle. Its specific gravity, according to Brisson, is 6,702; according to Bergman, 6,860. Its hardness is 6,5 §. It melts at 809° Fahrenheit ¶. If after this the heat be increased, the metal evaporates. On cooling it assumes the form of oblong crystals, perpendicular to the internal surface of the vessel in which it cools. It is to this crystallization that the laminated structure which antimony always assumes is owing.

§ *Kirwan's Miner.* ii. 244.
¶ *Bergman.*

144 Its oxyds,

Neither air nor water have much effect on this metal. When antimony is beat to powder, and exposed for some time to a gentle heat, it absorbs oxygen, and is converted into a grey powder. This is the *grey oxyd of antimony*. When this metal is kept for some time melted in contact with air, it sublimes in the form of a white powder, formerly called *snow* or *white flowers of antimony*. This is the *white oxyd of antimony*. This oxyd may be procured also by pouring nitric acid on antimony, and then evaporating to dryness. Antimony attracts the oxygen from the acid, and thus passes very rapidly into the state of an oxyd. This oxyd seems to consist of about 77 parts of antimony and 23 of oxygen.* The nature of these oxyds has never yet been accurately inquired into. It is not even known at present whether the white oxyd obtained by heat and that obtained by nitric acid contain the same quantity of oxygen. The experiments mentioned by Mr Kirwan make the contrary probable †; and yet these oxyds have too many qualities in common to render these experiments conclusive. The white oxyd of antimony is soluble in water ‡; and when fused, is converted into a transparent glass. The white oxyd obtained by nitric acid seems to possess many of the properties of an acid.

* *Kirwan's Miner.* ii. 489.
† *Ibid.*
‡ *Rouelle.*

The affinities of the grey oxyd of antimony are, according to Bergman, as follows:

Sebacic acid,
Muriatic,
Benzoic (D)?
Oxalic,
Sulphuric,
Pyromucous §,
Nitric,
Tartarous,
Saccholactic,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic.

§ *Schrickel.*

145 Sulphurets,

Sulphur combines readily with antimony. This compound is often found native: it was formerly called antimony, and the pure metal was then called *regulus of antimony*. Sulphuret of antimony is easily melted by a moderate heat: if the heat be continued, the sulphur sublimes, and at the same time the antimony absorbs oxygen, and is converted into a grey oxyd. This sulphuret is composed of 74 parts of antimony and 26 of sulphur.*

* *Bergman*, iii. 167.

The grey oxyd of antimony is also capable of combining with about $\frac{4}{100}$ of sulphur. This compound, by fusion, may be converted into glass. It was formerly used in medicine under the name of *glass of antimony*.

146 Phosphuret,

When equal parts of antimony and phosphoric glass are mixed together with a little charcoal powder, and melted in a crucible, phosphuret of antimony is produced. It is of a white colour, brittle, appears laminated when broken, and at the fracture there appear a number of small cubic facettes. When melted it emits a green flame, and then sublimes in the form of a white powder. Phosphuret of antimony may likewise be prepared by fusing equal parts of antimony and phosphoric glass, or by dropping phosphorus into melted antimony †.

† *Pelletier, Ann. de Chim.* xiii. 132.

Antimony is capable of combining with most of the metals.

147 Alloys,

1. Gold may be alloyed with antimony by fusing them together. The antimony is afterwards separable by an intense heat. This alloy is little known, and has never been applied to any use.

2. The alloy of silver and antimony is brittle, and its specific gravity, as Gellert has observed, is greater than intermediate between the specific gravities of the two metals which enter into it.

3. Platinum easily combines with antimony. The alloy is brittle, and much lighter than platinum.* The antimony cannot afterwards be completely separated by heat.

* *Dr Lewis.*

4. Mercury does not easily combine with antimony. Mr Gellert succeeded in amalgamating this metal by putting it into hot mercury, and covering the whole with water.

5. Copper combines readily with antimony by fusion. The alloy is of a beautiful violet colour, and its specific gravity is greater than intermediate †.

† *Gellert.*

6. Iron combines with antimony, and forms a brittle hard alloy, the specific gravity of which is less than intermediate. The magnetic quality of iron is much more diminished by being alloyed with antimony than with any other metal ‡.

‡ *Id.*

7. The alloy of tin and antimony is white and brittle; its specific gravity is less than intermediate §.

§ *Id.*

8. When equal quantities of lead and antimony are fused, the alloy is porous and brittle: three parts of lead and one of antimony form a compact alloy, malleable, and much harder than lead: 12 parts of lead and one of antimony form an alloy very malleable, and a good deal harder than lead: 16 parts of lead and one of antimony form an alloy which does not differ from lead except in hardness ¶. This alloy forms printers types.

¶ *Gmelin, Ann. de Chim.* viii. 319.

9. Zinc and antimony form a brittle alloy, the specific gravity of which is less than intermediate.* The alloys of antimony are little known. Gellert is almost the

* *Gellert.*

(D) Muriatic acid decomposes benzoat of antimony. *Trommsdorf, Ann. de Chim.* xi. 317.

the only perſon who has examined them. It would require a great number of experiments to be able to fix the proportions of their ingredients.

The affinities of antimony are, according to Bergman, as follows:

Iron,
Copper,
Tin,
Lead,
Nickel,
Silver,
Biſmuth,
Zinc,
Gold,
Platinum,
Mercury,
Arſenic,
Cobalt,
Sulphuret of arſenic,
Sulphur,
Phoſphorus?

Sect. XI. *Of Biſmuth.*

The ancients appear to have known nothing of biſmuth, nor do we know who diſcovered it; but it is firſt mentioned by George Agricola, who was born about the end of the 15th century.

148 Properties of biſmuth,

Biſmuth is of a yellowiſh or reddiſh white colour, and almoſt deſtitute both of taſte and ſmell.

It is brittle. Its hardneſs is 6*. Its ſpecific gravity is 9,8227‡. It melts at 460° Fahrenheit‡.

* Kirwan. † Briſſon. ‡ Lewis.

When heated in cloſe veſſels it ſublimes. When allowed to cool ſlowly after fuſion it cryſtallizes.

Biſmuth is not altered by water. When expoſed to the air it ſoon tarniſhes.

149 Its oxyds,

When biſmuth is kept fuſed in contact with air, it is gradually oxydated. When heated red hot, it emits a very faint blue flame, and its oxyd evaporates in the form of a yellowiſh ſmoke. When this ſmoke is collected, it is found to conſiſt of a brown coloured powder. This is the *brown oxyd of biſmuth*. It is compoſed of about 94 parts of biſmuth, and 6 of oxygen*. Biſmuth decompoſes nitric acid with great rapidity, by attracting its oxygen. If the quantity of acid be conſiderable, it diſſolves the oxyd as it forms; but the greater part of it may be precipitated by diluting the acid with water. This precipitate, which is a white powder, is *white oxyd of biſmuth*. It is compoſed of about 84 parts biſmuth, and 16 of oxygen†.

* Kirwan's Miner. ii. 489. † Ibid.

The affinities of the oxyds of biſmuth are, according to Bergman, as follows:

Oxalic acid,
Arſenic,
Tartarous,
Phoſphoric,
Sulphuric,
Sebacic,
Muriatic,
Benzoic(E)?
Nitric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Pruſſic,
Carbonic,
Ammonia.

150 Sulphuret,

Sulphur combines readily with biſmuth by fuſion. The ſulphuret of biſmuth is of a bluiſh grey colour, and cryſtallizes into beautiful tetrahedral needles. It is compoſed of 85 parts of biſmuth, and 15 of ſulphur‡.

‡ Wenzel, Kirwan's Miner. ii. 492.

151 Phoſphuret,

There appears to be little affinity between biſmuth and phoſphorus. Mr Pelletier attempted to produce the phoſphuret of biſmuth by various methods without ſucceſs. When he dropped phoſphorus, however, into biſmuth in fuſion, he obtained a ſubſtance which did not apparently differ from biſmuth, but which, when expoſed to the blow-pipe, gave evident ſigns of containing phoſphorus. Phoſphuret of biſmuth, according to Pelletier, is compoſed of about 96 parts of biſmuth, and four of phoſphorus*.

* Ann. de Chim. xiii. 130.

152 Alloys,

Biſmuth combines readily with moſt of the metals.

1. Equal parts of biſmuth and gold form a brittle alloy, nearly of the ſame colour with biſmuth†.

2. Equal parts of biſmuth and ſilver form alſo a brittle alloy, but leſs ſo than the laſt. The ſpecific gravity of both theſe is greater than intermediate‡.

† Keir, Macquer's Dict. ‡ Ibid.

3. The alloy of biſmuth and platinum is alſo very brittle. When expoſed to the air, it aſſumes a purple, violet, or blue colour. The biſmuth may be ſeparated by heat§.

§ Dr Lewis.

4. Mercury diſſolves biſmuth very eaſily. The amalgam is more fluid than pure mercury, and has the property of diſſolving lead and rendering it alſo fluid||. It is capable, however, of cryſtallizing. The cryſtals are either octahedrons, lamellated triangles, or hexagons. They are compoſed of one part of biſmuth and two of mercury¶.

|| Cramer. ¶ Chim. Dijon, i. 3.

5. The alloy of copper and biſmuth is not ſo red as copper.

6. Nothing is known concerning the alloy of iron and biſmuth.

7. Biſmuth and tin unite readily. A ſmall portion of biſmuth increaſes the brightneſs, hardneſs, and ſonorouſneſs of tin: It often therefore enters into the compoſition of the compound called *pewter*. Equal parts of tin and biſmuth form an alloy that melts at 280°: eight parts of tin, and one of biſmuth, melt at 390°: two parts of tin, and one of biſmuth, at 330°§.

§ Dr Lewis.

8. The alloy of lead and biſmuth is of a dark grey colour, a cloſe grain, but very brittle.

9. Biſmuth does not combine with zinc.

10. The alloy of antimony and biſmuth is unknown.

Biſmuth likewiſe enters into triple compounds with metals: Two parts of lead, three of tin, and five of biſmuth, form an alloy which melts at the heat of boiling water, which is 212°.

153 And affinities.

The affinities of biſmuth, according to Bergman, are as follows:

Lead,
Silver,
Gold,
Mercury,
Antimony,

(E) Muriatic acid decompoſes benzoat of biſmuth.—*Trommſdorf, Ann. de Chim.* xi. 317.

Antimony,
Tin,
Copper,
Platinum,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phoſphorus ?

Sect. XII. *Of Arſenic.*

The word *arſenic* (αρσενικον) occurs firſt in the works of Dioſcorides, and of ſome other authors who wrote about the beginning of the Chriſtian era. It denotes in their works the ſame ſubſtance which Ariſtotle had called σανδαραχη (F), and his diſciple Theophraſtus αρρενικον, which is a reddiſh coloured mineral, compoſed of arſenic and ſulphur, uſed by the ancients in painting, and as a medicine.

The *white oxyd of arſenic*, or what is known in commerce by the name of arſenic, is mentioned by Avicenna in the 11th century ; but at what period the metal called arſenic was firſt extracted from that oxyd is unknown. Paracelſus ſeems to have known it. It is mentioned by Schroeder in his Pharmacopœia publiſhed in 1649*.

* *Bergman*, ii. 278.

154 Properties of Arſenic.

Arſenic when pure is of a bluiſh white colour. It is exceedingly brittle. Its hardneſs is 7†. Its ſpecific gravity 8,310.‡.

† *Kirwan's Miner.* ii. 254.

When expoſed to the temperature of 354° in cloſe veſſels it ſublimes§, and cryſtallizes in regular tetrahedrons.

‡ *Bergman*, ii. 278.
§ *Ibid.*

It is not much altered by water. Boiling water, however, is capable of diſſolving and retaining $\frac{1}{100000}$th of arſenic ; but that part of the metal is no doubt reduced to the ſtate of an oxyd‖.

155 Its oxyds,

‖ *Hahneman*, *Chim. Ann.* 1788, i. 182.

When arſenic is expoſed to the open air, it very ſoon loſes its luſtre, and is gradually converted into a greyiſh black ſubſtance by combining with oxygen. This is called the *grey oxyd of arſenic.*

When expoſed to a moderate heat in contact with air, it ſublimes in the form of a white powder, and at the ſame time emits a ſmell reſembling garlic. If the heat be increaſed, it burns with an obſcure bluiſh flame. This ſublimate is *white oxyd of arſenic*, which is compoſed of 93 parts of arſenic and 7 of oxygen¶.

¶ *Kirwan's Mineral.* ii. 490.

It is of a ſharp acrid taſte, which at laſt leaves an impreſſion of ſweetneſs, and is one of the moſt virulent poiſons known. It has an aliacious ſmell. It is ſoluble in 80 parts of water at the temperature of 60°, and in 15 parts of boiling water‡. When this ſolution is evaporated, the oxyd cryſtallizes.† When heated to 283°, it ſublimes : if heat be applied in cloſe veſſels, it becomes pellucid like glaſs, but when expoſed to the air, it ſoon recovers its former appearance. The ſpecific gravity of this glaſs is 5,000 ; that of the white oxyd, 3,706‡. This oxyd is capable of combining with moſt of the metals, and in general renders them brittle. Its affinities, according to Bergman, are as follows :

§ *Bergman*, ii. 278.
† *Brandt*, *Act. Upſal.* 1733.
‡ *Bergman*, ii. 278.

Muriatic acid,
Oxalic,
Sulphuric,
Nitric,
Sebacic,
Tartarous,
Phoſphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Arſenic,
Acetous,
Pruſſic,
Ammonia,
Water,
Alcohol ?

Arſenic, or rather the white oxyd of arſenic, is capable of combining with an additional doſe of oxygen. The compound produced is *arſenic acid*, firſt diſcovered by Scheele, which contains 91 parts of arſenic and 9 of oxygen*.

* *Berthollet*, *Kirwan's Miner.* ii. 490.

156 Sulphuret,

Arſenic combines readily with ſulphur. When heat is applied to a mixture of white oxyd of arſenic and ſulphur, the oxyd is decompoſed, part of the ſulphur combines with its oxygen, and the remainder unites with the reduced metal. The ſulphuret of arſenic produced by this proceſs is of a yellow colour, and was formerly called *orpiment*. It is compoſed, according to Weſtrum, of 20 parts of arſenic, and 80 of ſulphur†. It is often found native. If a ſtronger heat be applied, ſo as to melt the ſulphuret, it aſſumes a ſcarlet colour, and is much leſs volatile than formerly. This new compound was formerly called *realgar*. It is compoſed, according to Weſtrum, of 80 parts of arſenic, and 20 of ſulphur‡. The difference, therefore, between it and orpiment is evident. During the fuſion, part of the ſulphur without doubt ſublimes. It might be called *red ſulphuret of arſenic.*

† *Kirwan's Miner.* ii. 492.
‡ *Ibid.*

157 Phoſphuret,

Arſenic combines readily with phoſphorus. The phoſphuret of arſenic may be formed by diſtilling equal parts of its ingredients over a moderate fire. It is black and brilliant, and ought to be preſerved in water. It may be formed likewiſe by putting equal parts of phoſphorus and arſenic into a ſufficient quantity of water, and keeping the mixture moderately hot for ſome time§.

§ *Pelletier*, *Ann. de Chim.* xiii. 139.

Arſenic unites with moſt metals, and in general renders them more brittle and more fuſible.

158 Alloys.

1. Melted gold takes up $\frac{1}{60}$th of arſenic‖. The alloy is brittle and pale.

‖ *Bergman*, *ibid.*

2. Melted ſilver takes up $\frac{1}{14}$th of arſenic¶. The alloy is brittle.

¶ *Ibid.*

3. The alloy of platinum and arſenic is brittle and very fuſible. It was firſt formed by Scheffer. The arſenic may be ſeparated by heat.

4. The amalgam of arſenic is compoſed of five parts of mercury and one of arſenic§.

§ *Ibid.*

5. Copper

(F) Pliny ſeems to make a diſtinction between ſandaracha and arſenic. See Lib. xxxiv. c. 18.

Cobalt.

5. Copper takes up $\frac{5}{6}$ths of arsenic†. This alloy is white; and when the quantity of arsenic contained in it is small, both ductile and malleable†. It is called *white tombac*.

† *Ibid.*
† *Gellert.*

6. Iron is capable of combining with more than its own weight of arsenic§. This alloy is white, brittle, and capable of crystallizing. It is found native‖.

§ *Bergman, Ann. de Chim.* xiii. 139.
‖ *Kirwan's Miner.* ii. 256.

7. The alloy of tin and arsenic is harder and more sonorous than tin, and has much resemblance externally to zinc. Tin often contains a small quantity of arsenic.

8. Lead takes up $\frac{1}{6}$th of arsenic¶. The alloy is brittle and dark coloured.

¶ *Bergman, ibid.*

9. Zinc takes up $\frac{1}{5}$th of arsenic, antimony $\frac{1}{8}$th, and bismuth $\frac{1}{15}$th.*

* *Ibid.*

159 And affinities.

The affinities of arsenic, according to Bergman, are as follows:

Nickel,
Cobalt,
Copper,
Iron,
Silver,
Tin,
Gold,
Platinum,
Zinc,
Antimony,
Sulphuret of alkali,
Sulphur,
Phosphorus.

Sect. XIII. *Of Cobalt.*

A mineral called *cobalt* (G), of a grey colour, and very heavy, has been used in different parts of Europe since the 15th century to tinge glass of a blue colour. From this mineral Brandt obtained in 1733 a new metal, to which he gave the name of *cobalt*†.

† *Act. Upsal.* 1733.

160 Properties of cobalt,

Cobalt is of a white colour, inclining to a bluish or steel grey. When pure, it is somewhat malleable while red hot‡. Its hardness is 8§. Its specific gravity is 8,15 (H). It requires for fusion a heat at least as great as cast iron, which melts at 130° Wedgewood. No heat has been produced great enough to volatilize it‖.

‡ *Leonbardi.*
§ *Kirwan's Miner.* ii. 268.
‖ *Bergman,* iv.

Cobalt, when pure, does not seem to be affected by air or water.

It is attracted by the magnet.

Cobalt.

161 Its oxyds,

It is not oxydated by heat without very great difficulty; but it has the property of decomposing nitric acid, and of attracting oxygen by that means with great rapidity.

The *oxyd of cobalt* is of so deep a blue as to appear black. The oxyd procured by heat is composed of 88 parts of cobalt and 12 of oxygen; that by nitric acid contains about 77 parts of cobalt and 23 of oxygen.* Its affinities, according to Bergman, are as follows:

* *Kirwan's Miner.* ii. 268. 490.

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phosphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arsenic,
Boracic,
Prussic,
Carbonic,
Ammonia.

162 Sulphuret,

The *sulphuret of cobalt* is not formed without difficulty. It is scarcely known.

163 Phosphuret,

Phosphuret of cobalt may be formed by heating the metal red hot, and then gradually dropping in small bits of phosphorus. It contains about $\frac{1}{15}$th of phosphorus. It is white and brittle, and when exposed to the air soon loses its metallic lustre. The phosphorus is separated by heat, and the cobalt is at the same time oxydated. This phosphuret is much more fusible than pure cobalt†.

† *Pelletier, Ann. de Chim.* xiii. 134.

164 Alloys,

The combinations of cobalt with other metals have been very little examined into.

1. The alloy of gold and cobalt is not known.

2. Cobalt does not combine with silver by fusion‡; but, according to Gellert, the alloy of silver and cobalt *may* be formed: it is brittle and of a grey colour§.

3. The alloy of platinum and cobalt is unknown.

4. Mer-

‡ *Bergman's Elect. Attract.*
§ *Metallur. Chim.*

(G) The word *cobalt* seems to be derived from *cobalus*, which was the name of a spirit that, according to the superstitious notions of the times, haunted mines, destroyed the labours of the miners, and often gave them a great deal of unnecessary trouble. The miners probably gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes, and rendering their labour often fruitless; for as it was not known at first to what use the mineral could be applied, it was thrown aside as useless. It was once customary in Germany to introduce into the church-service a prayer that God would preserve miners and their works from *kobalts* and spirits. See *Beckmann's History of Inventions*, II. 362.

Mathesius, in his tenth sermon, where he speaks of *cadmia fossilis* (probably cobalt ore), says, " Ye miners call it *kobolt;* the Germans call the black devil and the old devil's whores and hags, old and black *kobel*, which by their witchcraft do injury to people and to their cattle."

Lehmann, Paw, Delaval, and several other philosophers, have supposed that *smalt* (oxyd of cobalt melted with glass and pounded) was known to the ancients, and used to tinge the beautiful blue glass still visible in some of their works; but we learn from Gmelin, who analysed some of these pieces of glass, that they owed their *blue* colour, not to the presence of *cobalt* but of *iron*.

According to Lehmann, cobalt ore was first used to tinge glass blue by Christopher Schurer, a glass-maker at Plattan, about the year 1540.

(H) *Berg.* II. 231. According to Brisson, 7,8119.

Nickel.

4. Mercury does not appear to amalgamate with cobalt.

5. The alloy of copper and cobalt is ſcarcely known.

6. The alloy of iron and cobalt is very hard, and not eaſily broken. Cobalt generally contains ſome iron, from which it is with great difficulty ſeparated.

7. The alloy of tin and cobalt is of a light violet colour.

8. Cobalt does not combine with lead by fuſion.

9. The alloy of zinc and cobalt is not formed without difficulty.

10. The alloy of antimony and cobalt is unknown.

11. Cobalt does not combine with biſmuth by fuſion.*

12. Arſenic combines very readily with cobalt. The alloy is brittle, much more fuſible, and more eaſily oxydated than pure cobalt†.

165 And affinities. The affinities of cobalt are as follows:

Iron,
Nickel,
Arſenic,
Copper,
Gold,
Platinum,
Tin,
Antimony,
Zinc,
Sulphuret of alkali,
Sulphur,
Phoſphorus?

* Baumé.

† Bergman, iv.

Sect. XIV. *Of Nickel.*

A heavy mineral of a red colour is met with in ſeveral parts of Germany, which bears a ſtrong reſemblance to an ore of copper; but none of that metal can

166 Diſcovery of nickel. be extracted from it: for this reaſon the Germans called it *kupfer nickel* (devil's copper.) Hierne mentioned it in 1694. Cronſtedt was the firſt chemiſt who examined it with accuracy. He concluded from his experiments, which were publiſhed in the Stockholm Tranſactions for 1751 and 1754 that it contained a new metal, to which he gave the name of *nickel.*

Some chemiſts, particularly Mr Sage, affirmed, that it contained no new metal, but merely a compound of various known metals, which could be ſeparated from each other by the uſual proceſſes. Theſe aſſertions induced Bergman to undertake a very laborious courſe of experiments, in order if poſſible to obtain *nickel* in a ſtate of purity: for Cronſtedt had not been able to ſeparate a quantity of arſenic, cobalt, and iron, which adhered to it with much obſtinacy. Theſe experiments have been very fully detailed in the article Chemistry in the *Encycl.* to which we beg leave to refer. Bergman has ſhewn, that nickel poſſeſſes peculiar properties, and that it can neither be reduced to any other metal, nor formed artificially by any combination of metals. It muſt therefore be conſidered as a peculiar metal. It may poſſibly be a compound, and ſo may likewiſe many other metals; but we muſt admit every thing to be a peculiar body which has peculiar properties, and we muſt admit every body to be ſimple till ſome proof be actually produced that it is a compound; otherwiſe we forſake the road of ſcience, and get into the regions of fancy and romance.

Nickel is of a greyiſh white colour, and when leſs pure inclines a little to red.

It is both ductile and malleable. Its hardneſs is 8* 167 Its properties. Its ſpecific gravity 9,000†. It requires for fuſion a temperature at leaſt equal to 150° Wedgewood‡.

It is powerfully attracted by the magnet, and is even poſſeſſed of the property of attracting iron. This induced Bergman to ſuppoſe that nickel, when pureſt, was ſtill contaminated with about one-third of iron: but as this is the only proof of its containing iron, Klaproth, with reaſon, deems it an inſufficient one, and conſiders attraction by the magnet as a property of nickel§.

* Kirwan Miner. ii. 281.

† Bergman, ii. 231.

‡ Ibid.

§ Ann. de Chim. i. 170.

When expoſed to a ſtrong heat, nickel is oxydated ſlowly. Its oxyd is of a *brown* colour; if impure, it is *greeniſh*. The oxyd of nickel, according to Klaproth, is compoſed of 77 parts of nickel and 33 of oxygen¶. 168 Oxyds, Its affinities, according to Bergman, are as follows:

¶ Kirwan's Miner. ii. 490.

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phoſphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arſenic,
Boracic,
Pruſſic,
Carbonic,
Ammonia,
Potaſs?
Soda?

Cronſtedt found that nickel combined readily with 169 Sulphuret, ſulphur by fuſion. The ſulphuret which he obtained was yellow and hard, with ſmall ſparkling facets; but the nickel which he employed was impure.

Nickel combines very readily with phoſphorus, either 170 Phoſphuret, by fuſing it along with phoſphoric glaſs, or by dropping phoſphorus into it while red hot. The phoſphuret of nickel is of a white colour, and when broke exhibits the appearance of very ſlender priſms collected together. When heated, the phoſphorus burns, and the metal is oxydated. It is compoſed of 83 parts of nickel and 17 of phoſphorus*. The nickel, however, on which this experiment was made, was not pure.

* Pelletier, Ann. de Chim. xiii. 135.

Little is known concerning the alloys of nickel with other metals. Equal parts of ſilver and nickel form a white ductile alloy. Equal parts of copper and nickel 171 Alloys, form a red ductile alloy. The compounds which this metal forms with tin and zinc are brittle. It does not combine with mercury†. It has a very ſtrong affinity for iron, cobalt, and arſenic, and is ſcarcely ever found except combined with ſome of them.

† Bergman. ii. 231.

Its affinities, according to Bergman, are as follows: 172 And affinities.

Iron,
Cobalt,
Arſenic,

Copper,

Manganese

Copper,
Gold,
Tin,
Antimony,
Platinum,
Bismuth,
Lead,
Silver,
Zinc,
Sulphuret of alkali,
Sulphur,
Phosphorus ?.

Sect. XV. *Of Manganese.*

[173] Discovery of manganese,

The dark grey mineral called *manganese*, in Latin *magnesia* (according to Boyle, from its resemblance to the *magnet)*, has been long known and used in making glass. A mine of it was discovered in England by Mr Boyle. It was long supposed to be an ore of iron; but Pott and Cronstedt having demonstrated that it contained very little of that metal, the latter referred it in his Mineralogy to a distinct order of earths, which he called *terra magnesiæ*. Bergman, from its specific gravity, and several other qualities, suspected that it was a metallic oxyd: he accordingly made several attempts to reduce it, but without success; the whole mass either assuming the form of scoriæ, or yielding only small separate globules attracted by the magnet. This difficulty of fusion led him to suspect that the metal he was in quest of bore a strong analogy to platinum. In the mean time, Dr Gahn, who was making experiments on the same mineral, actually succeeded in reducing it by the following process: He lined a crucible with charcoal powder moistened with water, put into it some of the mineral formed into a ball by means of oil, then filled up the crucible with charcoal powder, luted another crucible over it, and exposed the whole for about an hour to a very intense heat. At the bottom of the crucible was found a metallic button, or rather a number of small metallic globules, equal in weight to one-third of the mineral employed*. It is easy to see by what means this reduction was accomplished. The charcoal attracted the oxygen from the oxyd, and the metal remained behind. This metal is called *manganese*.

* Bergman, i. 211.

174 Its properties,

Manganese is of a greyish white colour. It is not malleable, and yet not so brittle as to be easily broken. Its hardness is 8†. Its specific gravity is 7,000‡. Its fusion requires so great a heat, that it has been very seldom accomplished.

† Kirwan's Miner. ii. 288.

‡ Hielm.

When reduced to powder, it is attracted by the magnet.

175 Oxyds,

When exposed to the air, it very soon tarnishes, and assumes a darker colour, till at last it becomes black and friable. This change is produced by the absorption of oxygen. It takes place much more rapidly if heat be applied to the metal. The substance thus obtained is the *black oxyd of manganese*. This oxyd is found in great abundance in nature, though scarcely ever in a state of purity. It is composed of 75 parts of manganese, and 25 of oxygen*.

* Bergman, ii. 225.

If a quantity of muriatic acid be poured upon this oxyd, and heat applied, part of the acid combines with some of the oxygen of the oxyd, and flies off in yellow fumes. The oxyd is dissolved in the rest. If potass be added to this solution, a white powder is precipitated. This is the *white oxyd of manganese*. It contains, according to Bergman, about 80 parts of manganese and 20 of oxygen. It soon attracts more oxygen when exposed to the air, and is converted into *black oxyd*.

The affinities of the white oxyd, according to Bergman, are as follows:

Oxalic acid,
Citric,
Phosphoric,
Tartarous,
Fluoric,
Muriatic,
Sulphuric,
Nitric,
Saccholactic,
Succinic,
Sebacic,
Tartaric,
Formic,
Lactic,
Acetous,
Prussic,
Carbonic.

The sulphuret of manganese is unknown. 176

Phosphuret,

Phosphorus may be combined with manganese by melting together equal parts of the metal and of phosphoric glass; or by dropping phosphorus upon red hot manganese. The phosphuret of manganese is of a white colour, brittle, granulated, disposed to crystallize, not altered by exposure to the air, and more fusible than manganese. When heated the phosphorus burns and the metal becomes oxydated†.

† Pelletier, Ann. de Chim. xiii. 137.

177 Carburet,

Manganese combines readily with carbon by fusion(1).

178 Alloys,

Little is known concerning the alloys of manganese. It combines readily with copper. The compound, according to Bergman, is very malleable, its colour is red, and it sometimes becomes green by age. Gmelin made a number of experiments to see whether this alloy could be formed by fusing the black oxyd of manganese along with copper. He partly succeeded, and proposed to substitute this alloy instead of the alloy of copper and arsenic, which is used in the arts‡. We believe, however, that upon trial, the new alloy has been found not to answer.

‡ Ann. de Chim. i. 303.

Manganese combines readily with iron; indeed it has scarcely ever been found quite free from some mixture of that metal. It combines also very easily with arsenic and tin, not easily with zinc, and not at all with mercury§.

§ Bergman, ii. 211.

179 And affinities.

The affinities of manganese, according to Bergman, are as follows:

Copper,
Iron,
Gold,
Silver,

(1) *Bergman*, III. 379.—Sometimes manganese is very speedily oxydated by exposure to the air; sometimes scarcely altered by it, as Klaproth and Pelletier have observed. Mr Kirwan supposes, that the manganese which is soon altered contains carbon, and that this is the cause of the difference. See *Miner*. II. 288.

Tungſten.

Silver,
Tin,
Sulphuret of alkali,
Phoſphorus ?
Carbon ?

The three metals, *cobalt*, *nickel*, and *mangan eſe*, reſemble iron in ſeveral particulars: Like it they are magnetic, very hard, and very difficult to fuſe: but they differ from it in ſpecific gravity, malleability, and in the properties of all their combinations with other ſubſtances; the oxyds, for inſtance of iron, cobalt, nickel, and manganeſe, poſſeſs very different qualities.

Sect. XVI. *Of Tungſten.*

180 Diſcovery of tungſten,

There is a mineral found in Sweden of an opaque white colour, and great weight; from which laſt circumſtance it got the name of *tungſten*, or *ponderous ſtone*. Some mineralogiſts conſidered it as an ore of tin, others ſuppoſed that it contained iron. Scheele analyſed it in 1781, and found that it was compoſed of lime and a peculiar earthy-like ſubſtance, which he called from its properties *tungſtic acid*. Bergman conjectured that the baſis of this acid was a metal; and this conjecture was ſoon after fully confirmed by the experiments of Meſſrs D'Elhuyart, who obtained the ſame ſubſtance from a mineral of a browniſh black colour, called by the Germans *wolfram*, which is ſometimes found in tin mines. This mineral they found to contain $\frac{65}{100}$ of tungſtic acid; the reſt of it conſiſted of manganeſe, iron and tin. This acid ſubſtance they mixed with charcoal powder, and heated violently in a crucible On opening the crucible after it had cooled, they found in it a button of metal of a dark brown colour, which crumbled to powder between the fingers. On viewing it with a glaſs, they found it to conſiſt of a congeries of metallic globules, ſome of which were as large as a pin head. The metal thus obtained is called *tungſten*. The manner in which it was produced is evident; tungſtic acid is compoſed of oxygen and tungſten: the oxygen combined with the carbon, and left the metal in a ſtate of purity.

181 Its properties.

Tungſten is externally of a brown colour, internally of a ſteel grey*.

Its ſpecific gravity is 17,600‡. It is more infuſible than manganeſe‖.

When heat is applied to tungſten it is converted into a yellow powder, compoſed of 80 parts of tungſten and 20 of oxygen†. This is the *yellow oxyd of tungſten* or *tungſtic acid*.

The ſulphuret of tungſten is of a bluiſh black colour, hard, and capable of cryſtallizing.

Phoſphorus is capable of combining with tungſten§.

Of the alloys of tungſten we know nothing, except from the experiments of Elhuyarts, which have been tranſcribed into the article chemiſtry in the *Encyclopædia*; to which, therefore, we beg leave to refer.

* *Luyart.*
‡ *Id.*
‖ *Id.*
† *Id.*
§ *Pelletier, Ann. de Chim.* xiii. 137.

Sect. XVII. *Of Molybdenum.*

182 Diſcovery of molybdenum.

The Greek word *molybdena*, and its Latin tranſlation *plumbago*, ſeem to have been employed by the ancients to denote various oxyds of lead; but by the moderns they were applied indiſcriminately to all ſubſtances poſſeſſed of the following properties: Light, friable, and ſoft, of a dark colour and greaſy feel, and which leave a ſtain upon the fingers. Scheele firſt examined theſe minerals with attention. He found, that two very different ſubſtances had been confounded together. To one of theſe, which is compoſed of carbon and iron, and which has been already deſcribed, he appropriated the word *plumbago*; the other he called *molybdena*.

Molybdenum.

Molybdena is compoſed of ſcaly particles adhering ſlightly to each other. Its colour is bluiſh, very much reſembling that of lead. Scheele analyſed it, and obtained ſulphur and a whitiſh powder, which poſſeſſed the properties of an acid, and which, therefore, he called *acid of molybdena*. Bergman firſt ſuſpected that the baſis of this acid was a metal. It was at the requeſt of Bergman and Scheele that Mr Hielm began the laborious courſe of experiments by which he ſucceeded in obtaining a metal from this acid. His method was to form it into a paſte with linſeed oil, and then to apply a very ſtrong heat. This proceſs he repeated ſeveral times ſucceſſively. Klaproth and Pelletier alſo attempted to reduce it, and with equal ſucceſs. The metal is *molybdenum* (K).

183 Its properties.

Molybdenum is externally of a whitiſh yellow colour, but its fracture is a whitiſh grey.

Hitherto it has only been procured in ſmall grains, agglutinated together in brittle maſſes.

Its ſpecific gravity is 7,500. It is almoſt infuſible in our fires.

When expoſed to a ſtrong heat, it is gradually converted into a whitiſh-coloured oxyd‡. When nitric acid is poured upon it, molybdenum attracts oxygen, and is converted into a *white oxyd*, which poſſeſſes the properties of an acid†. This is the *molybdic acid*.

Molybdenum combines readily with ſulphur; and the compound has exactly the properties of molybdena, the ſubſtance which Scheele decompounded§. Molybdena is therefore *ſulphuret of molybdenum*. The reaſon that Scheele obtained from it molybdic acid was, that the metal combined with oxygen during his proceſs.

Molybdenum is alſo capable of combining with phoſphorus*.

Few of the alloys of this metal have been hitherto examined.

It ſeems capable of uniting with gold. The alloy is probably of a white colour‡.

It combines readily with platinum while in the ſtate of an oxyd. The compound is fuſible. Its ſpecific gravity is 20,00§.

The alloys of molybdenum with ſilver, iron and copper, are metallic and friable; thoſe with lead and tin are powders which cannot be fuſed*.

‡ *Pelletier Journ. de Phyſ.* 1785.
† *Ibid.*
§ *Ibid.*
* *Pelletier. Ann. de Chim.* xiii. 137.
‡ *Ruprecht, Ann. de Chim.* viii. 8.
§ *Hielm, Ann. de Chim.* iv. 17.
* *Pelletier, Journal de Phyſique,* Dec. 1785.

Sect. XVIII. *Of Uranium.*

184 Diſcovery of uranium.

There is a mineral found in the George Wagsfort mine at Johann-Georgenſtadt in Saxony, partly in a pure or unmixed ſtate, and partly ſtratified with other kinds of ſtones and earths. The firſt variety is of a blackiſh colour inclining to a dark iron grey, of a moderate ſplendor, a cloſe texture, and when broken preſent a ſomewhat uneven, and, in the ſmalleſt particles, a conchoidal ſurface. It is quite opaque, tolerably hard, and on being pounded yields a black powder. Its ſpecific gravity is about 7,500. The ſecond ſort is diſtinguiſhed

(K) This name was given it by Hielm.

Uranium. diſtinguiſhed by a finer black colour, with here and there a reddiſh caſt; by a ſtronger luſtre, not unlike that of pitcoal; by an inferior hardneſs; and by a ſhade of green, which tinges its black colour when it is reduced to powder.*

* Klaproth, Crell's Journal, Eng. tranſl. i. 126.

This foſſile was called *pechblende;* and mineralogiſts, miſled by the name (L), had taken it for an ore of zinc, till the celebrated Werner, convinced from its texture, hardneſs, and ſpecific gravity, that it was not a *blende*, placed it among the ores of iron. Afterwards he ſuſpected that it contained *tungſten;* and this conjecture was ſeemingly confirmed by the experiments of ſome German mineralogiſts, publiſhed in the Miners Journal ‡. But Klaproth, whoſe analyſes always diſplay the moſt conſummate ſkill, joined with the moſt rigid accuracy, examined this mineral about the year 1789, and found that it conſiſted chiefly of ſulphur combined with a peculiar metal, to which he gave the name of *uranium* (M).

‡ Ibid.

185 Its properties. Uranium is of a dark grey colour; internally it is ſomewhat inclined to brown ‡.

‡ Ibid. 233.

Its malleability is unknown. Its hardneſs is about 6. It requires a ſtronger heat for fuſion than manganeſe. Indeed Klaproth only obtained it in very ſmall conglutinated metallic grains, forming altogether a porous and ſpongy maſs.—Its ſpecific gravity is 6,440 ‖.

‖ Ibid.

When expoſed for ſome time to a red heat, it ſuffers no change. By means of nitric acid, however, it may be converted into a yellow powder. This is the *yellow oxyd of uranium.* This oxyd is found native mixed with the mineral above deſcribed. Its affinities have not yet been determined.

Uranium is capable of combining with ſulphur. The mineral from which Mr Klaproth firſt obtained it is a native ſulphuret of uranium.

Nothing is known concerning the alloys or affinities of uranium.

SECT. XIX. *Of Titanium.*

186 Diſcovery of titanium. THERE is a mineral found in Hungary which, from its external appearance, has been called *red ſhorl;* but Klaproth, who examined it about the year 1795, diſcovered that it conſiſted chiefly of a peculiar metal, to which he gave the name of *titanium.*

187 Its properties. Titanium is of a browniſh red colour, and conſiderable luſtre. It is brittle. Its hardneſs is 9; its ſpecific gravity 4,18.

When expoſed to a ſtrong heat in a clay crucible, it ſuffered no alteration, except that its colour became browner; but in a coal crucible it loſt its luſtre and broke to pieces.

It is found naturally cryſtallized in right-angled quadrangular priſms, longitudinally furrowed, and about ½ inch in length.

No acid had any effect in oxydating it; but when mixed with five times its weight of potaſs, and heated in a porcelain furnace, it melted, and formed when cold a denſe greyiſh maſs, the ſurface of which was cryſtallized. When diſſolved in boiling water, it ſoon let fall a white powder, weighing about one-third more than the titanium employed. This is the *oxyd of titanium.* Fifty grains of it were reduced by ignition to 38. While hot it was yellowiſh, but, like oxyd of zinc, became white as it cooled. When heated on charcoal, it aſſumes firſt a *roſy red*, and afterwards a *ſlate blue* colour, and at laſt melts into an imperfect bead with a finely ſtriated ſurface. Mr Klaproth did not ſucceed in reducing it to the metallic ſtate.

Titanium does not ſeem to have any affinity for ſulphur †.

† M'Gregor.

188 There was a ſubſtance diſcovered by Mr M'Gregor in the valley of Menachan in Cornwall, and hence called *menachanite.* Upon this ſubſtance Mr M'Gregor made a very intereſting ſet of experiments, which were publiſhed in the Journal de Phyſique for 1791. He ſuſpected it to contain a new metal. From its properties, Mr Kirwan conjectured that it was the ſame with titanium;* and this conjecture has been very lately confirmed by Mr Klaproth, who analyſed menachanite, and found it to be an ore of that metal. Menachanite.

* Mineral. ii. 331.

SECT. XX. *Of Tellurium.*

189 Diſcovery of tellurium. IN the mountains of Fatzbay, near Zalethna in Tranſylvania, there is a mine called *Mariahilf;* the ore of which is wrought for the gold that it contains. Mr Muller of Reichenſtein examined it in 1782, and ſuſpected that it contained a new metal; and Bergman, to whom he had ſent ſome of the ore, was of the ſame opinion: but the quantity of the mineral which theſe chemiſts had examined was too inconſiderable to enable them to decide with certainty. Klaproth analyſed a larger quantity of it about the year 1797, and found that 1000 parts of it conſiſted of 72 parts of iron, 2,5 of gold, and 925,5 of a new metal, to which he has given the name of *tellurium* (N).

190 Its properties. Tellurium is of a white colour like tin, approaching ſomewhat to the grey colour of lead.*

* Klaproth, Philoſophical Magazine, i. 78.

It is very brittle and friable. Its fracture is laminated. Its ſpecific gravity is 6,115.

It is as eaſily melted as lead. When ſuffered to cool quietly and gradually, it readily aſſumes a cryſtallized ſurface †.

† Muller.

When heated by the blowpipe upon charcoal, it burns with a very lively flame of a blue colour, inclining at the edges to green. It is ſo volatile as to riſe entirely in a whitiſh grey ſmoke; at the ſame time it exhales a diſagreeable odour like that of radiſhes. This ſmoke is the *white oxyd* of tellurium, which may be formed alſo by diſſolving the metal in nitro-muriatic acid, and pouring into the ſaturated ſolution a quantity of water: a white powder precipitates, which is the oxyd ‡.

‡ Klaproth.

When this oxyd is heated for ſome time in a retort, it melts, and appears, after cooling, of a yellow ſtraw colour, having acquired a ſort of radiated texture. When formed

(L) *Blende* is the name given to ores of zinc.

(M) From *Uranus* (Οὐρανος), the name given by Mr Bode to the new planet diſcovered by Herſchel; which name the German aſtronomers have adopted. Mr Klaproth called the metal at firſt *uranite;* but he afterwards changed that name for *uranium.*

(N) Mr Kirwan, in the new edition of his Mineralogy, which was publiſhed before Mr Klaproth's experiments were known, gives this metal the name of *Sylvanite.*—Tellurium exiſts in ſeveral other mines in the ſame mountains.

Tellurium. formed into a paste with any fat oil, and distilled in a red heat, brilliant metallic drops are observed to cover the upper part of the retort, which at intervals fall to the bottom of the vessel, and are immediately replaced by others. After cooling, metallic fixed drops are found adhering to the sides and at the bottom of the vessel; the remainder of the metal is reduced. Its surface is brilliant and almost always crystallized. When this oxyd is exposed to heat on charcoal, it is reduced with a rapidity that resembles detonation.*

* Klaproth.

Tellurium combines with sulphur. The sulphuret of this metal is of a grey colour and radiated structure. When placed on red hot charcoal, the metal burns as well as the sulphur with a blue flame.

Tellurium amalgamates with mercury by simple trituration§.—The other properties of this metal are unknown.

§ Muller.

191 Chromum. A new metal has lately been discovered by Vauquelin in the red lead ore of Siberia. It is grey, very hard, brittle, and easily crystallizes in small needles†. He has given it the name of *chromum* (o).

† Nicholson's Journal, ii. 146.

We have now described all the metals at present known. The following table will exhibit in one view their principal properties.

192 General table of the properties of the metals.

Metals.	Colour.	Hardness.	Specific Gravity.	Fusing Point.	Malleability.	Ductility	
Gold.	Yellow.	6	19,300	32 W. (P) 1298 F.	282000	500	
Silver.	White.	6½	10,510	28 W. 1044 F.	160000	270	
Platinum.	White.	7½	23,000	150 W.?		above 500	
Mercury.	White.		13,568	—39 F.			
Copper.	Red.	8	8,870	27 W. 1449 F.		299¼	
Iron.	Blue-grey.	9	7,788	150 W. 20577 F.		450	Magnetic.
Tin.	White.	6	7,299	410 F.	2000	49	
Lead.	Blue-white.	5	11,352	540 F.		29¼	
Zinc.	White.	6	7,190	700 F.		0	
Antimony.	Grey.	6½	6,860	700 F.	0	0	
Bismuth.	Yellow-white.	6	9,822	460 F.	0	0	
Arsenic.	White.	7	8,310	400 F. ?	0	0	
Cobalt.	White.	8	8,150	130 W. 17977 F.			Magnetic.
Nickel.	White.	8	9,000	150 W. 20577 F.			Magnetic.
Manganese.	White.	8	7,000	150 W. 20577 F.	0	0	Magnetic.
Tungsten.	Brown.	6	17,600		0	0	
Molybdenum.	Grey.		7,500		0	0	
Uranium.	Grey.	6	6,440				
Titanium.	Red.	9	4,180		0	0	
Tellurium.	White.		6,115	540 F.	0	0	
Chromum.	Grey.				0	0	

(o) From χρωμα, because it possesses the property of giving colour to other bodies in a remarkable degree.

(P) W. Wedgewood's pyrometer. F. Fahrenheit's thermometer.

We

Tellurium.

193 Remarks on metallic oxyds.

We have feen that all the metals are capable of combining with oxygen; that almoft every one forms various oxyds, containing different quantities of oxygen, and varying in colour and other properties according to the proportion of oxygen which they contain. No part of chemiftry has more engaged the attention of philofophers than the metallic oxyds; and yet fuch is the difficulty of the fubject, that fcarcely any part of chemiftry is more imperfectly underftood.

We neither know how many oxyds every particular metal is capable of forming, nor the manner in which they are formed: neither have the differences between oxyds of the fame metallic bafe been enquired into; though there cannot be a doubt that they differ, not only in their affinities, but in many of their other properties. The *white oxyd* of manganefe, for inftance, combines readily with acids, but the *black* is incapable of uniting with any.

Mr Prouft, in a very valuable paper which he lately publifhed concerning the oxyds of iron*, hints that metals are only capable of two degrees of oxydation, or, which is the fame thing, that only two different oxyds can be produced from the fame metal. We think he has proved this completely as far as iron is concerned; and probably the obfervation holds good with refpect to many other metals. Arfenic, copper, tin, molybdenum, and perhaps even mercury, feem to be capable of only two degrees of oxydation; but it would require a very numerous and accurate fet of experiments to be able to determine the matter, or even to form a probable conjecture. Analogy is certainly againft the fuppofition; for it has been demonftrated that fome fubftances at leaft are capable of combining with three different dofes of oxygen (q), and why may not this be the cafe alfo with the metals? (11).

* *Ann. de Chim.* xxiii. 85.—*Nicholfon's Journ.* i. 453.

There is one obfervation, however, which we owe to Mr Prouft, the truth of which cannot be doubted, and which is certainly of the higheft importance—that metals are not capable of indefinite degrees of oxydation, but only of a certain number; and that every particular oxyd confifts of a determinate quantity of the metal and of oxygen chemically combined. Iron, for inftance, is not capable, as has been fuppofed, of uniting with oxygen in all the intermediate degrees between $\frac{27}{100}$ and $\frac{48}{100}$, and confequently of forming 20 or 30 different oxyds; it can only combine with precifely $\frac{27}{100}$ parts, or $\frac{48}{100}$ parts, and with no other proportions; and therefore is only capable of forming two oxyds, the *green* and the *brown*. In like manner, every other metal combines with certain proportions of oxygen, and forms either two oxyds or more according to its nature. To talk therefore of oxydating a metal indefinitely is not accurate, except it be intended to fignify the combining of part of it with oxygen, while the reft remains in its natural ftate. If iron be oxydated at all, it muft be combined with $\frac{27}{100}$ of oxygen; if it be oxydated more than this, it muft be combined with $\frac{48}{100}$ of oxygen.

Tellurium.

We beg leave to add another obfervation, which we confider as of no lefs importance, and which will ferve in fome meafure to modify and explain what has been juft now faid. Oxygen is capable of uniting with metals, or with any other fubftance for which it has an affinity, only in *one* determinate proportion. Iron, for inftance, and oxygen can only combine in the proportion of 73 parts of iron and 27 of oxygen. Thefe two quantities faturate each other, and form a compound which is incapable of receiving into it any more oxygen or iron: this compound is the *green oxyd of iron.* How comes it then, it will be afked, that there is another oxyd of iron, the *brown oxyd*, which contains 52 parts of iron and 48 of oxygen, proportions certainly very different from 73 and 27? We anfwer, there is an affinity between the green oxyd of iron and oxygen; they are capable of combining together, and of faturating each other in the proportion of about 71,5 parts of green oxyd and 28,5 of oxygen; and the compound which they form is the *brown oxyd*, which of courfe contains 52 parts of iron and 48 of oxygen: But then it is not formed by the combination of thefe two fubftances directly, but by the combination of the green oxyd and oxygen. In like manner, the arfenic acid is not compofed of arfenic and oxygen combined directly, but of white oxyd of arfenic combined with oxygen. The very fame thing takes place in all the other metals. We cannot at prefent prove the truth of this obfervation in a fatisfactory manner, becaufe it would be neceffary to draw our proofs from combinations which are yet undefcribed; but we will have occafion to confider it afterwards (12).

We have feen, that all the metals hitherto tried are capable of combining with fulphur, except gold and titanium; that all of them on which the experiments have been made can be united with phofphorus; and that three of them, iron, zinc, and manganefe, united with carbon; and perhaps many more of them may hereafter be found capable of affuming the form of carburets.

We have feen, too, that they are capable of uniting with one another and forming alloys. This was long reckoned peculiar to metals, and it is at prefent one of the beft criterions for determining the metallic nature of any fubftance. Much is wanting to render the chemiftry of alloys complete. Many of them have never been examined; and the proportions of almoft all of them are unknown. Neither has any accurate method been yet difcovered of determining the affinities of metals for each other. The order of affinities which we have given for each metal was determined by Bergman; but he acknowledged himfelf that he wanted the proper data to enfure accuracy.

CHAP.

(q) We fhall fee afterwards that azot is one of thefe.

(11) When we oxyd any metal in a *low* temperature, it goes regularly on, combining with frefh portions of oxygen until it is faturated. How can we make this fact accord with the theory of each of the metals being capable of exifting in but two degrees of oxydation? Will it be fufficient to fay that the frefh portions of oxygen unite to frefh portions of the metal? Or would this account for the various colours fome metals affume in the courfe of oxydation? T. P. S.

(12) As this fanciful theory is founded on deductions from "combinations which are yet undefcribed," we fhall wait till we meet with them before we enter on its examination. T. P. S.

Chap. IV. *Of* Earths.

The word *earth*, in common language, has two meanings; it ſometimes ſignifies the *globe* which we inhabit, and ſometimes the *mould* on which vegetables grow. Chemiſts have examined this mould, and have found that it conſiſts of a variety of ſubſtances mixed together without order or regularity. The greateſt part of it, however, as well as of the ſtones, which form apparently ſo large a proportion of the globe, conſiſts of a ſmall number of bodies, which have a variety of common properties. Theſe bodies chemiſts have agreed to claſs together, and to denominate *earths*.

194 Properties of earths.

Every body which poſſeſſes the following properties is an *earth*:

1. Inſoluble in water, or nearly ſo; or at leaſt becoming inſoluble when combined with carbonic acid.

2. Little or no taſte or ſmell; at leaſt when combined with carbonic acid.

3. Incombuſtible, and incapable while pure of being altered by the fire.

4. A ſpecific gravity not exceeding 4,9.

5. When pure, capable of aſſuming the form of a white powder.

The earths at preſent known amount to eight; the names of which are, lime, magneſia, barytes, ſtrontites, alumina, ſilica, jargonia, glucina.

Every one of the above characteriſtics is not perhaps rigorouſly applicable to each of theſe bodies; but all of them poſſeſs a ſufficient number of common properties to render it uſeful to arrange them under one claſs.

Sect. I. *Of Lime.*

Lime has been known from the earlieſt ages. The ancients employed it in medicine: it was the chief ingredient in their mortar; and they uſed it as a manure to fertilize their fields.

195 Method of procuring lime.

It abounds in many parts of the world, or perhaps we ſhould rather ſay, that there is no part of the world where it does not exiſt. It is found pureſt in limeſtones, and marbles and chalk. None of theſe ſubſtances, however, is, ſtrictly ſpeaking, lime; but they are all capable of becoming lime by a well-known proceſs, by keeping them for ſome time in a white heat: this proceſs is called *the burning of lime;* the product is denominated *quicklime*. This laſt ſubſtance is what we call *lime*.

196 Properties of lime.

Pure lime is of a white colour, moderately hard, but eaſily reduced to a powder.

It has a hot burning taſte, and in ſome meaſure corrodes and deſtroys the texture of thoſe animal bodies to which it is applied. It has no ſmell. Its ſpecific gravity is 2,3*.

If water be poured on newly burnt lime, it ſwells and falls to pieces, and is ſoon reduced to a very fine powder. In the mean time, ſo much heat is produced, that part of the water flies off in vapour. If the quantity of lime ſlacked (as this proceſs is termed) be great, the heat produced is ſufficient to ſet fire to combuſtibles. In this manner, veſſels loaded with lime have ſometimes been burnt. When great quantities of lime are ſlacked in a dark place, not only heat, but light alſo is emitted, as Mr Pelletier has obſerved §. When ſlacked lime is weighed, it is found to be heavier than it was before. This additional weight is owing to the combination of part of the water with the lime; which water may be ſeparated again by the application of a red heat; and by this proceſs the lime becomes juſt what it was before being ſlacked ||.

* *Kirwan's Miner.* i. 5.

§ *Jour. de Phyſ.* t. 22.

|| *Dr Black.*

197 Lime-water.

Six hundred parts of water, at the temperature of 60°, diſſolve about one part of lime; boiling hot water diſſolves about double that quantity*. This ſolution is called *lime-water*. It is limpid, has an acrid taſte, and changes vegetable blue colours to green. One ounce troy of lime-water contains about one grain of lime.

* *Kirwan's Miner.* i. 5.

One thouſand parts of lime are capable of abſorbing, and retaining, at a heat of 600°, 228 parts of water §.

§ *Lavoiſier.*

Lime has never yet been obtained in the ſtate of cryſtals.

It is incapable of being fuſed by the moſt violent heat that can be produced in furnaces, or even by the moſt powerful burning glaſſes.

198 Sulphuret, and

Lime unites readily with ſulphur, and forms *ſulphuret of lime*. This compound may be obtained by mixing unſlacked lime and flowers of ſulphur together, and adding a little water. The heat produced by the ſlacking of the lime is ſufficient to make the ſulphur and the lime unite. This ſulphuret is of a red colour. When water is poured on it, ſulphurated hydrogen gas is emitted. The ſulphur is gradually converted into ſulphuric acid by uniting with the oxygen of the water, the hydrogen of which flies off in the form of gas, diſſolving at the ſame time a part of the ſulphur.

199 Phoſphuret of lime.

It is capable alſo of combining with phoſphorus.—The phoſphuret of lime decompoſes water by the aſſiſtance of a moderate heat, and gives out phoſphurated hydrogen gas.

200 Cauſe of the difference between limeſtone and lime,

Limeſtone and chalk, though they are capable of being converted into lime by *burning*, poſſeſs hardly any of the properties of that active ſubſtance. They are taſteleſs, ſcarcely ſoluble in water, and do not perceptibly act on animal bodies. Now, to what are the new properties of lime owing? What alteration does it undergo in the fire?

It had been long known, that limeſtone loſes a good deal of weight by being burned or *calcined*. It was natural to ſuppoſe, therefore, that ſomething was ſeparated from it during calcination. Accordingly, Van Helmont, Ludovicus, and Macquer, made experiments in ſucceſſion, in order to diſcover what that *ſomething* was; and they concluded from them that it was *pure water*, which the lime recovered again when expoſed to the atmoſphere. As the new properties of lime could hardly be aſcribed to this loſs, but to ſome other cauſe, Stahl's opinion, like all the other chemical theories of that wonderful man, was generally acceded to. He ſuppoſed that the new properties, which lime acquired by calcination, were owing entirely to the more minute diviſion of its particles by the action of the fire. Boyle indeed had endeavoured to prove, that theſe properties were owing to the *fixation of fire* in the lime; a theory which was embraced by Newton and illuſtrated by Hales, and which Meyer new modelled, and explained with ſo much ingenuity and acuteneſs as to draw the attention of the moſt diſtinguiſhed chemiſts. But while Meyer was thus employed in Germany, Dr Black of Edinburg publiſhed thoſe celebrated experiments which form ſo brilliant an era in the hiſtory of chemiſtry.

201 According to Stahl;

202 Explained by Dr Black

He firſt aſcertained that the quantity of water ſeparated from limeſtone during its calcination was not near-

Lime. ly equal to the weight which it loſt. He concluded in conſequence, that it muſt have loſt ſomething elſe than mere water. What this could be, he was at firſt at a loſs to conceive; but recollecting that Dr Hales had proved, that limeſtone, during its ſolution in acids, emitted a great quantity of *air*, he conjectured that *this* might probably be what it loſt during calcination. He calcined it accordingly, and applied a pneumatic apparatus to receive the product. He found his conjecture verified; and that the *air* and *the water* which ſeparated from the lime, were together preciſely equal to the loſs of weight which it had ſuſtained. Lime therefore owes its new properties to the loſs of *air*; and limeſtone differs from lime merely in being combined with a certain quantity of *air*: for he found that, by reſtoring again the ſame quantity of *air* to lime, it was converted into limeſtone. This air, becauſe it exiſted in lime in a fixed ſtate, he called *fixed air*. It was afterwards examined by Dr Prieſtley and other philoſophers, found to poſſeſs peculiar properties, and to be that ſpecies of gas now known by the name of *carbonic acid gas*. Lime then is a ſimple ſubſtance, that is to ſay, it has never yet been decompounded; and limeſtone is compoſed of carbonic acid and lime. Heat ſeparates the carbonic acid, and leaves the lime in a ſtate of purity.

203 Affinities of lime. The affinities of lime, according to Bergman, are as follows:

Oxalic acid,
Suberic (R)?
Sulphuric,
Tartarous,
Succinic,
Phoſphoric,
Saccholactic,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Arſenic,
Formic,
Lactic,
Citric,
Benzoic,
Sulphurous,
Acetous,
Boracic,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus,
Water,
Fixed oil.

Sect. II. *Of Magneſia.*

204 Diſcovery of magneſia. About the beginning of the eighteenth century, a Roman canon expoſed a white powder to ſale at Rome as a cure for all diſeaſes. This powder he called *magneſia alba*. He kept the manner of preparing it a profound ſecret; but in 1707 Valentini informed the public that it might be obtained by calcining the lixivium which remains after the preparation of nitre; and two years after, Slevogt diſcovered that it might be precipitated by potaſs from the mother ley (s) of common ſalt. This powder was generally ſuppoſed to be *lime*, till Frederic Hoffman obſerved that it formed very different combinations with other bodies.* But little was known concerning its nature till Dr Black publiſhed his celebrated experiments in 1755. Margraf publiſhed a diſſertation on it in 1759, and Bergman another in 1775, in which he collected the obſervations of theſe two philoſophers, and which he enriched alſo with many additions of his own.

* Bergman, i. 365.

205 Method of procuring it. As magneſia has never yet been found native in a ſtate of purity, it may be prepared in the following manner: *Sulphat of magneſia*, a ſalt compoſed of this earth and ſulphuric acid, exiſts in ſea water, and in many ſprings, particularly ſome about Epſom, from which circumſtance it was formerly called *Epſom ſalt*. This ſalt is to be diſſolved in water, and half its weight of potaſs added. The magneſia is immediately precipitated, becauſe potaſs has a ſtronger affinity for ſulphuric acid. It is then to be waſhed with a ſufficient quantity of water, and dried.

206 Its properties. Magneſia thus obtained is a very ſoft white powder, which has very little taſte, and is totally deſtitute of ſmell.—Its ſpecific gravity is about 2,3 §.

It is ſoluble in about 7900 times its own weight of water at the temperature of 60° ‖.

§ *Kirwan's Miner.* i. 8.

‖ *Ibid.*

Even when combined with carbonic acid (for which it has a ſtrong affinity) it is capable of abſorbing and retaining 1½ times its own weight of water, without letting go a drop; but on expoſure to the air, this water evaporates, though more ſlowly than it would from lime.

Magneſia has never yet been obtained in a cryſtallized form.

It tinges vegetable blues of an exceedingly ſlight green.

It is not melted by the ſtrongeſt heat which it has been poſſible to apply; but Mr D'Arcet obſerved that, in a very high temperature, it became ſomewhat agglutinated.

When magneſia and ſulphur are put into a veſſel of water, and kept for ſome time expoſed to a moderate heat, they combine, and form ſulphuret of magneſia; which, according to Fourcroy, is capable of cryſtallizing.

The phoſphuret of magneſia has never been examined.

207 Effect of heat on mixtures of lime and magneſia. Equal parts of lime and magneſia mixed together, and expoſed by Lavoiſier to a very violent heat, did not melt; neither did they melt when Mr Kirwan placed them in the temperature of 150° Wedgewood.—The following

(R) The affinity of this acid for lime is inferior to the oxalic, which decompoſes the ſuberat of lime. *Jameſon's Mineral. of Shetland and Arran*, p. 168.

(s) *The mother ley* is the liquid that remains after as much as poſſible of any ſalt has been obtained from it. Common ſalt, for inſtance, is obtained by evaporating ſea water. After as much ſalt has been extracted from a quantity of ſea water as will cryſtallize, there is ſtill a portion of liquid remaining. This portion is the mother ley.

Magnefia. following table, drawn up by Mr Kirwan from his own experiments, fhews the effect of heat on thefe two earths mixed together in different proportions,

Proportions.	Heat.	Effect.
80 Lime 20 Mag.	150° Wedg.	Went through the crucible.
75 Lime 25 Mag.	160	Went through the crucible.
66 Lime 33 Mag.		Went through the crucible.
20 Lime 80 Mag.	165	Did not melt.
33 Lime 66 Mag.	138	Did not melt.
30 Lime 10 Mag.	156	Melted into a fine greenifh yellow glafs; but the crucible was corroded throughout.

208 Affinities of magnefia. The affinities of magnefia, according to Bergman, are as follows:

Oxalic acid,
Phofphoric,
Sulphuric,
Fluoric,
Sebacic,
Arfenic,
Saccholactic,
Succinic,
Nitric,
Muriatic,
Tartarous,
Citric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruffic,
Sulphur,
Phofphorus?
Water.

Sect. III. *Of Barytes.*

209 Difcovery of barytes. A very heavy mineral is found in Sweden, Germany, and Britain, which Margraf confidered as a compound of fulphuric acid and lime. But Scheele and Gahn analyfed it in 1774, and found that it confifted of fulphuric acid combined with a peculiar fpecies of earth. This analyfis was foon after confirmed and extended by Bergman. The earth was at firft called *terra ponderofa*, *heavy earth*, on account of the great fpecific gravity of the fubftance from which it was obtained. Morveau called it *barote* (from *βαρυς*, *heavy*), which Bergman changed into *barytes*; and this laft term is now univerfally adopted.

Barytes.

210 Method of obtaining it. Barytes is generally found combined either with fulphuric or carbonic acid. From the firft of thefe compounds, which is by far the moft common, it may be obtained by the following procefs:

Reduce the mineral to a powder, and mix it with $2\frac{1}{2}$, its weight of carbonat of foda (T), previoufly deprived of all its water. Expofe the mixture to a red heat for an hour and a half, avoiding fufion, and a double decompofition takes place; the fulphuric acid unites with the foda, while the carbonic acid combines with the barytes. Wafh it in a fufficient quantity of water to diffolve the compound of fulphuric acid and foda, the carbonat of barytes, which is almoft infoluble, remains behind. Left it fhould be mixed with fome other earths, which is generally the cafe, boil it for three hours in ten times its weight of diftilled vinegar, the fpecific gravity of which is 1,033; by which the barytes will be diffolved, and likewife the lime and magnefia, if there happen to be any; but every other earth (U) remains untouched. Pour off the folution, and add to it fulphuric acid as long as any precipitate is formed. This precipitate confifts of the whole barytes and the lime (if there be any) combined with fulphuric acid. Wafh it in 50 times its weight of water, and all the lime will be diffolved. There will now remain nothing but barytes combined with fulphuric acid, which may be decompofed as before by carbonat of foda §. The carbonic acid may then be feparated by applying a very violent heat †; or, what is better, nitric acid may be poured upon it, which will feparate the carbonic acid and combine with the barytes; and then the nitric acid may be driven off by a moderate heat §.

§ *Afsvelius, Ann. de Chim.* iii.
† *Hope, Edin. Tranf.* iv. 36.
§ *Fourcroy* and *Vauquelin, Ann. de Chim.* xxi. 276.

211 Its properties. Barytes thus obtained is a light fpongy, porous, body, which may be very eafily reduced to powder. It has a harfh and more cauftic tafte than lime; and when taken into the ftomach, proves a moft violent poifon. It has no perceptible fmell.

Its fpecific gravity has not yet been afcertained.

It imbibes water with a hiffing noife, but, according to Dr Hope, without fwelling or fplitting as lime does ‖. However, when expofed to the air, as Fourcroy and Vauquelin inform us, it effloresces, cracks, burfts, fwells up, heats and becomes white, by abforbing moifture §.

‖ *Edin. Tranf. ibid.*
§ *Ann. de Chim. ibid.* and *Nicholfon's Jour.* i. 535.

Cold water diffolves about $\frac{1}{25}$ part of its weight of barytes, and boiling water more than half its weight. As the water cools, the barytes is depofited in cryftals, the fhape of which varies according to the rapidity with which they have been formed. When moft regular, they are flat hexagonal prifms, having two broad fides, with two intervening narrow ones, and terminated at each end by a four-fided pyramid, which in fome inftances conftitutes the larger part of the cryftal. When formed flowly, they are diftinct and large; but when the

(T) Soda is an alkali; which fhall be afterwards defcribed. Carbonat of foda is foda combined with carbonic acid, the common ftate in which it is obtained; potafs might alfo be ufed.

(U) Except ftrontites, which Pelletier has detected in this mineral.

Barytes. the water is faturated with barytes, they are depofited rapidly, and are generally more flender and delicate. Then, too, they are attached to one another in fuch a manner as to affume a beautiful foliacious appearance, not unlike the leaf of a fern ¶.

¶ *Hope, ibid.*

Thefe cryftals are tranfparent and colourlefs, and appear to be compofed of about 53 parts of water and 47 of barytes. When expofed to the heat of boiling water, they undergo the *watery fufion*, or, which is the fame thing, they melt without lofing any of the water which they contain. A ftronger heat makes the water fly off. When expofed to the air, they attract carbonic acid, and crumble into duft. They are foluble in $17\frac{1}{2}$ parts of water at the temperature of 60°; but boiling water diffolves any quantity whatever: the reafon of which is evident; at that temperature their own water of cryftallization is fufficient to keep them in folution§.

§ *Id.*

Water faturated with barytes is called *barytic water*. It has the property of converting vegetable blues to a green.

When barytes is expofed to the blow-pipe on a piece of charcoal, it fufes, bubbles up, and runs into globules, which quickly penetrate the charcoal‡. This is probably in confequence of containing water; for Lavoifier found barytes not affected by the ftrongeft heat which he could produce.

‡ *Fourcroy and Vauquelin, ibid.*

212
Sulphuret of barytes.

Barytes combines readily with fulphur. The eafieft way of forming fulphuret of barytes is to mix eight parts of fulphuret of barytes with one part of pounded charcoal, and to apply a ftrong heat. The charcoal combines with the oxygen of the fulphuric acid, and the compound flies off in the form of carbonic acid gas. There remains behind fulphur combined with barytes. Sulphuret of barytes is foluble in water: It is of a yellow colour. It is capable of cryftallizing; and then affumes a yellowifh white colour‖.

‖ *Fourcroy.*

The phofphuret of barytes has not been examined.

No mixture of barytes and lime, nor of barytes and magnefia is fufible in the ftrongeft heat which it has been poffible to apply§.

§ *Lavoifier, Acad. Par.* 1782.

213
Its affinities.

The affinities of barytes, according to Bergman, are as follows:

Sulphuric acid,
Oxalic,
Succinic,
Fluoric,
Phofphoric,
Saccholactic,
Suberic(v)?
Nitric,
Muriatic,
Sebacic,
Citric,
Tartarous,
Arfenic,
Fluoric,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruffic,
Sulphur,
Phofphorus,
Water,
Fixed oils.

Sect. IV. *Of Strontites.*

Strontites.

214
Difcovery of ftrontites.

About the year 1787, a mineral was brought to Edinburgh by a dealer in foffils, from the lead mine of Strontian in Argylefhire, where it is found imbedded in the ore, mixed with feveral other fubftances. It is fometimes tranfparent and colourlefs, but generally has a tinge of yellow or green. Its hardnefs is 5. Its fpecific gravity varies from 3,4 to 3,726. Its texture is generally fibrous; and fometimes it is found cryftallized in flender prifmatic columns of various lengths‡.

‡ *Hope, Edin. Tranf.* iv. 44.

This mineral was generally confidered as a carbonat of barytes; but Dr Crawford having obferved fome differences between its folution in muriatic acid and that of barytes, mentioned in his treatife on *muriat of barytes*, publifhed in 1790, that it probably contained a new earth, and fent a fpecimen to Mr Kirwan that he might examine its properties. Dr Hope had alfo fufpected that its bafis differed from barytes; and accordingly he made a fet of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1792. Thefe experiments fully proved that it contained a peculiar earth. Mr Kirwan likewife analyfed the ftrontian mineral, and drew precifely the fame conclufions. It has been analyfed alfo by Mr Klaproth of Berlin, and Mr Pelletier of Paris. It confifts of carbonic acid combined with a peculiar earth, to which Dr Hope gave the name of *ftrontites*. This appellation we fhall adopt.

The carbonic acid may be feparated by a heat of 140° Wedgewood, and then the ftrontites remains behind*.

* *Kirwan's Miner.* i. 332.

215
Its properties.

Strontites has been found in Argylefhire in Scotland, near Briftol in England, and in Pennfylvania†. It has been found alfo in France and in Sicily. It is of a white colour. It has a pungent acrid tafte. When pounded in a mortar, the powder that rifes is offenfive to the noftrils and lungs‡. It is not poifonous‖.

† *Klaproth,* ii. fect. 39.
‡ *Hope, ibid.*
‖ *Pelletier.*

One hundred and fixty-two parts of water, at the temperature of 60°, diffolve nearly one part of it. The folution is clear and tranfparent, and converts vegetable blues to a green. Hot water diffolves it in much larger quantities; and as it cools the ftrontites is depofited in colourlefs tranfparent cryftals. Thefe are in the form of thin quadrangular plates, generally parallelograms, the largeft of which feldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener confift of two facets, meeting together and forming an angle like the roof of a houfe. Thefe cryftals generally adhere to each other in fuch a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they affume a cubic form. They contain about 68 parts in 100 of water. They are foluble in 51,4 parts of water, at the temperature of 60°. Boiling water diffolves nearly half its weight of them. When expofed to the air, they lofe their water, attract carbonic acid, and fall into powder*.

* *Hope, ibid.*

When ftrontites is thrown into water, it attracts it with

(v) Suberic acid decompofes muriat and nitrat of barytes. *Jamefon's Mineral. of Shetland and Arran.*

Silica.

with a hiſſing noiſe, much heat is produced, and it falls into powder much more rapidly than lime†.

† *Id.*

It combines with ſulphur either by fuſion in a crucible, or by being boiled with it in water. The ſulphuret is of a dark yellowiſh brown colour. It is ſoluble in water‡.

‡ *Id.*

216 Its affinities.

The affinities of ſtrontites, as aſcertained by Dr Hope, are as follows:

Sulphuric acid,
Oxalic,
Tartarous,
Fluoric,
Nitric,
Muriatic,
Succinic,
Phoſphoric,
Acetous,
Arſenic,
Boracic,
Carbonic.

Sect. V. *Of Silica.*

217 Method of obtaining ſilica.

If one part of powdered flints or ſand, mixed with three parts of potaſs, be put into a crucible, and kept in a ſtate of fuſion for half an hour, a brittle maſs will be formed almoſt as tranſparent as glaſs, which quickly attracts moiſture from the atmoſphere, and is entirely ſoluble in water. This ſolution is called *liquor ſilicum*, or *liquor of flints*. It was firſt accurately deſcribed by Glauber, a chemiſt, who lived about the middle of the 17th century.

If an acid be poured into this liquor, a white ſpongy ſubſtance is precipitated, which may be purified from every accidental mixture, by waſhing it in acids, muriatic acid for inſtance. This ſubſtance is called *ſiliceous earth*, or *ſilica*. It was firſt diſtinguiſhed as a peculiar earth by Pott in 1746, though it had been known long before; and Cartheuſer, Scheele, and Bergman proved in ſucceſſion that it could not, as ſome chemiſts had ſuppoſed, be reduced to any other earth.

218 Its properties.

Silica, when dried, is a ſoft white powder, without either taſte or ſmell.

Its ſpecific gravity is 2,66*.

* *Kirwan's Miner.* i. 10.

It is inſoluble in water except when newly precipitated from the liquor ſilicum, and then one part of it is ſoluble in 1000 parts of water†. It has no effect on vegetable colours.

† *Ibid.*

It is capable of abſorbing about one-fourth of its weight of water without letting any drop from it; but on expoſure to the air, the water evaporates very readily‡.

‡ *Ibid.*

Silica may be formed into a paſte with a ſmall quantity of water: this paſte has not the ſmalleſt ductility, and when dried, forms a looſe, friable and incoherent maſs§.

§ *Scheele.*

Silica is capable of aſſuming a cryſtalline form. Cryſtals of it are found in many parts of the world. They are known by the name of *rock cryſtal*. When pure they are tranſparent and colourleſs like glaſs: they aſſume various forms; the moſt uſual is a hexagonal priſm, ſurmounted with hexagonal pyramids on one or both ends, the angles of the priſm correſponding with thoſe of the pyramids. Their hardneſs is very great, amounting to eleven. Their ſpecific gravity is 2,653*.

* *Kirwan's Min.* i. 242.

There are two methods of imitating theſe cryſtals by art. The firſt method was diſcovered by Bergman. He diſſolved ſilica in fluoric acid, the only acid in which it is ſoluble, and allowed the ſolution to remain undiſturbed for two years. A number of cryſtals were then found at the bottom of the veſſel, moſtly of irregular figures, but ſome of them cubes with their angles truncated. They were hard, but not to be compared in this reſpect with rock cryſtal*.

* *Bergman*, ii. 32.

The other method was diſcovered by accident. Profeſſor Seigling of Erfurt had prepared a liquor ſilicum, which was more than uſually diluted with water, and contained a ſuperabundance of alkali. It lay undiſturbed for eight years in a glaſs veſſel, the mouth of which was only covered with paper. Happening to look to it by accident, he obſerved it to contain a number of cryſtals, on which he ſent it to Mr Trommſdorf, profeſſor of chemiſtry at Erfurt, who examined it. The liquor remaining amounted to about two ounces. Its ſurface was covered by a tranſparent cruſt ſo ſtrong that the veſſel might be inverted without ſpilling any of the liquid. At the bottom of the veſſel were a number of cryſtals, which proved on examination to be ſulphat of potaſs and carbonat of potaſs (w). The cruſt on the top conſiſted partly of carbonat of potaſs, partly of cryſtallized ſilica. Theſe laſt cryſtals had aſſumed the form of tetrahedral pyramids in groups; they were perfectly tranſparent, and ſo hard that they ſtruck fire with ſteel.†

† *Nicholſon's Jour.* i. 217.

Silica endures the moſt violent heat without alteration.

It ſeems incapable of combining with ſulphur or phoſphorus.

219 Effect of heat on mixtures of lime and ſilica;

1. The effect of heat upon lime and ſilica, mixed in various proportions, will appear from the following experiments of Mr Kirwan‡.

‡ *Mineral.* i. 56.

Proportions.	Heat.	Effect.
50 Lime 50 Silica	150° Wedg.	Melted into a maſs of a white colour, ſemitranſparent at the edges, and ſtriking fire, tho' feebly, with ſteel: it was ſomewhat between porcelain and enamel.
80 Lime 20 Silica	156	A yellowiſh white looſe powder.
20 Lime 80 Silica	156	Not melted, formed a brittle maſs.

220 Magneſia and ſilica:

2. Equal parts of magneſia and ſilica melt with great difficulty into a white enamel when expoſed to the moſt violent heat which can be produced*. They are infuſible in inferior heats in whatever proportion they are mixed†.

* *Lavoiſier, Mem. Par.* 1787, p. 598.

† *Achard, Mem. Berl.* 1780, p. 33.

221 Barytes and ſilica;

3. The effect of heat on various mixtures of barytes and ſilica will appear from the following experiments of Mr Kirwan‡.

‡ *Mineral.* i. 57.

Proportions.

(w) Potaſs combined with ſulphuric acid and with carbonic acid.

Silica.

Proportions.	Heat.	Effect.
80 Silica 20 Barytes	155° Wedg.	A white brittle maſs.
75 Silica 20 Barytes	150	A brittle hard maſs, ſemitranſparent at the edges.
66 Silica 33 Barytes	150	Melted into a hard ſomewhat porous porcelain maſs.
50 Silica 50 Barytes	148	A hard maſs not melted.
20 Silica 80 Barytes	148	The edges were melted into a pale greeniſh matter between a porcelain and enamel.
25 Silica 75 Barytes	150	Melted into a ſomewhat porous porcelain maſs.
33 Silica 66 Barytes	150	Melted into a yellowiſh and partly greeniſh white porous porcelain.

4. The effect of heat on mixtures of ſtrontites and ſilica is not known.

222 And lime, magneſia, and ſilica.

5. It follows from the experiments of Achard, that equal parts of lime, magneſia, and ſilica, may be melted into a greeniſh coloured glaſs, hard enough to ſtrike fire with ſteel; that when the magneſia exceeds either of the other two, the mixture will not melt; that when the ſilica exceeds, the mixture ſeldom melts, only indeed with him in the following proportions; three ſilica, two lime, one magneſia, which formed a porcelain; and that when the lime exceeds, the mixture is generally fuſible.*

* *Mem. Berl. ibid.* and *Jour. de Phyſ.* xxiv.

223 Affinities of ſilica.

The affinities of ſilica are as follows:

Fluoric acid,
Fixed alkali.

SECT. VI. *Of Alumina.*

224 Method of obtaining alumina.

DISSOLVE alum in hot water, and add to the ſolution potaſs as long as any precipitate is formed. Decant off the fluid part, and waſh the precipitate in a ſufficient quantity of water, and then allow it to dry. The ſubſtance thus obtained is called *alumina*. Its properties were firſt aſcertained with accuracy by Margraf.

225 Its properties.

Alumina thus obtained is a very white ſpongy powder, without any ſmell or taſte.

Its ſpecific gravity is 2,00†. It is ſcarcely ſoluble in water, but may be diffuſed through it with great facility.

† *Kirwan's Miner.* i. 9.

Alumina.

With a ſmall quantity of water it forms a very tough ductile paſte, and does not readily mix with more.

In its uſual ſtate of dryneſs it is capable of abſorbing 2½ times its weight of water, without ſuffering any to drop out. It retains this water more obſtinately than any of the earths hitherto deſcribed. In a freezing cold it contracts more, and parts with more of its water than any other earth; a circumſtance which is of ſome importance in agriculture.*

* *Ibid.*

Alumina has never yet been obtained in a cryſtallized form. It has no effect whatever on vegetable colours.

The moſt intenſe heat does not fuſe it, but it has the ſingular property of diminiſhing in bulk in proportion to the intenſity of the fire to which it is expoſed. It becomes at the ſame time exceedingly hard: Mr Lavoiſier rendered it capable of cutting glaſs; and Mr Boyle had long before done the ſame thing.*

* *Shaw's Boyle*, iii. 422.

226 Wedgewood's thermometer.

Wedgewood took advantage of this property of alumina, and by means of it conſtructed an inſtrument for meaſuring high degrees of heat. It conſiſts of pieces of clay of a determinate ſize, and an apparatus for meaſuring their bulk with accuracy: One of theſe pieces is put into the fire, and the temperature is eſtimated by the contraction of the piece. For a more complete deſcription of this important inſtrument, we refer to the article THERMOMETER in the *Encycl.*

Alumina is hardly ſuſceptible of combining with ſulphur or phoſphorus; but from the experiments of La Grange, it appears to have an affinity for carbon‡.

‡ *Nicholſon's Jour.* ii. 101.

1. The effect of heat on various mixtures of lime and alumina will appear from the following table§.

§ *Kirwan*, i. 56.

227 Effect of heat on mixtures of lime and alumina;

Proportions.	Heat.	Effect.
75 Lime 25 Alumina	150° Wedg.	Not melted.
66 Lime 33 Alumina	150	Remained a powder.
33 Lime 66 Alumina	(x)	Melted.
25 Lime 75 Alumina	(x)	Melted.
20 Lime 80 Alumina	(x)	Melted.

228 Magneſia and alumina;

2. Magneſia and alumina have no action whatever on each other, even when expoſed to a heat of 150° Wedgewood.*

* *Ibid.* i. 57.

229 Barytes and alumina;

3. The effect of heat on different mixtures of barytes and alumina will appear from the following experiments of Mr Kirwan†.

† *Ibid.*

 Proportions.

(x) Theſe three experiments were made by Ehrman: The heat was produced by directing a ſtream of oxygen gas on burning charcoal, and is the moſt intenſe which it has been hitherto poſſible to produce.

Alumina.

Proportions.	Heat.	Effect.
80 Alumina 20 Barytes	150° Wedg.	Scarcely hardened.
75 Alumina 25 Barytes	156	No sign of fusion, a loose powder.
66 Alumina 33 Barytes	152	As the former.
50 Alumina 50 Barytes	150	As the former.
20 Alumina 80 Barytes	148	Somewhat harder, but no sign of fusion.
25 Alumina 75 Barytes	150	Harder, but no sign of fusion.

4. Nothing is known concerning the effect of heat on mixtures of strontites and alumina.

230 Alumina and silica; * Kirwan's Min. i. 58.

5. Equal parts of alumina and silica harden in the temperature of 160° Wedgewood, but do not fuse. Achard found them infusible in all proportions in a heat probably little inferior to 150° Wedgewood. Mixtures of these two earths in various proportions form *clays*, but these are seldom uncontaminated with some other ingredients.

231 Lime, magnesia, and alumina:

6. From the experiments of Achard, it appears that no mixture of lime, magnesia, and alumina, in which the lime predominates, is vitrifiable, except they be nearly in the proportions of three lime, two magnesia, one alumina; that no mixture in which magnesia predominates will melt in a heat below 166°; that mixtures in which the alumina exceeds are generally fusible, as will appear from the following table†:

† Ibid. i. 72.

3 Alumina 2 Lime 1 Magnesia	A porcelain.
3 Alumina 1 Lime 2 Magnesia	A porcelain.
3 Alumina 1 Lime 3 Magnesia	Porous porcelain.
3 Alumina 2 Lime 3 Magnesia	Porous porcelain.
3 Alumina 2 Lime 2 Magnesia	Porcelain.

232 Lime, silica, and alumina;

7. From the same experiments, and those of Kirwan, we learn, that, in mixtures of lime, silica, and alumina, when the lime exceeds, the mixture is generally fusible either into a glass or a porcelain, according to the proportions. The only infusible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina

That if the silica exceeds, the mixture is frequently fusible into an enamel or porcelain, and perhaps a glass; and that when the alumina exceeds, a porcelain may often be attained, but not a glass‡.

‡ Ibid. i. 73.

233 Magnesia, silica, and alumina;

8. As to mixtures of magnesia, silica, and alumina, when the magnesia exceeds, no fusion takes place at 150°. When the silica exceeds, a porcelain may often be attained; and three parts silica, two magnesia, and one alumina, formed a glass. When the alumina exceeds, nothing more than a porcelain can be produced.*

* Ibid. i. 72.

234 And Lime, magnesia, silica, and alumina.

9. Achard found that equal parts of lime, magnesia, silica, and alumina, melted into a glass. They fused also in various other proportions, especially when the silica predominated.

235 Affinities of alumina.

The affinities of alumina are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Oxalic,
Arsenic,
Fluoric,
Sebacic,
Tartarous,
Succinic,
Saccholactic,
Citric,
Phosphoric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic.

Sect. VII. *Of Jargonia.*

236 Discovery of jargonia.

Among the precious stones which come from the island of Ceylon, there is one called *jargon*, which is possessed of the following properties.

Its colour is various, grey, greenish white, yellowish, reddish brown, and violet. It is often crystallized, either in right angular quadrangular prisms surmounted with pyramids, or octahedrals consisting of double quadrangular pyramids. It has generally a good deal of lustre, at least internally. It is mostly semitransparent. Its hardness is from 10 to 16: Its specific gravity from 4,416 to 4,7.*

* Ibid. i. 333.

It loses scarcely any of its weight in a melting heat; for Klaproth found that 300 grains, after remaining in it for an hour and a half, were only one-fourth of a grain lighter than at first†. Neither was it attacked either by muriatic or sulphuric acid, even when assisted by heat. At last, by calcining it with a large quantity of soda, he dissolved it in muriatic acid, and found that 100 parts of it contained 31,5 of silica, five of a mixture of nick-

† Jour. de Phys. 36. 180.

el and iron, and 68 of an earth poffeffed of peculiar properties. This earth has been called *jargonia*.

237 Its properties.

Jargonia has a ftrong refemblance to alumina. It is of a white colour. Its fpecific gravity probably exceeds 4,000.

It differs from alumina in the compounds which it forms with other bodies, in being infoluble in a boiling folution of pure potafs or foda, and in being infufible by heat when mixed with thefe fubftances in a ftate of drynefs‡.

‡ *Kirwan's Mineral.* i. p. 14.

No more of its properties are yet known.

Sect. VIII. *Of Adamanta.*

238 Difcovery of adamanta.

There is a ftone found in China and in the Eaft Indies near Bombay, which from its hardnefs has been called *adamantine fpar*. Mr Greville firft received fome fpecimens of it, and made it known to feveral French and Englifh naturalifts.

The variety which comes from China is cryftallized in hexagonal prifms. It is of a grey colour. The entire pieces are opaque, but thin plates of it are tranfparent. It is fo hard, that it not only cuts glafs as eafily as the diamond, but even fcratches rock cryftal and many other very hard ftones. Its fpecific gravity is 3,710 The variety which comes from Bombay, and which is whiter than the other, is called *corundum**.

* *Klaproth, Ann. de Chim.* i. 188.

Mr Greville fent fome fpecimens of this ftone to Mr Klaproth, that he might analyfe it: a tafk which he found very difficult to perform, for the common proceffes had no effect upon it. At laft he fucceeded by fufing it 12 times in a filver crucible with 15 parts of foda, and expofing it each time for five hours to the ftrongeft heat which the crucible could endure. After each fufion he foftened the mafs with boiling water, precipitating by acids the earth which the foda had diffolved. He digefted alfo different times the undecompofed part in boiling acids. By this procefs he decompofed it, and found that it was compofed of two parts of alumina, and one of a peculiar earth which has been called *adamanta*.

239 Its properties.

This earth he at firft took for filica; but it differs from it in not being infufible when mixed with potafs or foda. Its fpecific gravity probably exceeds 3,00†. Nothing more is known concerning its properties.

† *Kirwan's Mineral.* i. 17.

240 Glucina.

A new earth has lately been difcovered by Mr Vauquelin in the beryl, to which he has given the name of *glucina*. His account of its properties we have not hitherto been able to procure: we muft therefore referve our defcription of it till we come in the order of the alphabet to the word Glucina.

241 Sidneia.

Thefe are all the fimple earths hitherto difcovered; for *Sidneia*(y), which was announced by Mr Wedgewood as a peculiar earth, has lately been proved by Mr Hatchet* to be merely a mixture of feveral earths which have been long known.

* *Phil. Tranf.* 1798.

242 Remarks on the earths.

The firft four earths have a great many common properties: they tinge vegetable blues green, they have a ftrong affinity for carbonic acid, and combine readily with all acids. They have fometimes been called *alkaline earths*.

There is a ftrong refemblance between filica and adamanta, and between alumina and jargonia.

None of the earths have been hitherto decompounded, nor has the fmalleft proof ever been brought that they are compounds. We muft therefore, in the prefent ftate of chemiftry, confider them as fimple bodies. Many attempts, indeed, have been made to fhew that there was but one earth in nature, and that all others were derived from it. The earth generally made choice of as the fimpleft was filica(z). But none of thefe attempts, notwithftanding the ingenuity of feveral of the authors, has been attended with the fmalleft fhadow of fuccefs.

We have mentioned formerly that it was almoft the univerfal opinion of chemifts that metals were compofed of fome of the earths united to phlogifton; but of late an attempt has been made to prove that all the earths are metallic oxyds, and that they can actually be reduced to the ftate of metals.

Baron had long ago fufpected that alumina had fomewhat of a metallic nature; and Bergman had been induced by its great weight, and feveral other appearances, to conjecture that barytes was a metallic oxyd: But the firft chemift who ventured to hint that all earths might be metallic oxyds was Mr Lavoifier*. About the year 1790, foon after the publication of Mr Lavoifier's book, Mr Tondi and Profeffor Ruprecht, both of Schemnitz, announced that they had obtained from barytes, by the application of a ftrong heat, a metal of the colour of iron, and attracted by the magnet, which they called *borbonium*; from magnefia another, which they called *auftrum*; a third from lime, alfo called *auftrum*; and a fourth from alumina, which they denominated *apulum*. Their method of proceeding was to apply a violent heat to the earths, which were furrounded with charcoal in a Heffian crucible, and covered with calcined bones in powder.

* *Chemiftry*, p. 217. Englifh tranfl.

But their experiments were foon after repeated by Klraproth, Savorefi, and Tihaufki; and thefe accurate chemifts foon proved, that the pretended metals were all of them *phofphurets of iron*. The iron, by the violence of the heat had been extracted from the crucible, and the phofphorus from the bones. The earths therefore muft ftill continue a diftinct clafs of bodies: and, as Klaproth has obferved, their properties are fo exceedingly different from thofe of metallic oxyds, that the fuppofition of their being compofed of the fame ingredients is contrary to every fact, and to every analogy with which we are acquainted.

Chap. V. *Of* Caloric.

Nothing is more familiar to us than *heat*; to attempt to define it therefore would be unneceffary. When we fay that *a perfon feels heat*, that *a ftone is hot*, the expreffions

(y) This fubftance was contained in a mineral brought from Sidney Cove in New-Holland. Wedgewood's analyfis was publifhed in 1790. Klaproth afterwards analyfed it without finding the new earth which it had been fuppofed to contain. But doubts were entertained concerning the identity of the minerals examined by thefe two philofophers. Thefe doubts have been removed by Mr Hatchet.

(z) Mr Sage, however, pitched upon lime.

expreſſions cauſe no difficulty; every one underſtands them perfectly: yet in each of theſe propoſitions the word *heat* has a diſtinct meaning. In the one it ſignifies the *ſenſation* of heat: in the other, the *cauſe* of that ſenſation. This ambiguity, though of little conſequence in common life, leads unavoidably in philoſophical diſcuſſions to confuſion and perplexity. It was to prevent this that the French chemiſts made choice of the word *caloric* to ſignify the *cauſe of heat*. When I put my hand on a hot ſtone, I experience a certain ſenſation, which I call the *ſenſation of heat*; the cauſe of this ſen-
243 ſation is *caloric*.

Whether caloric be a ſubſtance.

Concerning the nature of caloric, there are two opinions which have divided philoſophers ever ſince they turned their attention to the ſubject. Some ſuppoſe that caloric, like gravity, is merely a property of matter, and that it conſiſts, ſome how or other, in a peculiar vibration of its particles; others, on the contrary, think that it is a diſtinct ſubſtance. Each of theſe opinions has been ſupported by the greateſt philoſophers; and the obſcurity of the ſubject is ſuch that both ſides have been able to produce exceedingly plauſible and forcible arguments (13). The recent diſcoveries, however, in this branch of chemiſtry, have rendered the latter opinion much more probable than the former. Indeed we do not ſee how it is poſſible to account for many of the phenomena of nature, unleſs caloric be conſidered as a ſubſtance, as we truſt ſhall appear from the inveſtigation into which we are about to enter. We mean, then, with the generality of modern chemiſts, to take it for granted, that caloric is a ſubſtance, without pretending to be able to demonſtrate the truth of our opinion, but merely becauſe we conſider it as infinitely more plauſible than the other. If the receiver of an air-pump, while it contains a thermometer, be ſuddenly exhauſted of air, the thermometer ſinks ſeveral degrees, and then gradually riſes again to its former height. Now if heat be owing to vibration, how comes it that the ſmall quantity of matter remaining in the receiver is firſt inſufficient, and afterwards ſufficient to maintain the temperature? Is it not more probable that part of the caloric was carried off with the air, and that it gradually returned through the glaſs, which it is capable of pervading, though with difficulty*. When air is let into an exhauſted receiver, the thermometer, as Lambert firſt obſerved, riſes ſeveral degrees. Is not this owing to an additional quantity of caloric introduced by the air? The thermometer then ſinks ſlowly. Is not this becauſe the ſuperabundant caloric gradually pervades the glaſs and flies off? Taking it for granted then, that caloric is a ſubſtance, we proceed to examine its properties.

* See *Pictet ſur le Feu*, ch. ii.

244 Caloric expands bodies.

1. When bodies become hot, or which is the ſame thing, when caloric enters into them, they expand in every direction; and this expanſion is proportional to the accumulation of caloric. The firſt and moſt obvious property of caloric then is the power of expanding bodies. It does not, however, expand all ſubſtances equally, and we are ſtill ignorant of the law which it follows. All that can be done therefore is to collect facts till this law be diſcovered. A number of theſe may be ſeen in the following table:

TABLE *of the Expanſion of various Bodies at different Temperatures.*

* Blagden. † Newton.

Temperature.	Water*.	Mercury.	Linſeed Oil†.	Alcohol*.	Temperature.	Water*.	Mercury.	Linſeed Oil†.	Alcohol*.
30°	—	—	—	100000	100	100908	100711,8	—	104162
32	—	100000,0	100000	—	105	—	100762,7		
35	100000	100030,0	—	100267	110	—	100813,6		
40	99997	100081,0	—	100539	120	101404	100915,4		
45	100005	100131,9	—	101818	130	—	101017,2		
50	100023	100182,8	—	101105	140	—	101119,0		
55	100053	100253,7	—	101401	150	102017	101220,8		
60	100091	100304,6	—	101688	160	—	101322,6		
65	100141	100355,5	—	101984	167	102753	—		
70	100197	100406,4	—	102281	170	—	101424,4		
75	100261	100457,3	—	102583	180	—	101526,2		
80	100332	100508,2	—	102890	190	103617	101628,0		
85	100411	100559,1	—	103202	200	—	101729,8		
90	100694	100610,0	—	103517	212	104577	101835,0	107250	
95	100790	100660,9	102560	103840	408	—	—	115160	

(13) How can the ſupporters of the doctrine of heat being but a vibration of the particles of bodies, reconcile their hypotheſis with the well eſtabliſhed fact of a hot body communicating its heat to the ſurrounding bodies when ſuſpended in a Torricellian vacuum? Will it be ſufficient for them to ſay, that it is never perfectly free from air, and that the ſmalleſt portion is ſufficient to communicate this vibration?

TABLE *of the Expansion of various Bodies at different Temperatures continued.*

Temperature.	Sulph. acid.*	Nitric acid.*	Glass.†	Air.	Oxygen gas.§	Azotic gas.§	Hydrogen gas.§	Nitrous gas.§	Carb. acid gas.§	Ammoniacal gas.§
32°	—	—	100000	100000	100000	100000	100000	100000	100000	100000
40	—	—	—	101790						
45	—	100005	—	—						
50	100149	100149	—	104140						
55	100263	101074	100006	—						
60	100382	101389	—	106560						
65	100615	101767	—	—						
70	100751	102096	—	108950						
75	—	—	100014	—						
77	—	—	—	—	104520	103400	108390	106520	111050	127910
80	—	—	—	111300						
90	—	—	—	113590						
100	—	—	100023	—						
110	—	—	—	117580						
122	—	—	100033	—	124830	121860	122830	117630	130660	184870
130	—	—	—	121870						
150	—	—	100044	126030						
167	—	—	100056	—	190180	176640	137420‡	144370	173850	358780
170	—	—	—	130090						
190	—	—	100069	133970						
212	—	—	100083	134890	547670‡	694120	139120‡	160290‡	200940‡	680090‡ (A)

* *Kirwan.*
† *De Luc.*
§ *De Vernois, Encycl. Method. art. Air.*

TABLE *of the Expansion of Metals from 32° to 212°.*†

Temperature.	Antimony.	Steel.	Iron.	Cast-Iron.	Bismuth.	Copper.	Cast Brass.	Brass Wire.
32°	120000	120000	120000	120000	120000	120000	120000	120000
212	120130	120147	120151		120167	120204	120225	120232
White heat		123428*	121500*	122571*				

	Tin.	Lead.	Zinc.	Hammered Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin (B) 1
32°	120000	120000	120000	120000	120000	120000	120000	120000	120000
212	120298	120344	120355	120373	120323	120301	120247	120274	120218

† *Smeaton, Phil. Trans.* xlviii. 612.
* *Rinman.*

From

(A) This mark ‡ implies, that, owing to some inaccuracy in making the experiments, the numbers to which it is attached are not to be depended on.

(B) The metal whose expansion is here given was an alloy composed of three parts of copper and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus in the last column but two, the metal consisted of two parts of brass alloyed with one of zinc.

Caloric.

245 Exception. From this table, it appears that the gases are more expanded by caloric than fluids, and fluids more than solids; and that the expansion of all bodies hitherto examined, mercury alone excepted, goes on in an increasing series. To the expanding power of caloric there is one singular exception: From 30° to 40° Fahrenheit, *water*, instead of being expanded, suffers a remarkable contraction, as is evident from the following table of its bulk for every degree between 30° and 40.

	Bulk.
30°	100074
31	100070
32	100066
33	100063
34	100060
35	100058
36	100056
37	100055
38	100054
39	100054
40	100054.*

* Blagden.

From 40° it expands like other substances on being heated (B).

246 Thermometer. The expansion of bodies by caloric has furnished us with an instrument for measuring the various degrees of it in different substances, we mean the thermometer; and as mercury is the only fluid which expands equably, it is obviously the only proper one for thermometers (14). The thermometer uniformly used in this article is that of Fahrenheit, except when some other is particularly mentioned.

247 No body without caloric. 2. By means of the thermometer, we learn that there is no body which does not contain caloric, because there is none so cold that it cannot be made colder: and cooling a body is nothing else but abstracting a part of the caloric which it contains.

248 Equilibrium of caloric. 3. Caloric cannot be confined in any body while those in its neighbourhood are colder, but continues to rush out till every thing is reduced to the same temperature. This does not proceed from the attraction of the colder bodies, but from the tendency of caloric to exist everywhere in an equal degree of tension: For when hot bodies are placed in the exhausted receiver of an air-pump, as we learn from Mr Pictet †, or in the Torricellian vacuum, as Count Rumford has shewn us ‡, the caloric leaves them in the same manner, tho' more slowly, and they are equally reduced to the temperature of the surrounding bodies. This property has been called *the equilibrium of caloric*. The only way therefore to confine or accumulate this substance in a body, is to surround it with bodies which are hotter than itself.

† Sur le Feu, chap. vi.

‡ Phil. Trans. 1786, Part I.

249 The particles of caloric repel each other. 4. The equilibrium of caloric seems evidently to prove that its particles repel each other (15). This repulsion will cause them when accumulated in any place to fly off in every direction, and to continue to separate till they are opposed by caloric in other bodies of the same relative density with themselves, which, by repelling them in its turn, compels them to continue where they are. The caloric in bodies therefore is in what has been called by Mr Pictet a state of *tension* (c). Its particles are actuated by a force which would make them separate to an indefinite distance, were they not confined by the opposite force of the caloric which surrounds them. The *equilibrium* therefore depends on the balancing of two opposite forces; the repulsion between the particles of caloric in the body, which tends to diminish the temperature; and the repulsion between the caloric of the body and the surrounding caloric, which tends to raise the temperature. When the first force is greater than the second, as is the case when the temperature of a body is higher than that of the surrounding bodies, the caloric flies off, and the body becomes colder. When the last force is stronger than the first, as is the case when a body is colder than those which are around it, the particles of its caloric are obliged to approach nearer each other, new caloric enters to occupy the space which they had left, and the body becomes hotter. When the two forces are equal, the bodies are said to be of the same temperature, and no change takes place.*

* See Pictet sur le Feu, ch. i.

It is the action of these opposite forces which makes the thermometer a measure of temperature. When applied to any body, it continues to rise or fall till the caloric in it and in the body to which it is applied are of the same tension, and then it remains stationary. The thermometer therefore merely indicates that the temperature of the body to which it is applied is equal to its own. It is obvious that, in order to obtain the real temperature of bodies, the thermometer should be so small that the quantity of caloric, which enters or leaves it, may not materially affect the result.

This property of caloric seems to be the cause of the elasticity of the gases, in which, as we shall shew afterwards,

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(B) There was a curious fact concerning dilatation observed by Mr de Luc. A brass rod which he used as a thermometer became in summer *habitually* longer; that is to say, that after being for some time lengthened by heat, it did not contract by the application of cold to its old length, but continued somewhat longer. In winter the contrary phenomenon took place. After being contracted for some time by cold, it did not return to its old length on the application of heat, but kept somewhat shorter. A leaden rod shewed these effects in a greater degree. Glass has not this quality. De Luc suspects that this property is inversely as the elasticity of bodies. Glass is perfectly elastic, and lead is less elastic than brass.—*Journ. de Phys.* xviii. 369.

(14) Mercury does *not* expand regularly even according to the tables just given. For every five degrees it there appears that, in most instances, it expands 50.9, but betwixt 35° and 40° it expands 51. and between 50° and 55° it even expands 70.9, although betwixt 55° and 60° it expands again but 50.9. But this is not the only irregularity the thermometer is liable to. Glass is very irregular in its expansion. The tube and bulb therefore in which the mercury is contained must by their irregular expansions and contractions render this instrument inaccurate. T. P. S.

(15) Why need we consider caloric as a *principle of repulsion* when we can otherwise explain all its phenomena. T. P. S.

(c) The phrase was first used by Mr Volta.

Caloric. wards, it exists in great quantities. Perhaps it is the cause of elasticity in general; for we have no demonstrative evidence that the particles of elastic bodies repel each other (D), and we are certain that all of them contain caloric. Perhaps also it is owing to this repulsive property of caloric that the particles of no body actually touch each other; for the less caloric we leave in a body, the nearer its particles approach to one another. The expansion of bodies by caloric seems also to depend on the same property. The particles of caloric uniting with those of the body, endeavour to drag them along when they recede from each other. The expansion of bodies therefore ought to be inversely as their cohesion, and directly as the tension of the caloric which they contain. This property of caloric seems likewise to afford an explanation of a very curious fact, which was first, we believe, mentioned by De Luc in his Treatise

250 on the Modifications of the Atmosphere, and afterwards

Bodies become lighter by being heated, ascertained by Dr George Fordyce, that bodies become absolutely lighter by being heated. He took a glass globe three inches in diameter, with a short neck, and weighing 451 grains; poured into it 1700 grains of water from the New river, London, and then sealed it hermetically. The whole weighed 2150$\frac{11}{16}$ grains at the temperature of 32°. It was put for twenty minutes into a freezing mixture of snow and salt till some of it was frozen; it was then, after being wiped first with a dry linen cloth, next with clean washed dry leather, immediately weighed, and found to be $\frac{1}{16}$th of a grain heavier than before. This was repeated exactly in the same manner five different times. At each, more of the water was frozen and more weight gained. When the whole water was frozen, it was $\frac{3}{16}$ths of a grain heavier than it had been when fluid. A thermometer applied to the globe stood at 10°. When allowed to remain till the thermometer rose to 32°, it weighed $\frac{2}{16}$ths of a grain more than it did at the same temperature when fluid. We shall shew afterwards that ice contains less caloric than water of the same temperature with it. The balance used was nice enough to mark $\frac{1}{1000}$th part of a grain*. Morveau too found, much about the same time, that water put into vessels hermetically sealed weighed more when frozen than when fluid†: and Mr Chaussier found, that two pounds of sulphuric acid were three grains heavier when frozen than after they had recovered their fluidity‡. Now if the particles of caloric repel each other, bodies which contain it in great quantities must be somewhat repelled by each other. The more replete therefore that any

251 body is with caloric, the more it will be repelled by the

And why. earth, which always contains a great quantity; and this repulsion must in some degree counteract its gravitation. This explanation was first suggested, we believe, by Dr Black (16).

* Phil. Trans. 1785, Part II.

† Journ. de Phys. 1785, Oct.

‡ Journ. de Savans, 1785, p. 493.

252 Caloric moves more readily upwards than downwards.

The same property explains another curious fact discovered by Mr Pictet of Geneva, that caloric moves more readily vertically upwards than downwards. He took a tube of tinplate, two inches in diameter and 44 in length, and inclosed in it a bar of copper four lines in diameter and 33 inches in length, which was placed and fixed exactly in its axis. This tube was exhausted of air, by means of an air-pump, till the manometer* stood at the height of four lines. It was inclosed in another tube of pasteboard, except about two inches, exactly in the middle, to which place the sun's rays were directed for half an hour by means of a concave mirror. The ends of the copper bar were scooped out into concave hemispheres; and into each of these the bulb of a very sensible thermometer was fixed. The tube was placed vertically. The highest thermometer, which we shall call A, rose to 95°, a hundred and one seconds before the lowest B. The thermometer B rose no higher than 95°; but the thermometer A reached 101,75°. To see whether this difference was owing to the thermometers, the tube was inverted, and consequently the highest thermometer in the former experiment was lowest in this. The thermometer B now rose from 49° to 97,25° in 2810″; the thermometer A in 2763″, or 47″ sooner than B. It was evident from this result, that the thermometer A was more sensible than the thermometer B by 47″. If this be subtracted from 101″, the former difference, it will leave 54″, as the difference resulting from position. These experiments were repeated with only this difference, that round the ends of the bar and the bulbs of the thermometers (but without touching the bulbs) some folds of oiled paper were wrapped to confine the caloric. The superior thermometer A rose from 50° to 106,25° in 34 minutes, which was 93″ sooner than the inferior B: it rose to 110,75°, the thermometer B only to 106,25°. The tube being reversed, the thermometer A, which was now lowest, rose from 46° to 115,25° in 40′ 30′, or forty seconds sooner than the thermometer B. This subtracted from 93″, as formerly, leaves 53′ for the difference of situation. The superior thermometer mounted after the burning glass was removed 0,45°, remained stationary for 80″, and after five minutes had only descend 0,45°: the other did not ascend at all; in one minute it descended 0,225°, and in 6′ 8″ it descended 2,47. In 22′ 50″ the inferior descended 63,725°, the superior 61,475°*. From these experiments, it is obvious that the particles of caloric move somewhat faster, and in somewhat greater

* See Manometer in this Suppl.

* Pictet sur le Feu, chap. 2.

(D) We acknowledge that several philosophers of the first rank, Æpinus for instance, and Boscovich, have supposed, that the particles of all bodies both attract and repel each other; but we cannot help thinking it rather improbable (if it be possible) that two such opposite properties should exist together.

(16) We may, I think, explain these experiments without the aid of supposing caloric to possess absolute *levity*. While these gentlemen were weighing their vessels of frozen fluids, the caloric of the surrounding air kept constantly passing in, and thus it became condensed; this air would of consequence fall through the more rarified air below it and would be followed by a fresh quantity from above, which would be condensed in its turn, thus a constant stream of air would pass down on the cold body which would be sufficient to give it the small additional tendency of $\frac{3}{16}$ths of a grain downwards. Neither do these gentlemen appear to have paid any attention to the water which would be deposited, by the air, when it lost part of its caloric, on the vessels.
T. P. S.

Caloric.

er quantity, upwards than downwards; owing, doubtleſs, to the repulſive power of the caloric in the earth. The ſmall quantity of air that remained in the tube, may perhaps be ſuppoſed ſufficient to account for the difference, without allowing any ſuch tendency upwards in caloric. But it is evident from the experiments of the Florentine academicians on the ſame ſubject, with tubes full of air, that even when in great abundance, that fluid hardly affected the riſing of the ſuperior thermometer: ſurely then its effect muſt be altogether imperceptible when ſo little of it remained; and in the third and fourth experiments the oiled paper prevented any of the heated air from approaching the thermometer (17).

253 Conducting power of bodies:

5. If we take a bar of iron and a piece of ſtone of equal dimenſions, and putting one end of each into the fire, apply either thermometers or our hands to the other, we ſhall find the extremity of the iron ſenſibly hot long before that of the ſtone. Caloric therefore does not paſs through all bodies with the ſame celerity and eaſe. The power that bodies have to allow it a paſſage through them is called their *conducting power*; thoſe that allow it to paſs with facility, are called *good conductors*; thoſe through which it paſſes with difficulty, are called *bad conductors*; and thoſe which do not allow it to paſs at all, *non-conductors*.

254 Of wood and charcoal;

It is probable that all ſolids conduct heat in ſome degree, at leaſt this is the caſe with every one at preſent known. Wood and charcoal are exceeding bad conductors of caloric (E). Count Rumford informs us, that a piece of green oak plank was employed to ſtir the melted metal of which cannons were founding at Munich, and it was often allowed to remain a conſiderable time in the furnace; yet the caloric had penetrated to ſo inconſiderable a depth, that at the diſtance of $\frac{1}{20}$th of an inch below the ſurface, the wood did not ſeem to have been the leaſt affected by it; the colour remained unchanged, and it did not appear to have loſt even its moiſture*.

* *Rumford's Eſſays*, ii. 229.

255 Of glaſs;

Glaſs is alſo a very bad conductor; and this is the reaſon that it is ſo apt to crack on being heated or cooled ſuddenly; one part of it receiving or parting with its caloric before the reſt, expands or contracts, and deſtroys the coheſion.

256 Of metals;

Metals are the beſt conductors of caloric of all the ſolids hitherto examined. The conducting powers of all, however, are not equal. Dr Ingenhouſz procured cylinders of ſeveral metals exactly of the ſame ſize, and having coated them with wax, he plunged their ends into hot water, and judged of the conducting power of each by the length of wax-coating melted. From theſe experiments he concluded, that the conducting powers of the metals which he examined were in the following order*:

Silver,
Gold,
Copper, } nearly equal,
Tin,
Platinum, } much inferior to the others.
Iron,
Steel,
Lead,

* *Journ. de Phyſ.* 1789, p. 68.

257 Of ſtones and ſolids capable of melting.

Next to metals ſtones ſeem to be the beſt conductors; but this property varies conſiderably in different ſtones. Bricks are much worſe conductors than moſt ſtones. All ſolids capable of being melted become non conductors the moment they are heated to the melting point: the caloric enters them eaſily enough, but it remains in them.

258 All fluids non-conductors of caloric.

All fluids hitherto examined are *non conductors of caloric*. They can receive it indeed from other ſubſtances, and they can give it out to other ſubſtances; but one particle can neither receive it nor give it out to another particle. Before a fluid therefore can either be heated or cooled, every particle muſt go individually to the ſubſtance from which it receives or to which it gives out caloric. For this very important diſcovery the world is indebted to Count Rumford. Before the publication of his eſſays it had not even been ſuſpected; ſo far from it, that fluids had been ranked among the beſt conductors of caloric.

259 How this was diſcovered.

In a ſet of experiments on the communication of heat, he made uſe of thermometers of an uncommon ſize. Having expoſed one of theſe (the bulb of which was near four inches in diameter) filled with alcohol to as great a heat as it could ſupport, he placed it in a window to cool where the ſun happened to be ſhining. Some particles of duſt had by accident been mixed with the alcohol: theſe being illuminated by the ſun, became perfectly viſible, and diſcovered that the whole liquid in the

(17) Theſe experiments of Mr Pictet are undoubtedly ingenious, but by no means concluſive. There ſtill remained a conſiderable quantity of air in the tube. This air became rarified juſt in the centre of the tube where the mirror converged the ſun's rays. Hence this air would riſe up to the top of the tube, and part with its extra quantum of heat to the upper thermometer. This air would be replaced from above, and thus a conſtant ſtream of warm air towards the upper thermometer would be produced. Thus might we account for the riſe of the upper thermometer without the aid of a *principle of levity*. That the lower thermometer ſhould riſe but ſlowly is not ſurpriſing when we conſider the experiments of Count Rumford on the conducting powers of air, which, *at leaſt*, prove it to be a *very bad* conductor of caloric. The oiled paper not preventing the thermometer riſing is no proof that it is not this ſtream of warm air which cauſes the upper thermometer to riſe, unleſs it be proved that it is a non-conductor of caloric, and if it were I do not ſee how the caloric is to get through to the thermometer eaſier if it poſſeſſes abſolute *levity* than if it be a gravitating fluid. All, I think, theſe experiments prove is, that the ſpecific gravity of caloric is leſs than that of the imperfect vacuum Mr Pictet made uſe of. T. P. S.

(E) This fact merits the attention of chemiſts. It is obvious, that when metallic oxyds are ſurrounded with charcoal powder, their temperature cannot be raiſed near ſo high as it otherwiſe would be. It is not unlikely that ſome part of the difficulty which has been experienced in attempting to reduce and fuſe ſeveral metallic ſubſtances may have been owing to this cauſe.

Caloric.

the tube of the thermometer was in a most rapid motion, running swiftly in opposite directions upwards and downwards at the same time. The *ascending* current occupied the axis, the *descending* current the sides of the tube. When the sides of the tube were cooled by means of ice, the velocity of both currents was accelerated. It diminished as the liquid cooled; and when it had acquired the temperature of the room, the motion ceased altogether. This experiment was repeated with linseed oil, and the result was precisely the same. These currents were evidently produced by the particles of the liquid going individually to the sides of the tube, and giving out their caloric. The moment they did so, their specific gravity being increased, they fell to the bottom, and of course pushed up the warmer part of the fluid, which was thus forced to ascend along the axis of the tube. Having reached the top of the tube, the particles gave out part of their caloric, became specifically heavier, and tumbled in their turn to the bottom.

As these internal motions of fluids can only be discovered by mixing with them bodies of the same specific gravity with themselves, and as there is hardly any substance of the same specific gravity with water which is not soluble in it, Count Rumford had recourse to the following ingenious method of ascertaining whether that fluid also followed the same law. The specific gravity of water is increased considerably by dissolving any salt in it; he added, therefore, potash to water till its specific gravity was exactly equal to that of amber, a substance but very little heavier than pure water. A number of small pieces of amber were then mixed with this solution, and the whole put into a glass globe with a long neck, which, on being heated and exposed to cool, exhibited exactly the same phenomena with the other fluids. A change of temperature, amounting only to a very few degrees, was sufficient to set the currents a-flowing; and a motion might at any time be produced by applying a hot or a cold body to any part of the vessel. When a hot body was applied, that part of the fluid nearest it ascended; but it descended on the application of a cold body.

260 Proofs of the non-conducting power of water,

If caloric pass through water only by the internal motion of its particles, as this experiment seems to prove, it is evident that every thing which embarrasses these motions must retard its transmission: and accordingly Count Rumford found this to be the case. He took a large linseed-oil thermometer with a copper bulb and glass tube: the bulb was placed exactly in the centre of a brass cylinder, so that there was a void space between them all around 0,25175 of an inch thick. The thermometer was kept in its place by means of four wooden pins projecting from the sides and bottom of the cylinder, and by the tube of it passing through the cork stopper of the cylinder. This cylinder was filled with pure water, then held in melting snow till the thermometer fell to 32°, and immediately plunged into a vessel of boiling water. The thermometer rose from 32° to 200° in 597″. It is obvious that all the caloric which served to raise the thermometer must have made its way through the water in the cylinder. The experiment was repeated exactly in the same manner, but the water in the cylinder, which amounted to 2276 gr. had 192 gr. of starch boiled in it, which rendered it much less fluid. The thermometer now took 1109″ to rise from 32° to 200°. The same experiment was again repeated with the same quantity of pure water, having 192 gr. of eiderdown mixed with it, which would merely tend to embarrass the motion of the particles. A quantity of stewed apples were also in another experiment put into the cylinder. The following tables exhibit the result of all these experiments.

Time the Caloric was in passing into the Thermometer.

Temperature.	Through the Water and Starch	Thro' the Water and Eiderdown.	Through stewed Apples	Through pure Water
Therm. rose from 32° to 200° in	Seconds. 1109	Seconds, 949	Seconds. $1096\frac{1}{2}$	Seconds. 597
Therm. rose 80°, *viz* from 80° to 160°, in	341	269	335	172

Time the Caloric was in passing out of the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through stewed Apples.	Through pure Water.
Therm. fell from 200° to 40° in	Seconds. 1548	Seconds. 1541	Seconds. $1749\frac{1}{2}$	Seconds. 1032
Therm. fell 80°, *viz.* from 160° to 80°, in	468	460	520	277

Now, neither the starch nor the eiderdown could produce any alteration in the water except impeding its internal motions: consequently whatever impedes these motions diminishes the conducting power of water. But this could not happen unless every individual particle actually went from the cylinder to the thermometer.

Only one proof more was wanting to remove every doubt; and this proof also Count Rumford has given us. If water be a non-conductor, it is evident that no caloric can pass downwards when the heat is applied to the surface; for as the particles of water become specifically lighter by being heated, they cannot sink to the bottom. Accordingly Count Rumford found, that water might be made actually to boil near the top of a glass tube, while that at the bottom was not sensibly warmed. Owing to the law already mentioned, indeed, that water, after being cooled down to 40°, expands instead of contracting when its temperature is lowered, a mass of water may be raised to 40° by applying the heat to its upper surface; because water at 40° is heavier than at any degree below it, and will therefore sink to the bottom; but its temperature cannot be raised any higher. This Count Rumford proved, by shewing that water of the temperature of 40°, placed above ice, will

Caloric.

melt as much of it in the fame time as water at any higher temperature whatever, even boiling hot.

Into a cylindrical glafs jar 4,7 inches in diameter and 13,8 inches high, he put 43,87 cubic inches, or 1 lb. 11$\frac{1}{7}$ oz. troy of water, and placing the jar in a freezing mixture compofed of pounded ice and common fea falt, he froze the water into one compact mafs. The jar was then put into a mixture of pounded ice and pure water, reaching exactly to the top of the ice in it, and fuffered to remain there four hours, that the ice might come to the temperature of 32°; then boiling water was cautioufly poured on it, and the jar ftill allowed to ftand in the ice and water. He foon found that a confiderable quantity of ice was melted at the very beginning of the experiment, owing to the agitation into which the water was thrown by the act of pouring it into the veffel. To prevent this as much as poffible, he covered the ice with a fmall quantity of ice cold water, upon which he placed a flat fhallow difh of light wood 4$\frac{1}{2}$ inches in diameter, and about one-fourth of an inch thick at the bottom. This veffel was perforated by feveral hundred very fmall holes. The hot water was poured into this difh through a long wooden tube, the bottom of which was ftopped up, and the water made to iffue through fmall holes in the fide at the lower end. As this difh always floated on the furface of the water, and as the fluid paffing through it by a number of fmall holes was not projected with force, it is evident that a confiderable part of thefe violent motions was prevented. The following is the refult of three experiments made in this manner.

Number of Experiments.	Time the hot Water was on the Ice.	Temperature of the hot Water one inch below its furface.		Quantity of Ice melted.
		At the beginning.	At the end	
	Minutes.			Grains.
1	10	192°	182°	580
2	30	190°	165°	914
3	180	190°	95°	3200

From thefe experiments he determined the quantity of ice melted in the act of pouring the water into the jar, fuppofing equal quantities to be melted in equal times. If 3200 grains were melted in 180′, fubtracting 580, the quantity melted in 10′, there remains 2620 gr. for the quantity melted in 170′, in every ten of which 154 gr. muft have been melted; for 170 : 10 : : 2620 : 154 nearly. Subtracting 154 from 580, the quantity melted in the firft ten minutes, there remains 426 gr. for the quantity melted in pouring the water into the jar. From the fecond experiment it follows, by a fimilar calculation, that 159 gr. were melted every 10 minutes; which fhows that the motions produced by pouring in the water had not ceafed in 30 minutes. It will be nearer the truth, therefore, if we endeavour to difcover the quantity melted every ten minutes by comparing the fecond and third experiments. By a fimilar calculation to the above, it comes out to be 152 gr. The following table exhibits the refults of feveral experiments, made exactly in the fame manner, but with water at a much lower temperature.

Number of Experiments.	Temper. of the Water in the Jar one inch below its furface.		Temper. of the Air.	Time the Water remained on the Ice.	Quantity of Ice melted.
	Before.	After.			
1	41°	40°	41°	10′	203 gr.
2	41	40	41	10	220
3	41	40	41	10	237
4	41	40	41	10	228
5	41	38	41	30	617
6	41	38	41	30	585

From thefe experiments it appears that the quantity of ice melted in 10′ by water at the temperature of 41° was 222 gr. while boiling water melted only 152 gr. in the fame time. To difcover whether any of this was melted in the act of pouring in the water; from a mean of the two laft experiments it appears, that 601 grains were melted in 30′: if from this 222 grains (the mean of the four firft) be deducted, there will remain 379 grains for the quantity melted in 20′, confequently 189$\frac{1}{2}$ grains is what muft have been melted in the ordinary courfe of the procefs; a quantity confiderably above 152 grains. Therefore water at 41° melts more ice in the fame time than boiling water. This Count Rumford accounts for by fuppofing, that in the hot water the defcending current from the top of the veffel, and afcending one from the ice, meeting one another in that part of the veffel where the temperature is 40°, retard each others motions, and thus prevent the melting procefs from going on fo rapidly as when there is no defcending current. And he found accordingly, that when the cooling of the water above was retarded by wrapping up the jar in a warm covering, the ice melted fafter; and when the cooling above was accelerated, it melted flower. It is evident, that in the one cafe the velocity of the defcending current was diminifhed, in the other accelerated.

Thus it has been completely proved, that water is a non-conductor of caloric. But is this the cafe alfo with other liquids? 261

Oil and mercury;

When water was frozen in a glafs jar by means of a freezing mixture, Count Rumford obferved, that the ice firft began to be formed at the fides, and gradually increafed in thicknefs; and that the water on the axis of the veffel, which retained its fluidity longeft, being compreffed by the expanfion of the ice, was forced upwards, and when completely frozen formed a pointed projection or nipple, which was fometimes half an inch higher than the reft of the ice. Upon ice frozen in this manner, he poured olive oil, previoufly cooled down to 32°, till it ftood at the height of three inches above the ice.

Caloric. ice. The veſſel was ſurrounded as high as the ice with a mixture of pounded ice and water. A ſolid cylinder of wrought iron, $1\frac{1}{4}$th inch in diameter and 12 inches long, provided with a hollow cylindrical ſheath of thick paper, was heated to the temperature of 210° in boiling water; and being ſuddenly introduced into its ſheath, was ſuſpended from the ceiling of the room, and very gradually let down into the oil, until the middle of the flat ſurface of the hot iron, which was directly above the point of conical projection of the ice, was diſtant from it only $\frac{2}{10}$ths of an inch. The end of the ſheath deſcended $\frac{1}{10}$th of an inch lower than the end of the hot metallic cylinder. Now it is evident, that if olive oil was a conductor, caloric would paſs down through it from the iron and melt the ice. None of the ice, however, was melted; and when mercury was ſubſtituted for oil, the reſult was juſt the ſame;* conſequently it follows, that neither oil nor mercury is a conductor of heat. We may conclude, therefore, with Count Rumford, that this is the caſe with liquids in general.

* *Rumford, Eſſay* vii. Part ii. chap. I.

262 Air;

Sennebier obſerved ſome time ago, that air was a very bad conductor of caloric, and that it reſiſted every change of temperature very much.* But it was reſerved for Count Rumford to prove, that it conducted it at all only by the internal motions of its particles, or that it was in fact a *non-conductor*, exactly in the ſenſe that liquids are non-conductors.* This he eſtabliſhed by ſhewing, that whatever tended to obſtruct or impede the internal motions of its particles, diminiſhed its conducting power. By mixing with a quantity of air $\frac{1}{10}$th of its bulk of eiderdown, he diminiſhed its conducting power more than one half. The warmth of furs and feathers and ſilk depends on a very ſtrong attraction between them and air, which is therefore confined in their interſtices, and thus the caloric prevented from paſſing out of the body. A *ſingle* metallic cover to a boiler in a ſhort time grew ſo hot that it could not be touched, while another of exactly the ſame form, but *double*, with a quantity of air confined in the middle, ſcarcely felt hot ‡. There can be no doubt that all the gaſes are alſo non-conductors; and Count Rumford has proved the ſame thing of ſteam by the following experiment, which we ſhall relate in his own words †:

* *Journ. de Phyſ.* 1788.

* *Phil. Tranſ.* 1792, Part I.

‡ *Rumford, Eſſay* vi.

† *Ibid.* p. 61.

263 And ſteam.

" A large globular bottle being provided, of very thin and very tranſparent glaſs, with a narrow neck, and its bottom drawn inward ſo as to form a hollow hemiſphere about 6 inches in diameter; this bottle, which was about 8 inches in diameter externally, being filled with cold water, was placed in a ſhallow diſh, or rather plate, about 10 inches in diameter, with a flat bottom formed of very thin ſheet braſs, and raiſed upon a tripod, and which contained a ſmall quantity (about $\frac{2}{10}$ths of an inch in depth) of water; a ſpirit lamp being then placed under the middle of this plate, in a very few minutes the water in the plate began to boil, and the hollow formed by the bottom of the bottle was filled with clouds of ſteam, which, after circulating in it with ſurpriſing rapidity 4 or 5 minutes, and after forcing out a good deal of air from under the bottle, began gradually to clear up. At the end of 8 or 10 minutes (when, as I ſuppoſed, the air remaining with the ſteam in the hollow cavity formed by the bottom of the bottle had acquired nearly the ſame temperature as that of the ſteam) theſe clouds totally diſappeared; and though the water continued to boil with the utmoſt violence, the contents of this hollow cavity became ſo perfectly inviſible, and ſo little appearance was there of ſteam, that, had it not been for the ſtreams of water which were continually running down its ſides, I ſhould almoſt have been tempted to doubt whether any ſteam was actually generated.

" Upon lifting up for an inſtant one ſide of the bottle, and letting in a ſmaller quantity of cold air, the clouds inſtantly returned, and continued circulating ſeveral minutes with great rapidity, and then gradually diſappeared as before. This experiment was repeated ſeveral times, and always with the ſame reſult; the ſteam always becoming viſible when cold air was mixed with it, and afterwards recovering its tranſparency when, part of this air being expelled, that which remained had acquired the temperature of the ſteam.

" Finding that cold air introduced under the bottle cauſed the ſteam to be partially condenſed, and clouds to be formed, I was deſirous of ſeeing what viſible effects would be produced by introducing a cold ſolid body under the bottle. I imagined that if ſteam was a conductor of heat, ſome part of the heat in the ſteam paſſing out of it into the cold body, clouds would of courſe be formed; but I thought if ſteam was a non-conductor of heat, that is to ſay, if one particle of ſteam could not communicate any part of its heat to its neighbouring particles, in that caſe, as the cold body could only affect the particles of ſteam actually in contact with it, no cloud would appear, and the reſult of the experiment ſhewed that ſteam is in fact a non-conductor of heat; for, notwithſtanding the cold body uſed in this experiment was very large and very cold, being a ſolid lump of ice nearly as large as an hen's egg, placed in the middle of the hollow cavity under the bottle, upon a ſmall tripod or ſtand made of iron wire; yet as ſoon as the clouds which were formed in conſequence of the unavoidable introduction of cold air in lifting up the bottle to introduce the ice, were diſſipated, which ſoon happened, the ſteam became ſo perfectly tranſparent and inviſible, that not the ſmalleſt appearance of cloudineſs was to be ſeen anywhere, not even about the ice, which, as it went on to melt, appeared as clear and as tranſparent as a piece of the fineſt rock cryſtal." Thus, then, it appears, that all elaſtic fluids are non-conductors as well as liquids.

6. If equal quantities of water and of mercury be placed at the ſame diſtance from a fire, the mercury will 264
become hot much ſooner than the water. After a ſufficient interval, however both of them acquire the ſame temperature. Now caloric flows into all bodies while they continue of a lower temperature than thoſe around them, and it flows with equal rapidity into all bodies of the ſame conducting powers, as is the caſe with theſe two fluids: But if equal quantities of caloric were conſtantly flowing into the mercury and the water, and yet the water took a longer time to become hot than the mercury, it muſt require a greater quantity of caloric to raiſe water to a given temperature than it does to raiſe mercury. Bodies that require a greater quantity of caloric to raiſe them to a particular temperature than other bodies require, are ſaid to have a greater *capacity* for caloric. That the capacity for caloric is different in different bodies, was firſt obſerved by Dr Black.

Specific caloric of bodies, what.

Dr

Caloric.

Dr Irvine afterwards investigated the subject, and Dr Crawford published a great number of experiments on it in his *Treatise on Heat*. Professor Wilcke of Stockholm, also discovered the same property of bodies. He called the quantity of caloric necessary to raise the temperature of substances a given number of degrees, their *specific caloric*; a term which we shall also employ, because the phrase *capacity for caloric* is liable to a great deal of ambiguity, and has introduced confusion into this subject (F). If two substances of unequal temperatures, as water at 100° and alcohol at 50°, be mixed together, the mixture will be of a temperature different both from that of the water and the alcohol, the water will become colder and the alcohol hotter: the water will give out caloric to the alcohol till both are reduced to the same temperature. Now if it requires just as much caloric to raise alcohol a certain number of degrees as it does to raise water the same number, that is, if these two fluids are of the same specific caloric, it is evident that the temperature of the mixture will be just 75°; for as soon as the water has given out 25° of caloric, the alcohol has acquired 25°, consequently both will be reduced to the same temperature, and will remain stationary; but if the specific caloric of the water be greater than that of the alcohol, the temperature of the mixture will be higher than 75°: for 25° of caloric in that case would raise alcohol more than 25°. If the specific caloric of water be so much greater than that of alcohol, that what raises water 20° will raise alcohol 30°; then the temperature after mixture will be 80°, because, when the water has given out 20°, the alcohol will have risen 30°, and of course both will be of the same temperature. On the contrary, if the specific caloric of alcohol were greater than that of water, the temperature of the mixture would be under 75°. If the same quantity of caloric that raised alcohol 20°, raised water 30°, then the temperature of the mixture would be 70°. Thus the ratios of the specific caloric of bodies may be discovered by mixing them together at different temperatures (18).

265
Experiments on specific caloric by Wilcke,

The first set of experiments on this subject, in point of time, were probably those of Mr Wilcke. They were first published in the Stockholm Transactions for 1781, but had been made long before. The manner in which they were conducted is exceedingly ingenious, and they furnish us with the specific caloric of many of the metals. The metal on which the experiment was to be made was first weighed accurately (generally one pound was taken), and then being suspended by a thread, was plunged into a large vessel of tinplate, filled with boiling water, and kept there till it acquired a certain temperature, which was ascertained by a thermometer. Into another small box of tinplate exactly as much water at 32° was put as equalled the weight of the metal. Into this vessel the metal was plunged, and suspended in it so as not to touch its sides or bottom; and the degree of heat, the moment the metal and water were reduced to the same temperature, was marked by a very accurate thermometer. He then calculated what the temperature would have been if a quantity of water equal in *weight* to the metal, and of the same temperature with it, had been added to the ice-cold water instead of the metal.

Let M be a quantity of water at the temperature C, m another quantity at the temperature c, and let their common temperature after mixture be x; according to a rule demonstrated long ago by Richman, $x = \frac{MC + mc}{M + m}$. In the present case the quantities of water are equal, therefore M and m are each $= 1$; C, the temperature of the ice-cold water $= 32$: therefore $\frac{MC + mc}{M + m} = \frac{32 + c}{2}$. Now c is the temperature of the metal. Therefore if 32 be added to the temperature of the metal, and the whole be divided by 2, the quotient will express the temperature of the mixture, if an equal weight of water with the metal, and of the same temperature with it, had been added to the ice-cold water instead of the metal.

He then calculated what the temperature of the mixture would have been if, instead of the metal, a quantity of water of the same temperature with it, and equal to the metal in *bulk*, had been added to the ice-cold water. As the weights of the ice-cold water and the metal are equal, their volumes are inversely as their specific gravities. Therefore the volume of ice-cold water is to a quantity of hot water equal in volume to the metal, as the specific gravity of the metal to that of the water. Let M = volume of cold water, m = volume of hot water, g = specific gravity of the metal, 1 = specific gravity of water; then $m : M :: 1 : g$; hence

$m =$

(F) The term *specific caloric* has been used in a different sense by Seguin. He used it for the *whole caloric* which a body contains.

(18) This appears to me to be by no means a just method of judging of the specific caloric of bodies even when it can be practised. The very foundation is error. It is considering the properties of the constituent principles by that of the compound. This never can be done with certainty and in this particular case facts prove it to be peculiarly erroneous. According to the principles of this *test*, if any two substances were mixed together at the *same* temperature the compound would be of the same temperature as each of them would have a sufficiency of caloric to maintain them just at that temperature. Let us combine sulphuric acid and water, and water and muriat of ammoniac, at equal temperatures, and observe what takes place. In the first case the temperature is much encreased and in the other decreased. Why do these changes take place? Because the compound is not of a mean *specific caloric* to the constituent principles. No inference from its temperature therefore can be drawn as to the *specific caloric* of those principles. T. P. S.

Caloric. $m = \frac{M}{g}$ = (M being made = 1) $\frac{1}{g}$. Subſtituting this value of m in the formula, $\frac{MC + mc}{M + m} = x$, in which M = 1 and C = 32, x will be = $\frac{32\,g + c}{g + 1}$. Therefore if the ſpecific gravity of the metal be multiplied by 32, and the temperature of the metal be added, and the ſum be divided by the ſpecific gravity of the metal + 1, the quotient will expreſs the temperature to which the ice-cold water would be raiſed by adding to it a volume of water equal to that of the metal, and of the ſame temperature with it.

He then calculated how much water at the temperature of the metal it would take to raiſe the ice-cold water the ſame number of degrees which the metal had raiſed it. Let the temperature to which the metal had raiſed the ice-cold water be = N, if in the formula $\frac{MC + mc}{M + m} = x$, x be made = N, M = 1, C = 32, m will be = $\frac{N - 32}{c - N}$. Therefore if from the temperature to which the ice-cold water was raiſed by the metal 32 be ſubtracted, and if from the temperature of the metal be ſubtracted the temperature to which it raiſed the water and the firſt remainder be divided by the laſt, the quotient will expreſs the quantity of water of the temperature of the metal which would have raiſed the ice-cold water the ſame number of degrees that the metal did.

Now $\frac{N - 32}{c - N}$ expreſſes the ſpecific caloric of the metal, that of water being = 1. For (neglecting the ſmall difference occaſioned by the difference of temperature) the weight and volume of the ice-cold water are to the weight and volume of the hot water as 1 to $\frac{N - 32}{c - N}$, and the number of particles of water in each are in the ſame proportion. But the metal is equal in weight to the ice-cold water; it muſt therefore contain as many particles of matter; therefore the quantity of matter in the metal muſt be to that in the hot water, as 1 to $\frac{N - 32}{c - N}$. But they give out the ſame quantity of caloric; which, being divided equally among their particles, gives to each particle a quantity of caloric inverſely as the bulks of the metal and water; that is, the ſpecific caloric of the water is to that of the metal as 1 to $\frac{N - 32}{c - N}$ (G).

We ſhall now give a ſpecimen or two of his experiments, and the calculations founded on them, as above deſcribed.

GOLD. *Specific Gravity* 19,040.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temper. to which it would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temperature to which it would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fractions $\frac{N-32}{c-N} = \frac{1}{\frac{c-N}{N-32}}$, the numerator being 1.
1	163,4°	38,3°	97,7°	38,555°	19,857
2	144,5	37,4	88,25	37,58	19,833
3	127,4	36,5	79,7	36,68	20,500
4	118,4	36,05	75,2	36,15	20,333
5	103,1	35,6	65,75	35,42	18,750
6	95	34,45	63,5	35,06	19,000

Mean 19,712

LEAD. *Specific Gravity* 11,456.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temperature to which the water would have been raiſed by a quantity of water equal in weight and beat to the metal.	Temperature to which the water would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{1}{\frac{c-N}{N-32}}$
1	186,8	38,3	109,4	44,425	23,571
2	181,40	37,85	106,7	43,473	24,538
3	165,2	37,4	98,6	42,692	23,666
4	163,4	37,4	97,7	42,548	23,333
5	136,4	36,5	84,2	40,344	22,200
6	131	36,05	81,5	39,947	24,700
7	126,5	36,05	79,25	39,585	22,333
8	107,6	35,15	69,8	38,339	23,000
9	94,1	34,7	63,05	36,085	22,000

Mean 23,515

It

(G) We have altered all theſe formulas to make them correſpond with Fahrenheit's thermometer. They are a good deal ſimpler when the experiments are made with Celſius's thermometer as Mr Wilcke did. In it the freezing point is zero; and conſequently inſtead of 32 in the formula, 0 is always ſubſtituted.

Caloric. It is needlefs to add, that the laft column marks the denominator of the fpecific caloric of the metal; the numerator being always 1, and the fpecific caloric of water being 1. Thus the fpecific caloric of gold is $\frac{1}{19,712}$. In exactly the fame manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke afcertain the fpecific caloric of a number of other bodies. He afcertained at the fame time, that the fpecific caloric of a body did not vary with the temperature, but continued always the fame. This will appear evident from the experiments on gold and lead above exhibited.

266 Crawford, Next, in point of time, and not inferior in ingenious contrivances to enfure accuracy, were the experiments of Dr Crawford, made by mixing together bodies of different temperatures. Thefe were publifhed in his *Treatife on Heat*.

267 Lavoifier and La Place, Several experiments on the fpecific caloric of bodies were made alfo by Lavoifier and De la Place, which, from the well-known accuracy of thefe philofophers, cannot but be very valuable.

Their method was exceedingly fimple and ingenious; it was firft fuggefted by De la Place. An inftrument was contrived, to which Lavoifier gave the name of *calorimeter*. It confifts of three circular veffels nearly infcribed into each other, fo as to form three different apartments, one within the other. Thefe three we fhall call the *interior*, *middle*, and *external cavities*. The interior cavity *ffff* (fee fection of the inftrument fig. 4.), into which the fubftances fubmitted to experiment are put, is compofed of a grating or cage of iron wire, fupported by feveral iron bars. Its opening or mouth LM is covered by the lid HG, which is compofed of the fame materials. The middle cavity *bbbb* is filled with ice. This ice is fupported by the grate *mm*, and under the grate is placed a fieve. The external cavity *aaaa* is alfo filled with ice. We have mentioned already, that no caloric can pafs through ice. It can enter ice, indeed, but it remains in it, and is employed in melting it. The quantity of ice melted, then, is a meafure of the caloric which has entered into the ice. The exterior and middle cavities being filled with ice, all the water is allowed to drain away, and the temperature of the interior cavity to come down to 32°. Then the fubftance, the fpecific caloric of which is to be afcertained, is heated a certain number of degrees, fuppofe to 212°, and then put into the interior cavity inclofed in a thin veffel. As it cools, it melts the ice in the middle cavity. In proportion as it melts, the water runs through the grate and fieve, and falls through the conical funnel *ccd* and the tube *xy* into a veffel placed below to receive it. The external cavity is filled with ice, in order to prevent the external air from approaching the ice in the middle cavity and melting part of it. The water produced from it is carried off through the pipe ST. The external air ought never to be below 32°, nor above 41°. In the firft cafe, the ice in the middle cavity might be cooled too low; in the laft, a current of air flows through the machine and carries off fome of the caloric. By putting various fubftances at the fame temperature into this machine, and obferving how much ice each of them melted in cooling down to 32°, it was eafy to afcertain the fpecific caloric of each. Thus, if water, in cooling from 212 to 32, melted one pound of ice, and mercury ,029 of a pound; the fpecific caloric of water was one, and that of mercury ,029. This appears by far the fimpleft method of making experiments on this fubject; and muft alfo be the moft accurate, provided we can be certain that all the melted fnow flows into the receiver. But from an experiment of Mr Wedgewood, one would be apt to conclude that this does not happen. He found that the melted ice, fo far from flowing out, actually *froze* again, and choaked up the paffage. Caloric.

268 And Kirwan. A table of the fpecific caloric of various bodies was likewife drawn up by Mr Kirwan, and publifhed by Magellan in his Treatife on Heat.

269 Refult of thefe experiments. From all thefe fources we have drawn up the following table, which exhibits at one view the fpecific caloric of thofe bodies on which experiments have hitherto been made.

We have added to it a column, expreffing the fpecific caloric of equal bulks of the fame bodies; which feems to be a more accurate way of confidering this fubject, and indeed the only way in which the phrafe *capacity for caloric* is intelligible. This column was formed by multiplying the fpecific caloric of equal weights of the various fubftances into their refpective fpecific gravities.

TABLE

TABLE *of the Specific Caloric of Various Bodies, that of Water being* = 1,0000. (H)

Bodies.	Specific Gravity.	Specific Caloric of equal Weight.	Specific Caloric of equal Volumes.
I. GASES.*			
Hydrogen gas - -	0,000094	21,4000	0,00214
Oxygen gas - - -	0,0034	4,7490	0,006411
Common air - - -	0,00122	1,7900	0,002183
Carbonic acid gas -	0,00183	1,0459	0,001930
Steam - - - - -		1,5500	
Azotic gas - - -	0,00120	0,7036	0,000952
II. LIQUIDS.			
Water - - - - -	1,0000	1,0000	1,0000
Carbonat of ammonia†		1,851	
Arterial blood* - -		1,030	
Cows milk* - - -	1,0324	0,9999	1,0322
Sulphuret of ammonia†	0,818	0,9940	0,8130
Venous blood* - -		0,8928	
Solution of brown sugar†		0,8600	
Nitric acid‡ - - -		0,844	
Sulphat of magnesia 1, Water 8 †		0,844	
Common salt 1, Water 8 †		0,832	
Nitre 1, Water 8 ‡ - - -		0,8167	
Muriat of ammonia 1, Water 1,5 †		0,779	
Tartar 1, Water 237,3 † -		0,765	
Solution of potass † -	1,346	0,759	1,2216
Sulphat of iron 1, Water 2,5 †		0,734	
Sulphat of soda 1, Water 2,9 †		0,728	
Oil of olives † - -	0,9153	0,710	0,6498
Ammonia † - - -	0,997	0,7080	0,7041
Muriatic acid † - -	1,122	0,6800	0,763
Sulphuric acid 4, Water 5 ‡		0,6631	
Alum 1, Water 4,45 † -		0,649	
Nitric acid $9\frac{1}{7}$, Lime 1 ‡ -		0,6181	
Nitre 1, Water 3 † - - -		0,646	
Alcohol* - - - -	0,8371	0,6021	0,4993
Sulphuric acid§ - -	1,840	0,5968	1,120
Nitrous acid † - -	1.355	0,576	0,780
Linseed oil † - - -	0,9403	0,528	0,4964
Spermaceti oil* - -		0,5000	
Oil of turpentine † -	0,9910	0,472	0,4132
Vinegar † - - - -		0,3870	0 3966
Lime 9, Water 16 ‡ - -		0,3346	
Mercury ¶ - - -	13 568	0,3100	4,123
Distilled vinegar † -		0,1030	0,1039

TABLE *of the Specific Caloric of Various Bodies, that of Water being* = 1,0000, *continued.* (H)

Bodies.	Specific Gravity.	Specific Caloric of equal Weight.	Specific Caloric of equal Volumes.
III. SOLIDS.			
Ice † - - - - - -		0,9000	
Ox-hide with the hair*		0,787	
Lungs of a sheep* -		0,769	
Lean of ox-beef* -		0,7400	
Rice* - - - - -		0,5050	
Horse beans* - -		0,5020	
Dust of the pine tree*		0,5000	
Pease* - - - -		0,4920	
Wheat* - - - -		0,4770	
Barley* - - - -		0,4210	
Oats* - - - -		0,4160	
Pitcoal* - - - -		0,2777	
Charcoal* - - -		0,2631	
Chalk* - - - -		0,2564	
Rust of iron* - -		0,2500	
White oxyd of antimony washed* - - -		0,2270	
Oxyd of copper nearly freed from air* -		0,2272	
Quicklime (c) - -		0,2199	
Stone-ware† - - -		0.195	
Agate** - - -	2,648	0,195	0,517
Crystal ‡ - - - -	3,189 ?	0,1929	0,6151
Cinders* - - - -		0,1923	
Swedish glass** -	2,386	0,187	0,448
Ashes of cinders* -		0,1885	
Sulphur † - - - -	1,99	0,183	0,3680
Flint glass † - - -	3,3293	0,174	0,5792
Rust of iron nearly freed from air* - - -		0,1666	
White oxyd of antimony ditto* - - -		0,1666	
Ashes of the elm* -		0,1402	
Oxyd of zinc nearly free from air* - - -		0,1369	
Iron (d) - - - -	7,876	0,1264	0,993
Brass (d) - - - -	8,358	0,1141	0,971
Copper (d) - - -	8,784	0,1121	1,027
Sheet iron ‡ - - -		0,1099	
Oxyd of lead and tin*		0,102	
Gun metal ‖ - - -		0,1100	
White oxyd of tin nearly free from air* -		0,0990	
Zinc (d) - - - -	7,154	0,0981	0,735
Ashes of charcoal* -		0,0909	
Silver** - - -	10,001	0,082	0,833
Yellow oxyd of lead nearly freed from air*		0,0680	
Tin (e) - - - -	7,380	0,0661	0,444
Antimony (d) - -	6,107	0,0637	0,390
Gold** - - -	19,040	0,050	0,966
Lead (e) - - - -	11,456	0,0424	0,487
Bismuth** - - -	9,861	0,043	0,427

(H) The specific caloric of the substances marked* was ascertained by Dr Crawford, those marked † by Mr Kirwan, ‡ by Lavoisier and La Place,** by Wilcke, ‖ by Count Rumford. § Is the mean of Crawford, Kirwan, and Lavoisier; ¶ mean of Lavoisier and Kirwan; (c) mean of Crawford and Lavoisier; (d) mean of Wilcke and Crawford; (e) mean of Wilcke, Crawford, and Kirwan.

Caloric.

270 Latent caloric, or

7. If a quantity of ice, at a low temperature, suppose at 20°, be suspended in a warm room, it will become gradually less cold, as may be discovered by means of a thermometer, till it reaches the temperature of 32°; but there it stops. The ice, however, dissolves slowly; and at the end of several hours, when it is all just melted, the thermometer still stands at 32°. After this it begins to rise, and soon reaches the temperature of the room. Here the ice continues for several hours colder than the air around it. Caloric must then be continually flowing into it; yet it does not become hotter; it is changed, however, into water. Ice therefore is converted into water by a quantity of caloric uniting with it. This caloric has been called *latent caloric*, because its presence is not indicated by the thermometer. It might, perhaps with more propriety, as Professor Pictet observes†, be called *caloric of fluidity*; for there are other cases in which caloric exists in bodies without raising their temperature. This very important discovery was made by Dr Black as early as 1757, and seems to have led the way to all the subsequent discoveries in this part of chemistry, which have almost completely changed the appearance of the science: for the discovery that caloric may exist in bodies while the thermometer cannot indicate its presence, is one of the strongest links in the chain of facts by which the nature of combustion was ascertained.

271 Caloric of fluidity.

† Sur le Feu, ch. 1.

The caloric which unites with ice, and renders it fluid, appears again during the act of *freezing*. If a quantity of water be carried into a room where the temperature is below the freezing point, suppose at 20° it cools gradually down to 32°; but it becomes no colder till it is all frozen, which takes up some time. The moment it is all converted into ice, it begins again to cool, and soon reaches the temperature of the room. In this case the water is surrounded by a colder atmosphere; it must therefore be giving out caloric constantly; yet it does not become colder till it is all frozen, that is to say, till it has lost all its *caloric of fluidity*.

Dr Black proved, by a very accurate experiment, that the quantity of *caloric of fluidity* is sufficient to raise the same quantity of water 140°.

All solids become fluid by absorbing a quantity of caloric. Laudriani proved that this is the case with sulphur, alum, nitre, and several of the metals‡ and it has been found to be the case with every substance hitherto examined. Fluidity, therefore, is owing to a union between the solid, and a certain quantity of caloric.

‡ Jour. de Phys. xxvi.

The late Dr Irvine of Glasgow advanced a theory on this subject different from that of Dr Black. The specific caloric of water being greater than that of ice, it requires a greater quantity of caloric to raise it to a given temperature than it does to raise ice. The caloric does not therefore become *latent*; it only seems to do so from the greater specific caloric of water. This theory was zealously adopted by Dr Crawford. Dr Black observed very justly that it did not account for the production of fluidity at all. The specific caloric of water is indeed greater than that of ice; but how is the ice converted into water? This is an objection which the advocates for Dr Irvine's, or Dr Crawford's theory (as it has been improperly called) will not easily answer. Let us now examine whether this theory accounts for the apparent loss of caloric. It follows from Mr Kirwan's experiments, that the specific caloric of water is to that of ice as 10 to 9 (1). Dr Black proved that as much caloric entered the ice as would have raised it, had it been water, 140°. Let us suppose that it would only have raised the ice 140°; in that case the melted ice ought to have been of the temperature of 158°, for 10 : 9 : : 140 : 126; but it was only 32°: Therefore 126° of caloric have disappeared, and cannot be accounted for by the change of specific caloric, nor can the accuracy of Dr Black's experiment be suspected: it has been repeated in every part of the world, and varied in every possible way. We cannot doubt, therefore, that caloric unites with substances, and causes them to become fluid, or that *there is in fact a caloric of fluidity different from specific caloric*.

272 Caloric of evaporation.

Water also is converted into *steam* by uniting with caloric. Dr Black put an iron vessel, containing four ounces of water at the temperature of 53°, upon a cast-iron table which was red hot. The water rose to the boiling point in three minutes; but it did not afterwards become any hotter. It evaporated, however, in 18 minutes; and the steam was precisely at the temperature of 212°. During the first three minutes, it received 159° of caloric, and as much must have been entering it during every three minutes while the evaporation continued, as the temperature was always much lower than that of the table. This caloric, instead of raising the temperature of the water, was employed in converting it into steam. There is also, therefore, a quantity of latent caloric in steam. It might, as Mr Pictet observes, be called, with propriety, *caloric of evaporation*. This caloric appears again if the steam be condensed. If it be made to pass, for instance, through a pipe surrounded with cold water, it is condensed in the pipe, and drops out from it in the form of water. The caloric of the steam enters into the water around the pipe, and the quantity of it in degrees may be discovered by the number of degrees which it raises that water. By an experiment of this kind, it was proved, that the caloric of evaporation would be sufficient to heat water red hot, were it employed only in raising its temperature, instead of converting it into steam. It is therefore at least equal to 800°. Mr Watt shewed afterwards that it was 920°.

Even spontaneous evaporation, as Dr Black first observed, is owing to the same cause. And this explains why bodies cool when water is evaporated from their surface; a fact which has long been known, and which has been employed in warm countries to diminish the temperature of liquids, and even to convert them into ice

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(1) We do not know how this was ascertained: Not by mixing water and ice surely; because that would be taking for granted the thing to be proved; because it would give a very different result, and what is still worse, the specific caloric in that case would differ according to the temperature, and the quantity of water. To give an instance: Mr Gadolin concludes, from 180 experiments made by mixing hot water and ice, that the specific caloric of ice is to that of water only as 1 to 2*; and had he varied the quantities and the temperatures, he might have obtained several other ratios.

* Ann. de Chim. xi. 27.

Caloric.

ice (K). That water is evaporated by uniting with caloric, and not by folution in air, has been proved very completely by De Luc in his Treatife on Meteorology.

The evaporation of alcohol, ether, and every other fubftance on which experiments have been made, has been found owing to the fame caufe. Bodies, therefore, are converted into vapour by uniting with caloric.

273 Real zero, what.

8. If caloric, as has been fhewn, exifts in bodies at the loweft temperature which we are able to procure, and if it exifts in them while the thermometer cannot difcover its prefence—is there any method of afcertaining its abfolute quantity in bodies? At what degree would a thermometer ftand (fuppofing the thermometer capable of meafuring fo low) were the body to which it is applied totally deprived of caloric? or what degree of the thermometer correfponds to the real zero?

274 Irvine's theorem to difcover it,

The firft perfon (as far as we know), at leaft fince men began to think accurately on the fubject, who conceived the poffibility of determining this queftion, was Dr Irvine of Glafgow. He invented a theorem in order to afcertain the real zero, which has, we know not for what reafon, been afcribed by feveral writers to Mr Kirwan. He took it for granted, and the fact is proved by all the experiments hitherto made) that the fpecific caloric of bodies continued the fame in every degree of temperature, as long as they remained in the fame ftate, that is to fay, as long as they continued either folid or fluid, or in a ftate of vapour: but that the fpecific caloric of the fame body while folid was lefs than while fluid, and lefs while fluid than while in a ftate of vapour. He took it for granted too, that the 140 degrees of caloric which entered ice during its folution without raifing its temperature, entered merely in confequence of the increafed fpecific caloric of the water, and that they were exactly proportional to this increafed fpecific caloric. He took it for granted, likewife, that the fpecific caloric of bodies was proportional to their *abfolute caloric*, or to all the caloric which exifted in each.

On thefe data he reafoned in the following manner: Let A be a body in a ftate of fluidity; B the fame body in a ftate of folidity. If the fpecific caloric of A and of B be known, and if it be known how many degrees

 the

(K) Galen informs us, that the ancient Egyptians were accuftomed to put water previoufly boiled into earthen jars, and expofe them all night on the upper part of their houfes to the air. Before funrife thefe veffels were put into the ground moiftened on the outfide with water, and then furrounded with frefh plants; by which means the water was preferved cool during the whole day. *Comment. in lib.* vi. *Hippoc. de morbis vulgar.* 4. 10. p. 396.

By a fimilar procefs, water, in the Eaft Indies, is converted into ice.

The following fingular paffage, which has been pointed out to us by the ingenious Dr Barclay, lecturer on anatomy in Edinburgh, furnifhes a ftriking proof that the ancients were led, by a very different method of reafoning, to deduce from their philofophical theory of the four elements, conclufions concerning the nature of heat, not very different from thofe of the moderns.

"Sic enim res fe habet, ut omnia, quæ alantur, et quæ crefcant, contineant in fe vim caloris; fine qua neque ali poffent nec crefcere. Nam omne, quod eft calidum et igneum, cietur et agitur motu fuo: quod autem alitur et crefcit, motu quodam utitur certo et æquabili; qui quandiu remanet in nobis, tamdiu fenfus et vita remanet: refrigerato autem et extincto calore, occidimus ipfi et extinguimur. Quod quidem Cleanthes his etiam argumentis docet, quanta vis infit caloris in omni corpore: negat enim ullum effe cibum tam gravem, quin is nocte et die concoquatur; cujus etiam in reliquiis ineft calor his quas natura refpuerit. Jam vero venæ et arteriæ micare non definunt, quafi quodam igneo motu; animadverfumque fæpe eft, cùm cor animantis alicujus evolfum ita mobiliter palpitaret, ut imitaretur igneam celeritatem. Omne igitur quod vivit, five animal five terra editum, id vivit propter inclufum in eo calorem. Ex quo intellegi debet, eam caloris naturam, vim habere in fe vitalem per omnem mundum pertinentem. Atque id faciliùs cernemus, toto genere hoc igneo, quod tranat omnia, fubtiliùs explicato. Omnes igitur partes mundi (tangam autem maxumas) calore fultæ fuftinentur. Quod primùm in terrena natura perfpici poteft. Nam et lapidum conflictu atque tritu elici ignem videmus; et recenti foffione

——*terram fumare calentem;*

atque etiam ex puteis jugibus aquam calidam trahi, et id maxùme fieri temporibus hibernis quòd magna vis caloris, terræ contineatur cavernis; eaque hieme fit denfior; ob eamque cauffam, calorem incitum in terris contineat arctiùs.

"Longa eft oratio, multæque rationes, quibus doceri poffit omnia, quæ terra concipiat, femina, quæque ipfa ex fe generata ftirpibus infixa contineat, ea temperatione caloris et oriri et augefcere. Atque aquæ etiam admixtum effe calorem primùm ipfe liquor, tum aquæ declarat effufio: quæ neque conglaciaret frigoribus, neque nive pruinaque concrefceret, nifi eadem fe admixto calore liquefacta et dilapfa diffunderet. Itaque et aquilonibus reliquifque frigoribus durefcit humor: et idem viciffim mollitur tepefactus et tabefcit calore. Atque etiam maria agitata ventis ita tepefcunt, ut intellegi facilè poffit, in tantis illis humoribus effe inclufum calorem. Nec enim ille externus et adventicius habendus eft tepor, fed ex intimis maris partibus agitatione excitatus: quod noftris quoque corporibus contingit, cùm motu atque exercitatione recalefcunt. Ipfe verò aër, qui natura eft maxumè frigidus, minime eft expers caloris. Ille verò et multo quidem calore admixtus eft: ipfe enim oritur ex refpiratione aquarum: earum enim quafi vapor quidam aër habendus eft. Is autem exiftit motu ejus caloris, qui aquis continetur. Quam fimilitudinem cernere poffumus in his aquis, quæ effervefcunt fubditis ignibus. Jam verò reliqua quarta pars mundi, ea et ipfa tota natura fervida eft, et ceteris naturis omnibus falutarem impertit et vitalem calorem. Ex quo concluditur, cùm omnes mundi partes fuftineantur calore, mundum etiam ipfum fimili parique natura in tanta diuturnitate fervari: eoque magis quòd intellegi debet calidum illud atque igneum ita in omni fufum effe natura, ut in eo infit procreandi vis et cauffa gignendi, à quo et animantia omnia, et ea quorum ftirpes terra continentur, et nafci fit neceffe et augefcere. *Cicero de natura Deorum*, lib ii. c. 9, *et* 10.

Caloric. the caloric, difengaged during the change of B into A, would raife the temperature of A, it may be found by an eafy procefs how many degrees all the caloric contained in B would raife the temperature of A; and the fum of thefe two numbers will reprefent in degrees the whole quantity of caloric in A: for the quantity of caloric in A muft be juft equal to the caloric in B, together with what entered into it in paffing from the ftate of B to that of A. Let the fpecific caloric of A be 6, that of B 1; and let the quantity of caloric difengaged during the change of A into B be fufficient to raife the temperature of A 500°. If the fpecific caloric be proportional to the abfolute caloric, it muft contain exactly 6 times as much caloric as B. The 500° which entered into A when it changed its ftate, muft be juft 5 times as great as all the caloric of B; becaufe when added to the caloric of B, it formed the caloric in A, which is juft 6 times as great as the caloric in B. Therefore to difcover the caloric in B, we have only to divide 500 by 5, or, which is the fame thing, to ftate this proportion 6—1 : 500 :: 1 : 100. The caloric in B, therefore, in this cafe is juft as much as would raife the temperature of A 100°. Therefore, if to 100°, the caloric of B, be added 500°, = caloric difengaged in the paffage of A to B, this will give 600°, = to all the caloric in A. Therefore, in all cafes, the difference between the numbers expreffing the fpecific caloric of the folid and fluid, is to the number expreffing the fpecific caloric of the folid, as the quantity of caloric difengaged during the paffage of the fluid into a folid is to the quantity of caloric in the fluid.

Dr Crawford embraced this theorem; and concluded, from a number of experiments made on purpofe to afcertain the fact, that the real zero was 1268° below 0, or 1300° below the freezing point.

275 Examined, This fubject deferves to be confidered with attention. If this theorem in fact furnifhes us with the real zero, it is one of the moft important difcoveries which has ever been made in chemiftry; but if it proceeds on erroneous principles, it will only involve us in endlefs mazes of error and abfurdity.

In the firft place, if the real zero has any meaning at all, it muft fignify the degree to which the thermometer (fuppofing it could be ufed) would fink on being applied to a body which contained no heat. It muft therefore be a fixed point; and were the theorem which we are examining well founded, experiments upon every different fubftance, if conducted with accuracy, would lead to the fame refult. Let us fee whether this be the cafe.

From Dr Crawford's experiments, it follows, as we have feen, that the real zero is 1268° below 0.

Mr Kirwan, from comparing the fpecific caloric of water and ice, fixed the real zero at 1048° below 0.

From the experiments of Lavoifier and La Place on a mixture of water and quicklime, in the proportion of 9 to 16, it follows, that the real zero is 2736° below 0.

From their experiments on a mixture of 4 parts of fulphuric acid and 3 parts of water, it follows, that the real zero is 5803,4° below 0.

Their experiments on a mixture of 4 parts of fulphuric acid and 5 of water, place it at 2073,3° below 0.

Their experiments on $9\frac{1}{7}$ parts of nitric acid and 1 of lime, place it at $\frac{1889}{-0,01783}$ below 32°*.

* See Seguin, Ann. de Chim. vii.

Thefe refults differ from one another fo enormoufly, and the laft of them, which makes the real zero a negative quantity, is fo abfurd, that they are alone fufficient to convince us that the data on which they are founded are not true. Should it be faid that their difference is not owing to any defect in the theorem, but to inaccuracies in making the experiments—we anfwer, that the theorem itfelf is founded on fimilar experiments; and if experiments of this nature, even in the hands of the moft accurate chemifts, cannot be freed from fuch enormous errors, how can we depend on any confequences deduced from them? and where, then, is our evidence for the truth of the theorem?

But, farther, there is no proof whatever that the fpecific caloric of bodies is proportional to their abfolute caloric. The fpecific caloric of iron is greater than that of water, or even azotic gas; yet furely it is very improbable that iron contains more abfolute caloric than either of thefe fubftances.

If the fpecific caloric of bodies has any meaning at all, it can only be, that the fame quantity of caloric raifes the temperature of one body a greater number of degrees than it does another. When we fay that the fpecific caloric of A is = 6, and that of B = 1, what do we mean, unlefs that the quantity of caloric which raifes B 6° raifes A only 1°, or that what raifes B 60° or 600°, raifes A only 10° or 100°? When we fay that the fpecific caloric of water is 10, and that of ice 9, do we not mean, that the quantity of caloric which raifes the ice 10° or 100°, raifes water only 9° or 90°? Yet during the change of ice into water, 140° of caloric enter it without raifing its temperature; a quantity greater than what can be accounted for by the difference of fpecific caloric by 126°. The quantity that difappears, therefore, is *not* proportional to the difference of fpecific caloric; and therefore any theory which depends on that fuppofition cannot be well founded. When water is converted into fteam, 800° of caloric difappear; yet the fpecific caloric of fteam is to that of water, according to Dr Crawford's own experiments, only as 155 to 100: fo that no lefs than 283° difappear, which cannot be accounted for according to this theory.

Dr Irvine's theorem, therefore, is infufficient for afcertaining the real zero; and hitherto no method has been difcovered which can folve this problem (19). 276 And found infufficient.

9. If there be no body without caloric, if it exifts in different quantities in different bodies, even when their temperatures are the fame, and while the thermometer cannot indicate its prefence—in what ftate does it exift in them? We cannot furely fuppofe that it is contained by them juft as water is contained by a veffel of wood or metal, or that they are filled with it in the fame manner that a hollow globe of tin-plate perforated with holes is filled with water when it is plunged into a quantity of that liquid; or that bodies are filled with caloric merely becaufe they are immerfed in an ocean of caloric. Were that the cafe, the fpecific and abfolute caloric of bodies would always be proportional; and they 277 Caloric exifts in bodies

(19) He attempted to compute the real zero as much without data, as a mathematician who fhould attempt to compute the length of a line by knowing that part of it was an inch long, without knowing the proportion of that part to the whole. T. P. S.

Caloric.

they would of necessity be inversely as the specific gravity of the respective bodies; because the less the specific gravity, the more room would be left for the particles of caloric. But this is by no means the case: the specific gravity of iron, for instance, is greater than that of tin, yet the specific caloric of iron is more than double that of tin: the specific gravity of oxygen gas is greater than that of common air, yet the specific caloric of the first of these substances is more than three times as great as that of the other. There must be something, therefore, in bodies themselves quite different from, and unconnected with the vacuities between their particles, which disposes some to admit more caloric than others. And what can that be but a disposition in different bodies to unite with a greater or a smaller quantity of caloric, and to retain it with more or less firmness according to their *affinity* for it? Dr Black pointed out, long ago, by discovering latent heat, that caloric unites with bodies; and this seems to be the only real key for unfolding the actions of this extraordinary substance. If caloric be matter, can it be destitute of that property which all other matter possesses, we mean attraction? And if it possesses attraction, must it not combine with those bodies that attract it just as other bodies combine with each other? Must there not be formed a chemical union between caloric and other substances, which can only be broken by chemical means, by presenting a third body which has a greater affinity either for the caloric or the body to which it is united, than they have for each other?

278 In a state of chemical combination.

279 Proved to be the case in liquids, vapours,

That it unites chemically with some bodies, at least, cannot be doubted; as we have shewn already, that whenever a solid is converted into a liquid, a quantity of caloric enters, and remains in it; and that both the solid and the caloric lose their characteristic properties. This is precisely what takes place in every chemical union. All liquids, therefore, consist of solids combined with caloric. We have seen, too, that liquids are converted into vapours by the very same process. There are therefore, at least, two very large classes of bodies liquids and vapours, in which we are certain that caloric exists in a state of chemical combination.

280 And gases;

There is another class of bodies which resemble vapours in almost all their properties: these are the gases. Like them, they are invisible and elastic, and capable of indefinite expansion. Is it not probable, then, that the gases also, as well as the vapours, owe their properties to caloric? that they also consist of their respective bases combined with that subtile substance? This probability has been reduced to certainty by an experiment of Lavoisier. By adding two tubes to the calorimeter formerly described, he contrived to make known quantities of air to pass through the interior cavity, and to support combustion. He found, that when a pound of oxygen gas was made to combine in this manner with phosphorus, as much caloric was disengaged as melted $87\frac{1}{2}$ pounds of ice*. Now every pound of ice absorbs as much caloric in the act of melting as is sufficient to raise a pound of water 140°. Therefore the whole caloric disengaged was sufficient to raise a pound of water 12250°. All this could not have come from the phosphorus, because it had been converted into a liquid, and must therefore have absorbed instead of parted with caloric, and because the quantity of caloric disengaged in all cases of combustion is proportional, not to the combustible, but to the oxygen absorbed. Oxygen gas, then, is composed of oxygen and caloric: and if this be the case with one gas, why not with all?

* *Lavoisier*, p. i. ch. 9.

We may conclude, therefore, that the gases, as well as liquids and vapours, owe their form to the caloric which they contain. The only difference between them and vapours is, that the latter return to their liquid state by the mere action of cold; whereas most of the gases resist the lowest temperature which it has been possible to apply. It was natural to expect, that if caloric combined chemically with bodies, its affinity would be different for different substances, and that its affinity for some bodies would be so great that it would not leave them to combine with any other. It was natural to expect this, because it is the case with every other substance with which we are acquainted. The difference, then, between the gases and vapours is not surprising. The affinity of the former for caloric is not only much greater than that of the latter, but much greater than that of any other substances.

281 And to be the cause of their gaseous form.

It is owing to this strong affinity between oxygen, hydrogen, and azot and caloric, that they cannot be obtained except in a gaseous form: and we shall describe several other substances afterwards exactly in the same circumstances. Had we any substance possessed of a greater affinity for caloric than they have, we should be able, by presenting it, to deprive them of their gaseous form. Doubtless there is a difference in the affinity between these bodies themselves and caloric; but as all of them are already saturated, this difference cannot be discovered. If we could obtain them uncombined with caloric, that is to say, in a concrete state, it would be easy to ascertain this point. Suppose, for instance, that hydrogen had the strongest affinity for caloric, and that we possessed it in a concrete state—it would be easy, by presenting it to the other gases, to deprive their bases of the caloric with which they are united, and thus to obtain them also uncombined with any other substance.

282 Why caloric appears during combustion,

But though we are acquainted with no substance that has a greater affinity for caloric than the bases of the gases, there are many substances which have a greater affinity for these bases than caloric has. When any such substance is presented, the base combines with it, and the caloric is left at liberty. Thus, when phosphorus is presented to oxygen gas, the phosphorus and oxygen unite together, and the caloric flies off. We are now, therefore, able to answer one of the questions proposed at the end of the second chapter. Whence comes the caloric which appears during combustion? It is separated from the oxygen, which leaves it in order to enter into a new combination.

283 And during many chemical combinations.

The caloric also, which sometimes appears when two bodies combine together, is set at liberty exactly in the same manner. When sulphuric acid and water, for instance, are mixed together, a very considerable heat is produced; a good deal of caloric, therefore, becomes sensible. In this case, the water combines with the acid, and at the same time lets go the caloric with which it was formerly combined, and becomes denser. In the same manner, to give another instance, when water is poured upon quicklime, a very great quantity of caloric becomes manifest. The water in this case combines with the quicklime, and assumes a concrete form, and of course lets go the caloric with which it was previously united.

10. It

Caloric.

284 Why certain mixtures produce cold.

10. It is no uncommon thing in nature to obferve two bodies, after combining together, manifefting a much ftronger affinity for a third body than either of them had while feparate. Thus, filver has no perceptible affinity for fulphuric acid, neither has oxygen: but unite them together, and they combine with that acid very readily. A great many inftances of the fame kind might be produced. Were there fubftances, then, which, after combining together, have a greater affinity for caloric than any of them had while feparate, this ought not to furprife us, becaufe the fame phenomenon is often obferved in other bodies. Now this is actually the cafe with regard to caloric. Mix together, for inftance, common falt and fnow, the mixture inftantly becomes liquid, and fo cold, that it finks the thermometer down to zero. In this cafe, the fnow and falt united have a much ftronger affinity for caloric than either of them had while feparate; they attract it therefore from other bodies with which they happen to be in contact, till they have obtained a dofe fufficient for their faturation; and this faturation they manifeft by becoming liquid. It is for this reafon that all falts produce cold during their folution in water, when the freezing point of the folution formed is below that of water. All fuch folutions have a ftrong affinity for caloric; they therefore attract it till they are faturated, which appears by their becoming fluid. A number of experiments have been lately made in order to procure artificial cold by means of fuch combinations. The moft complete fet of experiments of that nature with which we are acquainted, is thofe of Mr Walker, publifhed in the Philofophical Tranfactions for 1795. We fhall prefent the refult of his experiments in the following table:

Table of Freezing Mixtures.

Mixtures.		Thermometer finks.
Muriat of ammonia Nitre - Water - -	5 parts. 5 16	From 50° to 10°.
Muriat of ammonia Nitre - Sulphat of foda Water -	5 5 8 16	From 50 to 4.
Nitrat of ammonia Water -	1 1	From 50 to 4.
Nitrat of ammonia Carbonat of foda Water -	1 1 1	From 50 to 7.
Sulphat of foda Diluted nitric acid	3 2	From 50 to 3.
Sulphat of foda Muriat of ammonia Nitre - Diluted nitric acid	6 4 2 4	From 50 to 10.
Sulphat of foda Nitrat of ammonia Diluted nitric acid	6 5 4	From 50 to 14.
Phofphat of foda Diluted nitric acid	9 4	From 50 to 12.
Phofphat of foda Nitrat of ammonia Diluted nitric acid	9 parts. 6 4	From 50° to 21°.
Sulphat of foda Muriatic acid	8 5	From 50 to 0.
Sulphat of foda Diluted fulphuric acid	5 4	From 50 to 3.
Snow Common falt	1 1	From 32 to 0.
Snow or pounded ice Common falt	2 1	From 0 to —5.
Snow or pounded ice Common falt - Muriat of ammonia and nitre -	1 5 5	From —5 to —18.
Snow or pounded ice Common falt Nitrat of ammonia	12 5 5	From—18 to —25.
Snow and diluted nitric acid		From 0 to —46.
Snow - - Diluted fulphuric acid Diluted nitric acid	2 1 1	From —10 to—56.
Snow - - Diluted fulphuric acid	1 1	From 20 to —60.

Caloric.

In order to produce thefe effects, the falts employed muft be frefh cryftallized, and newly reduced to a very fine powder. The veffels in which the freezing mixture is made fhould be very thin, and juft large enough to hold it, and the materials fhould be mixed together as quickly as poffible. The materials to be employed in order to produce great cold ought to be firft reduced to the temperature marked in the table, by placing them in fome of the other freezing mixtures; and then they are to be mixed together in a fimilar freezing mixture. If, for inftance, we wifh to produce a cold = —46, the fnow and diluted nitric acid ought to be cooled down to 0, by putting the veffel which contains each of them into the 12th freezing mixture in the above table before they are mixed together. If a ftill greater cold is required, the materials to produce it are to be brought to the proper temperature by being previoufly placed in the fecond freezing mixture. This procefs is to be continued till the required degree of cold has been procured†.

† *Walker, Phil. Tranf.* 1795.

285 Subftances which contain moft caloric.

11. From the facts already known we may conclude, that the particles of caloric have two properties, that of repelling each other, and of attracting and being attracted by other fubftances. As there is no body in nature which does not contain caloric, we may fafely conclude that there is no body in nature which has not an affinity for it. When it unites with bodies, though the repulfion of its particles may be overcome by their attraction for the particles of the body, and by the attraction

traction of thefe particles for each other—we cannot fuppofe it annihilated: It muft therefore be the more powerful the greater the quantity of caloric combined in any body is. Probably, then, there is moft caloric combined with gafes, lefs with fluids, and leaft with folids. It does not follow, however, from this that the quantity of caloric combined with any body is proportional to the diftance between its particles, becaufe that may depend on other caufes. Thus, though hydrogen gas is much rarer than oxygen gas, it does not follow that hydrogen is combined with more caloric than oxygen, becaufe the rarity may be owing to the fmaller cohefive force of the particles of hydrogen allowing a fmaller quantity of caloric to produce a greater effect.

286 Caloric may be added indefinitely to bodies,

If caloric unites *only* chemically with bodies, there ought to be a certain point of faturation between it and the fubftances with which it combines, becaufe this takes place in all other chemical combinations. Oxygen gas, for inftance, confifts of a certain quantity of oxygen united with caloric. Now if this gas be a *chemical* compound, the two ingredients ought to faturate each other in fuch a manner, that no more of either could be admitted. But it cannot be denied, that more caloric can ftill be added to oxygen gas, for its temperature may be raifed at pleafure as high as we think proper. This, at firft fight, feems to be an infuperable objection to the theory that caloric only combines chemically with bodies. It ought to be remembered, however, that caloric is not fingular in this refpect. There are other bodies in nature, and bodies too which certainly combine with other fubftances only by affinity, which exhibit the very fame phenomenon. Water is capable of combining with fulphuric acid and many other falts almoft in any proportion, at leaft no limits have hitherto been obferved. Oxygen, too, combines with almoft every body in various proportions: We have feen, that with almoft every metal it forms at leaft two different oxyds. Why then may not caloric be capable of uniting in the fame manner? Allowing, therefore, that it were impoffible to explain why bodies are capable of combining with caloric after faturation, this could be no objection to the theory that it only unites chemically with bodies, becaufe the fame phenomenon is exhibited by other bodies which it cannot be doubted combine only by means of affinity.

287 And why.

The manner in which thefe other combinations are formed, has been already hinted, and fhall be confidered more fully afterwards; at prefent we fhall only attempt to explain the action of caloric. Let us fuppofe, then, that caloric is prefented to oxygen; that they combine together in a certain proportion, and faturate each other. The product of this combination is oxygen gas; a fubftance poffeffed of properties very different from thofe of caloric or oxygen in a concrete ftate; it is incapable of being decompofed by any merely mechanical method, and exhibits all the appearances of a fimple fubftance. Let us therefore confider this compound for a moment as a fimple fubftance. May it not ftill have an affinity for caloric? and will it not, in that cafe, unite with it? Oxygen gas and caloric have an affinity for each other; accordingly, when prefented to one another they combine in a certain proportion, and form a new compound, differing from oxygen gas, properly fo called, in elafticity, fpecific gravity, and feveral other particulars. The affinity, however, between oxygen gas and caloric is much feebler than that between oxygen and caloric; for the new compound is eafily broken, and the caloric abforbed by many other fubftances. We can even conceive this new compound ftill to have an affinity for caloric, to unite with it, and to form another compound, the affinity between the ingredients of which is ftill feebler. And in this manner may the indefinite increafe of temperature be accounted for.

288 Caufe of the different conducting powers of different bodies.

Subftances may be conceived to be conductors of caloric inverfely as their affinity for it. Good conductors may have very little affinity for caloric; and for that reafon it may be eafily forced through them by the repulfion of its own particles. But thofe fubftances which have a great affinity for caloric, combine with it the moment it is prefented to them; and confequently it cannot pafs through them. Thus, when it is prefented to ice the affinity between the two fubftances is fo great, that the caloric unites with the very firft particles of ice which it meets with. The particles behind thefe cannot receive any caloric except by attracting it from the particles with which it has already combined. But the affinity of one particle of ice for caloric cannot be greater than that of another particle of ice, and the union of two bodies cannot be broken by a force not greater than that which unites them; therefore the caloric cannot pafs from one particle to another. Confequently, fuppofing all the particles to keep their places, no new caloric could enter. Juft as when a piece of marble is put into fulphuric acid, the cruft of fulphat of lime which very foon covers it prevents the acid from getting to the particles of marble within. But as foon as a particle of ice unites with caloric, water, the new compound, leaves its ftation, and allows the caloric a paffage to the other particles.

In the fame manner, when caloric is prefented to water, it combines with the outermoft ftratum of particles, and forms with them a compound which cannot be decompofed by the other particles of the water, becaufe their affinity for caloric is no greater than that of the particles already united with it. No more caloric, then, could gain admiffion, were it not that (the fpecific gravity of the new compound being inferior to that of the uncombined water) it immediately changes its place, and allows another ftratum of particles to occupy its room. Thefe unite with caloric, and are difplaced in their turn. And in this manner the procefs goes on, till all the particles have combined with caloric, or, which is the fame thing, till the whole of the water is heated.

289 How heat paffes thro folids.

But fuppofing the firft ftratum of particles to remain in their place after their union with caloric, we can conceive an affinity ftill to fubfift between the new compound thus formed, and caloric. In that cafe the new compound which we fhall call A, would combine with an additional dofe of caloric, and form a fecond compound B, differing in feveral refpects from the firft. We can conceive alfo the affinity between the firft compound A and caloric to be inferior to that between water and caloric. In that cafe, the fecond ftratum of particles of water would feparate the additional dofe with which the firft ftratum had united. In this manner would two ftratums of particles combine with caloric. The firft ftratum of particles would combine with another dofe of caloric, and form a fecond compound B as before. But this compound could not now

Caloric. now be decompofed by the fecond ftratum of particles, becaufe they had already united with a dofe of caloric; and therefore their affinity for a new dofe could be no greater than that of the firft ftratum of particles. The procefs of heating could go on no farther. But we can conceive the fecond compound B, into which the firft ftratum has entered, ftill to have an affinity for caloric, to combine with a dofe of it, and to form with it a third compound C. We can conceive, at the fame time, the affinity between the fecond compound B and caloric to be lefs than that between the firft compound A and caloric. In that cafe, the fecond ftratum of particles would take this laft dofe from the firft ftratum, and form with it a fecond compound B. The third ftratum of particles, which is ftill uncombined with caloric, would now attract this new dofe from the fecond ftratum, and combine with it. And, fuppofing the caloric ftill flowing towards the water, the firft ftratum would again form the third compound C, by uniting with a frefh dofe: this new dofe would be again attracted by the fecond ftratum, and the firft ftratum would again form the third compound C, by uniting with another dofe of caloric. Thus three ftratums of particles would be combined with caloric; the firft ftratum would contain three dofes, the fecond ftratum two, and the third one. The procefs of heating would again ftop; becaufe now the affinity of the fecond ftratum is no greater than that of the firft, nor the affinity of the third ftratum greater than that of the fecond, nor that of the fourth than that of the third. But we can conceive an affinity ftill to fubfift between caloric and the third compound C, into which the firft ftratum has entered, and this affinity at the fame time weaker than that between the fecond compound B and caloric. In that cafe they would combine and form a fourth compound D. This new dofe would be attracted by the fecond ftratum of particles, which would combine with it and form the third compound C; the third ftratum would attract it from the fecond, and form with it the fecond compound B; and the fourth ftratum would attract it from the third, and enter into the firft compound A. The firft ftratum would again enter into the fourth compound D; which would be again decompofed by the fecond ftratum; and the compound formed by the fecond ftratum, by the third ftratum. The fourth compound D would be again formed by the firft ftratum, and again decompofed by the fecond ftratum. It would be formed a third time, and could not now be decompofed. Four ftratums of particles would now have combined with caloric: the firft ftratum with four dofes; the fecond, with three dofes; the third, with two; and the fourth, with one. We can conceive this procefs to go on exactly in the fame manner, till all the particles of water have combined with a dofe of caloric. In that cafe, the quantity of caloric combined with every ftratum of particles would form a regular decreafing feries from that part of the water at which the caloric enters to that part which is fartheft diftant from it. The procefs of heating would go on very flowly; and the heat of that part of the water which is fartheft diftant from the fource of caloric could never be nearly equal to that of the part which is neareft to that fource. This feems in fact to be the manner in which all thofe folids are heated which are bad conductors of caloric: in all probability it is the way in which all folids are heated.

290 Bodies cool each other reciprocally.

That caloric combines with bodies merely by means of affinity, feems at firft fight contrary to fact; for there is no fubftance whatever which may not be cooled indefinitely merely by furrounding it with other bodies which are colder than itfelf. Place a piece of hot iron, for inftance, in cold water, it is very foon cooled down to the temperature of that liquid. This feems plain enough; the attraction of water for caloric is greater than that of iron: but reverfe the experiment; put hot water within cold iron, and the water is cooled in its turn down to the temperature of the iron: fo that the iron alfo has a greater affinity for caloric, as well as the water; which is abfurd.

291 And why.

But it ought to be remembered, that caloric not only poffeffes affinity, but that it has another property alfo, of which every other fpecies of matter, except perhaps light, feems to be deftitute, a repulfion between its own particles. It is neceffary for all organifed bodies, and probably for all bodies, that they fhould poffefs a certain quantity of caloric; and on this account the greateft care has been taken to fecure its equal diftribution. This feems to be one ufe at leaft of its repulfive power; a power which is never deftroyed, however clofely caloric is united with other bodies. We have fhewn already, that this power is increafed by diminifhing the quantity of furrounding caloric; and when thus increafed to a certain degree, it may at laft equal, and even exceed, the affinity between the caloric and the bodies to which it is united; and in that cafe part of the caloric would neceffarily fly off. It feems to be in this manner that bodies reciprocally cool each other, and that they have always a tendency to an equilibrium of temperature. Thus fteam by cold is converted into water, and water into ice. And the affinity between bodies and that caloric which is employed in regulating the temperature feems to be fo weak, that the repulfion between the particles of caloric eafily overcomes it, and reftores the equilibrium. But the affinity between fome fubftances and caloric is fo great, that no diminution of temperature has been found fufficient to overcome it. This is the cafe, as we have already feen, with oxygen gas.

292 Caufe of the difference in the fpecific caloric of bodies.

The fpecific caloric of bodies feems to depend on two things; their affinity for caloric, and the diftance between their particles. For what is temperature but the difpofition of a body to part with caloric? The more caloric a body is difpofed to part with, we call its temperature the higher; the lefs it parts with when a colder body is applied, its temperature is faid to be the lower. If oxygen gas parts with no caloric to a thermometer which ftands at —10°, we fay its temperature is —10°; yet we know that even then it contains, in all probability, much more caloric than the mercury in the thermometer does. Now the ftronger the affinity between any fubftance and caloric, the greater quantity of caloric will be required before the repulfion between its particles is fufficient to overcome this attraction; confequently the more caloric is neceffary to raife it a given number of degrees. And the farther diftant the particles of bodies are, the farther from one another muft the particles of caloric be to which they are united; and confequently the weaker muft be the repulfion between them.

We cannot deny how new this theory of the action of caloric will appear to thofe who have been accuftomed ed to look upon Dr Crawford's opinions on this ſubject as fully proved; nor do we pretend that it can be reconciled with theſe opinions. But this, we hope, is no proof of its falſehood. We think it can be fairly deduced from Dr Black's doctrine of latent heat: we know, too, that Bergman believed caloric capable of combining chemically with bodies: and Morveau has not only embraced the ſame opinion, but ſeems to affirm, that all the combinations into which caloric enters are chemical*. And were this queſtion to be decided by authority, we appeal to all the world, whether other three men could be produced to whoſe deciſions one would more willingly ſubmit (1). We do not, however, mean to reſt its evidence on authority; let it be compared with facts, and put to the teſt of experiment; and by its correſpondence with theſe let it ſtand or fall.

* Encycl. Method. Chim. art. Affinité.

293
Caloric haſtens ſolution, and increaſes the ſolvent power of water.

12. Caloric both haſtens the ſolution of ſalts in water, and increaſes the ſolvent power of the water; for water diſſolves a much greater quantity of almoſt every ſalt when hot than when cold. The reaſon that caloric produces theſe effects is obvious from thoſe properties of it which have been deſcribed. It haſtens ſolution by putting the particles of the fluid in motion, and thus bringing all of them in their turn into contact with the ſalt: for only thoſe particles can act as ſolvents which are in contact with the ſalt. It increaſes the ſolvent power of the fluid by combining with it, and forming a compound which has a greater affinity for the ſalt, and which therefore diſſolves more of it than the fluid alone would have done. This new compound is deſtroyed by cooling; and then the additional doſe of the ſalt which had been diſſolved is precipitated.

13. We ſhould come now to the conſideration of the two remaining queſtions propoſed at the end of the ſecond chapter. Why do bodies combine with oxygen at one temperature and not at another? And why is caloric neceſſary to produce this union? But as the difficulty of theſe queſtions is not inferior to their importance, we ſhall delay any attempt to anſwer them till we come to treat of *affinity*.

294
Methods of obtaining caloric.

14. It now only remains to conſider the methods by which caloric may be obtained in a ſenſible ſtate. Theſe methods may be reduced to four; combuſtion, percuſſion, friction, and light: the laſt of which ſhall be conſidered afterwards.

295
Combuſtion explained.

We have ſeen already, that the combuſtion of *ſimple combuſtibles and metals* is merely their combination with oxygen, during which the oxygen parts with the caloric with which it was formerly united. Now the very ſame thing takes place in other combuſtions. The combuſtible unites with oxygen, which at the ſame time gives out its caloric. The change then which the combuſtible body ſuffers is not owing to the action of caloric on it, but to its combining with oxygen. The very ſame change can be brought about without any of the uſual phenomena which attend combuſtion, ſimply by preſenting the oxygen combined with ſome other body inſtead of caloric. Nitric acid, for inſtance, is a body which contains in it a good deal of oxygen: If phoſphorus be mixed with this acid, it attracts part of the oxygen, and, without any of the uſual phenomena which attend combuſtion, is converted into phoſphoric acid. Strictly ſpeaking, then, combuſtion is nothing elſe but the combination of oxygen with the burning body, and the term might therefore be uſed in every caſe where ſuch an union takes place; and in this ſenſe indeed it is now employed by ſeveral writers. But the term *combuſtion* is in common language confined to thoſe caſes where the oxygen was previouſly combined with caloric, and where a quantity of heat and light become ſenſible; and perhaps it would be better, in order to prevent ambiguity, never to employ it in any other ſenſe.

296
Whether it ever takes place when oxygen is not preſent.

We are not yet abſolutely certain that caloric and light may not become ſenſible in other combinations beſides thoſe into which oxygen enters. There are other ſubſtances beſides oxygen capable of combining with caloric; for inſtance, hydrogen and azot: and unleſs their affinity for caloric be greater than for any other ſubſtance, they may be capable of combining with other ſubſtances, and ſeparating from caloric, at leaſt the impoſſibility of this has never yet been demonſtrated. It is improper, therefore, to appropriate the word *combuſtion* to the combinations of oxygen, till it can be ſhewn that the phenomena uſually denoted by that name are never owing to any other cauſe. There is even one caſe in which theſe phenomena preſent themſelves, in which we are next to certain that oxygen has no ſhare. There is an affinity between ſulphur and iron, and a high temperature promotes their union. When theſe ſubſtances are mixed together, and heated till they juſt begin to appear red hot, they combine together, and at the ſame time, as the Dutch chemiſts firſt obſerved, a good deal of caloric and light is evolved. The very ſame phenomena appear in a vacuum, or in any kind of air whatever. The explanation of them is very ſimple and obvious. The ſulphur or the iron, or perhaps both, had previouſly been combined with a quantity of caloric; and when they united together, this caloric of courſe ſeparated from them.

297
Stahl's theory of combuſtion by the extrication of phlogiſton.

The theory of combuſtion adopted by the earlier chemiſts was very different from the preceding. Stahl, as has been already explained, conſidered combuſtion in every inſtance as owing to the ſeparation of phlogiſton; and this opinion ſoon became univerſal. He conſidered phlogiſton as the ſame thing with the element of fire; which was capable both of becoming fixed in bodies, and of exiſting in a ſtate of liberty. Two of its properties in this laſt ſtate were heat and light. The heat and the light, then, which became ſenſible during combuſtion, were nothing elſe, according to Stahl, but two properties of phlogiſton or the element of fire.

298
Improved by Macquer,

Macquer, to whoſe illuſtrious labours ſeveral of the moſt important branches of chemiſtry owe their exiſtence, was, we believe, the firſt perſon who perceived a ſtriking defect in this theory of Stahl. Sir Iſaac Newton had proved that light is a body; it was abſurd, therefore, to make it a mere property of phlogiſton or the element of fire. Macquer accordingly conſidered phlogiſton as nothing elſe but light fixed in bodies. This opinion was embraced by a great number of the moſt diſtin-

(1) The ſame opinion has been embraced by Seguin, Pictet, Gadolin, and ſeveral other philoſophers. We did not mention them, becauſe the theory given above differs in a few particulars from theirs. But we have derived much inſtruction from their ingenious writings; and many of the facts, which we have given, were obtained from them

Caloric.

distinguished chemists; and many ingenious arguments were brought forward to prove its truth. But if phlogiston be only light fixed in bodies, whence comes the heat that manifests itself during combustion? Is this heat merely a property of light? Dr Black proved that heat is capable of combining with, or becoming fixed in bodies which are not combustible, as in ice and water: and concluded of course, that it is not a property but a body. From that time heat or caloric was considered by the greatest number of chemists as a distinct substance from phlogiston.

299 Priestley,

Soon after this, a phenomenon, which had been observed from the earliest ages, and which probably, for that very reason, had been neglected, began to be attended to; that combustibles would not burn except in contact with air. Dr Priestley observed, that the air in which combustibles had been suffered to burn till they were extinguished, had undergone a very remarkable change; for no combustible would afterwards burn in it, and no animal could breathe it without suffocation (K). He concluded, as Dr Rutherford had done before him, that this change was owing to phlogiston; that the air had combined with that substance; and that air was necessary to combustion, by attracting the phlogiston, for which it had a strong affinity. If so, phlogiston could not be light any more than caloric; for if it separated from the combustible merely by combining with air, it could not surely display itself in the form of light. The question then recurred with double force, What is phlogiston? Dr Crawford, of whose ingenious experiments on the specific caloric of bodies we have already given an account, without attempting to answer this question, made a considerable improvement in the theory of combustion, by supposing that the phlogiston of the combustible combined with the air, and at the same time separated the caloric and light with which that fluid had been previously united. The heat and the light, then, which appeared during combustion, existed previously in the air. This theory was very different from Stahl's, and certainly a great deal more satisfactory. But still the question, What is phlogiston? remained to be answered. Mr Kirwan, who had already raised himself to the first rank among chemical philosophers by many important discoveries, and many ingenious investigations of some of the most difficult parts of chemistry, attempted to answer this question, and to prove that phlogiston was the same with hydrogen.* The subject was now brought to a state capable of the most complete decision. Does hydrogen actually exist in all combustible substances? and is it separated from them during every combustion? The French chemists who answered his treatise, shewed that this is by no means the case; and that therefore there was no proof whatever of the identity of phlogiston and hydrogen. And Mr Kirwan in consequence, with that candour which distinguishes superior minds, gave up his opinion as untenable.

300 And Crawford.

301 Kirwan's theory of phlogiston

* In his *Treatise on Phlogiston.*

302 Refuted.

303 Existence of phlogiston disproved.

Mr Lavoisier had already put the question, What proof is there of the existence of phlogiston at all? There is only this single proof, that substances after combustion are different from what they formerly were. That this difference takes place is certainly true; but it is owing, not to the separation of any substance, but to the combination of one. It follows, therefore, that there is no proof whatever of the existence of any such substance as *phlogiston* in nature; and of course we must conclude, that no such substance exists (L).

304 Production of caloric by percussion,

15. It is well known, that heat is produced by the percussion of hard bodies against each other. When a piece of iron is smartly and quickly struck with a hammer, it becomes red hot; and the production of sparks by the collision of flint and steel is too familiar a fact to require being mentioned. No heat, however, has ever been observed to follow the percussion of liquids, nor of soft bodies which easily yield to the stroke.

305 Owing partly to condensation,

It has long been known, that hammering increases the density of metals. The specific gravity of iron before hammering is 7,788; after being hammered, 7,840: that of platinum before hammering is 19,50; after it, 23,00. Now condensation diminishes the specific caloric of bodies. After one of the clay pieces used in Wedgewood's thermometer has been heated to 120°, it is reduced to one half of its former bulk, though it has lost only two grains of its weight, and its specific caloric is at the same time diminished one-third.* But we cannot conceive the specific caloric of a body to be diminished without its giving out at the same time a quantity

* *T. Wedgewood, Phil. Transf.* 1792.

(K) These very observations had been made almost a century before by Mayow; but chemistry was then in its infancy; little attention was paid to them, and they had been forgotten.

(L) Mr Lavoisier was therefore the author of what is called the *antiphlogistic theory* in chemistry, or the theory which accounts for the phenomena of chemistry without the assistance of phlogiston. It has been so called in opposition to the theory of Stahl, which explained every thing by means of *phlogiston*, and which is therefore called the *phlogistic theory*.

Some chemists have affected to omit Lavoisier's name altogether, when they spoke of the antiphlogistic theory. According to them, that theory was founded upon the experiments and discoveries of other chemists, and Lavoisier had no other merit but that of bringing it into public notice.

That Mr Lavoisier virtually at least claimed several of the discoveries of others, we are sorry to be under the necessity of acknowledging; and that many of the experiments, brought forward to disprove the existence of phlogiston, were first made by others, is known to all the world: but it is equally evident, that the first person who actually formed the theory was Lavoisier; and surely the merit lies in that. It is not those who collect the stones, and the timber, and the mortar, but he who lays the plan, and shows how to put the materials together, that is in reality the builder of the house. Who did not know, as well as Newton, that a stone fell to the ground, and that the planets revolved round the sun? and yet, who but Newton could have formed the theory of gravitation? We would not be understood to detract any thing from the merit of the other illustrious philosophers who have adorned the present age, many of whom are at least equal, and some of them superior to Lavoisier.

Caloric.

quantity of caloric; and we know for certain that caloric is evolved during condensation. A thermometer placed within a condenser rises several degrees every time air is thrown in †. We can even see a reason for this. When the particles of a body are forced nearer each other, the repulsive power of the caloric combined with them is increased, and consequently a part of it will be apt to fly off. Now, after a bar of iron has been heated by the hammer, it is much harder and brittler than before. It must then have become denser, and consequently must have parted with caloric. It is an additional confirmation of this, that the same bar cannot be heated a second time by percussion until it has been exposed for some time to a red heat. It is too brittle, and flies to pieces under the hammer. Now brittleness seems in most cases owing to the absence of the usual quantity of caloric. Glass *unannealed*, or, which is the same thing, that has been cooled very quickly, is always extremely brittle. When glass is in a state of fusion, there is a vast quantity of caloric accumulated in it, the repulsion between the particles of which must of course be very great; so great indeed, that they would be disposed to fly off in every direction with inconceivable velocity, were they not confined by an unusually great quantity of caloric in the surrounding bodies: consequently if this surrounding caloric be removed, the caloric of the glass flies off at once, and more caloric will leave the glass than otherwise would leave it, because the velocity of the particles must be greatly increased. Probably then the brittleness of glass is owing to the deficiency of caloric; and we can scarcely doubt that the brittleness of iron is owing to the same cause, if we recollect that it is removed by the application of new caloric. Part therefore of the caloric which appears in consequence of percussion seems to proceed from the body struck; and this is doubtless the reason why those bodies, the density of which is not increased by percussion, as liquids and soft substances, are not heated at all.

† *Darwin, Phil. Transf.* 1788.

306 And partly to combustion.

We say *part* of the caloric, because, often at least, part of it is probably owing to another cause. By condensation, as much caloric is evolved as is sufficient to raise the temperature of some of the particles of the body high enough to enable it to combine with the oxygen of the atmosphere. The combination actually takes place, and a great quantity of additional caloric is separated by the decomposition of the gas. That this happens during the collision of flint and steel cannot be doubted: for the sparks produced are merely small pieces of iron heated red hot by uniting with oxygen during their passage through the air, as any one may convince himself by actually examining them. Mr Lane has shewn that iron produces no sparks in the vacuum of an air-pump; but Mr Kirwan has observed that they are produced under common spring water; and we know that iron at a certain temperature is capable of decomposing water.

307 Sparks emitted by quartz stones on elision.

When quartz, rock-crystal (M), or other very hard stones, are struck against one another, they emit sparks. If they be often made to emit sparks above a sheet of white paper, there are found upon it a number of small black bodies, not very unlike the eggs of flies. These bodies are hard but friable, and when rubbed on the paper leave a black stain. When viewed with a microscope, they seem to have been melted. Muriatic acid changes their colour to a green, as it does that of lavas.* These substances evidently produced the sparks by being heated red hot. Lamanon (N) supposes that they are particles of quartz combined with oxygen. Were that the case, the phenomenon would be precisely similar to that which is produced by the collision of flint and steel. That they are particles of quartz cannot be doubted; but to suppose them combined with oxygen is contrary to all experience: for these stones never shew any disposition to combine with oxygen even when exposed to the most violent heat. La Metherie made experiments on purpose to see whether Lamanon's opinion was well founded; but they all turned out unfavourable to it. And Monge ascertained, that the particles described by Lamanon were pure crystal unaltered, with a quantity of black powder adhering to them. He concludes accordingly, that these fragments had been raised to so high a temperature during their passage through the air, that they set fire to all the minute bodies that came in their way †. We must therefore either suppose that all the caloric was produced by mere condensation, which is not probable, or acknowledge that we cannot explain the phenomenon.

* *Lamanon, Journ. de Phys.* 1785.

308 Cause of this unknown.

† *Ann. de Chim.* xvi. 206.

309 Emission of caloric on friction,

16. Caloric is not only produced by percussion, but also by friction. Fires are often kindled by rubbing pieces of dry wood smartly against one another. It is well known that heavy loaded carts sometimes take fire by the friction between the axle-tree and the wheel.

310 Not owing to condensation,

Now in what manner is the caloric evolved or accumulated by friction? Not by increasing the density of the bodies rubbed against each other, as happens in cases of percussion; for heat is produced by rubbing soft bodies against each other, the density of which therefore cannot be increased by that means, as any one may convince himself by rubbing his hand smartly against his coat. It is true, indeed, that heat is not produced by the friction of liquids, but then they are too yielding to

(M) These stones are composed of almost pure silica.

(N) This ingenious and unfortunate young man, to whom we are indebted for these facts, fell a victim to his ardour for knowledge. He accompanied La Peyrouse in his last voyage, and was murdered with the most savage cruelty, together with La Langle and several others, by the natives of the island of Maouna. When a man of genius, anxious to acquire honest fame, and a man too so nobly disinterested as Lamanon, thus falls prematurely before he has attained the object of his wishes,

" Cut off from nature's and from glory's course!
" Which never mortal was so fond to run,"

who can withhold the tribute of regret and admiration, when they

——" conjecture what he might have proved,
" And think life only wanting to his fame."

Caloric.

311 Nor to decreafe of fpecific caloric, † *Nicholfon's Journal*, ii. 106.

to be fubjected to ftrong friction. It is not owing to the fpecific caloric of the rubbed bodies decreafing; for Count Rumford found, that there was no fenfible decreafe†: nor, if there were a decreafe, would it be fufficient to account for the vaft quantity of heat which is fometimes produced by friction.

Count Rumford took a cannon caft folid and rough as it came from the foundery; he caufed its extremity to be cut off, and formed, in that part, a folid cylinder attached to the cannon, $7\frac{1}{4}$ inches in diameter, and $9\frac{8}{10}$ inches long. It remained joined to the reft of the metal by a fmall cylindrical neck. In this cylinder a hole was bored 3,7 inches in diameter, and 7,2 inches in length. Into this hole was put a blunt fteel borer, which by means of horfes was made to rub againft its bottom; at the fame time a fmall hole was made in the cylinder perpendicular to the bore, and ending in the folid part a little beyond the end of the bore. This was for introducing a thermometer to meafure the heat of the cylinder. The cylinder was wrapt round with flannel to keep in the heat. The borer preffed againft the bottom of the hole with a force equal to about 10,000lb. avoirdupois, and the cylinder was turned round at the rate of 32 times in a minute. At the beginning of the experiment the temperature of the cylinder was 60°; at the end of 30 minutes, when it had made 960 revolutions, its temperature was 130°. The quantity of metallic duft or fcales produced by this friction amounted to 837 grains. Now, if we were to fuppofe that all the caloric was evolved from thefe fcales, as they amounted to juft $\frac{1}{948}$ part of the cylinder, they muft have given out 948° to raife the cylinder 1°, and confequently 66360° to raife it 70° or to 130°, which is certainly incredible†.

† *Ibid.*

312 Nor to combuftion,

Neither is the caloric evolved during friction, owing to the combination of oxygen with the bodies themfelves or any part of them. By means of a piece of clockwork, Mr Pictet made fmall cups (fixed on the axis of one of the wheels) to move round with confiderable rapidity, and he made various fubftances rub againft the outfides of thefe cups, while the bulb of a very delicate thermometer placed within them marked the heat produced. The whole machine was of a fize fufficiently fmall to be introduced into the receiver of an air pump. By means of this machine a piece of adamantine fpar was made to rub againft a fteel cup in air: fparks were produced in great abundance during the whole time, but the thermometer did not rife. The fame experiment was repeated in the exhaufted receiver of an air pump (the manometer ftanding at four lines); no fparks were produced, but a kind of phofphoric light was vifible in the dark. The thermometer did not rife. A piece of brafs being made to rub in the fame manner againft a much fmaller brafs cup in air, the thermometer (which almoft filled the cup) rofe 0,3°, but did not begin to rife till the friction was over. This fhews us that the motion produced in the air carried off the caloric as it was evolved. In the exhaufted receiver it began to rife the moment the friction began, and rofe in all 1,2°. When a bit of wood was made to rub againft the brafs cup in the air, the thermometer rofe 0,7°, and on fubftituting alfo a wooden cup it rofe 2,1°, and in the exhaufted receiver 2,4°, and in air condenfed to $1\frac{1}{2}$ atmofpheres it rofe 0,5°*.

* *Pictet fur le Feu*, ch. 9.

If thefe experiments be not thought conclufive, we have others to relate which will not leave a doubt that the heat produced by friction is not connected with the decompofition of oxygen gas. Count Rumford contrived, with his ufual ingenuity, to inclofe the cylinder above defcribed in a wooden box filled with water, which effectually excluded all air, as the cylinder itfelf and the borer were furrounded with water, and at the fame time did not impede the motion of the inftrument. The quantity of water amounted to 18,77lbs. avoirdupois, and at the beginning of the experiment was at the temperature of 60°. After the cylinder had revolved for an hour at the rate of 32 times in a minute, the temperature of the water was 107°; in 30 minutes more it was 178°; and in 2 hours and 30 minutes after the experiment began, the water *actually boiled*. According to the computation of Count Rumford, the caloric produced would have been fufficient to heat 26,58lbs. avoirdupois of ice-cold water boiling hot; and it would have required 9 wax candles of a moderate fize, burning with a clear flame all the time the experiment lafted, to have produced as much heat. In this experiment all accefs of water into the hole in the cylinder where the friction took place was prevented. But in another experiment the refult of which was precifely the fame, the water was allowed free accefs†.

† *Nicholfon, ibid.*

313 And confequently at prefent inexplicable.

The caloric, then, which appears in confequence of friction, is neither produced by an increafe of the denfity, nor by an alteration in the fpecific caloric of the fubftances expofed to friction, nor is it owing to the decompofition of the oxygen of the atmofphere—Whence then is it derived? This queftion we are altogether unable to anfwer. We cannot, however, think, that the conclufion which Count Rumford is difpofed to draw from his experiments is warranted by the premifes. He fuppofes, that becaufe we cannot explain the manner that caloric is accumulated by friction, there is no fuch fubftance as caloric at all, but that it is merely a *peculiar kind of motion*. We would beg leave to afk, how the facts mentioned in the former part of this chapter, many of which were furnifhed by this ingenious philofopher himfelf, and all of which combine to render the exiftence of caloric as a fubftance probable, can be deftroyed and fet afide, merely becaufe there are other phenomena in nature connected with caloric which cannot be accounted for? Were it poffible to prove that the accumulation of caloric by friction is *incompatible* with its being a fubftance, in that cafe Count Rumford's conclufion would be a fair one; but this furely has not been done. We are certainly not yet fufficiently acquainted with the laws of the motion of caloric (allowing it to be a fubftance) to be able to affirm with certainty that friction could not caufe it to accumulate in the bodies rubbed. This we know at leaft to be the cafe with electricity. Nobody has been hitherto able to demonftrate in what manner it is accumulated by friction; and yet this has not been thought a fufficient reafon to deny its exiftence.

314 This no proof that caloric is not a body.

315 Analogy between caloric and electricity.

Indeed there feems to be a very clofe analogy between caloric and electric matter. Both of them tend to diffufe themfelves equally, both of them dilate bodies, both of them fufe metals, and both of them kindle combuftible fubftances. Mr Achard has proved, that electricity can be fubftituted for caloric even in thofe cafes where its agency feems peculiarly neceffary; for he found that, by conftantly fupplying a certain quantity of the electric

Caloric. tric fluid, eggs could hatched just as when they are kept at the temperature of 103°. An accident indeed prevented the chickens from actually coming out; but they were formed and living, and within two days of bursting their shell. Electricity has also a great deal of influence on the heating and cooling of bodies. Mr Pictet exhausted a glass globe, the capacity of which was 1200,199 cubic inches, till the manometer within it stood at 1,75 lines. In the middle of this globe was suspended a thermometer, which hung from the top of a glass rod, fixed at the bottom of the globe, and going almost to its top. Opposite to the bulb of this thermometer, two lighted candles were placed, the rays of which, by means of two concave mirrors, were concentrated on the bulb. The candles and the globe were placed on the same board, which was supported by a non-conductor of electricity. Two feet and a half from the globe there was an electrifying machine, which communicated with a brass ring at the mouth of the globe by means of a metallic conductor. This machine was kept working during the whole time of the experiment; and consequently a quantity of electric matter was constantly passing into the globe, which formed an atmosphere, not only within it, but at some distance round, as was evident, from the imperfect manner in which the candles burned. When the experiment began, the thermometer stood at 49,8°. It rose to 70,2° in 732″. The same experiment was repeated, but no electric matter thrown in; the thermometer rose from 49,8° to 70,2° in 1050″; so that the electricity hastened the heating almost a third. In the first experiment the thermometer rose only to 71,3°, but in the second it rose to 77°. This difference was doubtless owing to the candles burning better in the second than the first experiment; for in other two experiments made exactly in the same manner, the maximum was equal both when there was and was not electric matter present. These experiments were repeated with this difference, that the candles were now insulated, by placing their candlesticks in dishes of varnished glass. The thermometer rose in the electrical vacuum from 52,2° to 74,7° in 1050″ in the simple vacuum of 965″. In the electrical vacuum the thermometer rose to 77°; in the simple vacuum to 86°. It follows from these experiments, that when the globe and the candles communicated with each other, electricity hastened the heating of the thermometer; but that when they were insulated separately, it retarded it*. One would be apt to suspect the agency of electricity in the following experiment of Mr Pictet: Into one of the brass cups formerly described, a small quantity of cotton was put to prevent the bulb of the thermometer from being broken. As the cup turned round, two or three fibres of the cotton rubbed against the bulb, and without any other friction, the thermometer rose five or six degrees. A greater quantity of cotton being made to rub against the bulb, the thermometer rose 15 degrees†.

* *Pictet sur le Feu*, ch. 6.

† *Ibid.* ch. 9.

316 Electricity may be an agent in the heating of bodies by friction.

We do not mean to draw any other conclusion from these facts, than that electricity is very often concerned in the heating of bodies, and that probably some such agent is employed in accumulating the heat produced by friction. Supposing that electricity is actually a substance, and taking it for granted that it is different from caloric, does it not in all probability contain caloric as well as all other bodies? Has it not a tendency to accumulate in all bodies on friction, whether conductors or non-conductors? May it not then be accumulated in those bodies which are rubbed against one another? or if they are good conductors, may it not pass through them during the friction in great quantities? May it not part with some of its caloric to these bodies, either on account of their greater affinity, or some other cause? And may not this be the source of the caloric which appears during friction? Light.

Chap. VI. *Of* Light.

317 Newtonian theory of light.

By means of *light* bodies are rendered visible. Light has been considered as a substance composed of small particles moving in straight lines from luminous bodies with inconceivable rapidity. The discoveries of Newton established this opinion on the firm basis of mathematical demonstration; and since his time it has been generally embraced. Huyghens, indeed, and Euler, advanced another (o). They considered light as a subtile fluid, filling all space, which rendered bodies visible by its undulations. But they supported their hypothesis rather by starting objections to the theory of Newton, than by bringing forward direct proofs. Their objections, even if valid, instead of establishing their own opinions, would prove only that the phenomena of light are not completely understood; a truth which no man will refuse to acknowledge, whatever side of the question he adopts. Newton and his disciples, on the contrary, have shewn that the known phenomena of light are *inconsistent* with the undulations of a fluid, and have brought forward a great number of direct arguments, which it has been impossible to answer, in support of their theory. It can hardly be doubted, therefore, that the Newtonian theory of light is the true one.

318 Velocity of light.

Dr Bradley, who, by a number of very accurate experiments, and a process of reasoning peculiarly ingenious, discovered the aberration of light of the fixed stars, has shewn from it that the velocity of light is to that of the earth in its orbit as 10313 to 1. Light therefore moves at the rate of 195218 miles in a second.

319 Divisible into seven rays,

Light, by means of a prism, may be separated into seven rays, differing from each other in colour; red, orange, yellow, green, blue, indigo, violet. None of these are capable of farther decomposition. Marat, indeed, pretended that he had reduced them to three; but his experiments are now known to have been merely philosophical frauds.

320 Differing in refrangibility,

When light passes obliquely into a denser medium, it is *refracted towards* the perpendicular; when into a rarer, *from* the perpendicular. Sir Isaac Newton discovered that the rays differed in their refrangibility in the order in which they have been named, the red being the least, the violet the most refrangible. Mr Blair has observed, that the ratios of the refrangibility of the different rays, though not their order, vary somewhat in different mediums†.

† *Edinburgh Phil. Trans.* iii.

When

(o) Dr Franklin did the same, without taking any notice of these philosophers, of whose opinions perhaps he was ignorant. See *Trans. Philad.* III. 5.

Light.

321 Inflection, deflection,

When light passes within a certain distance of a body, parallel to which it is moving, it is bent *towards* it; when it passes at a greater distance, it is bent *from* it. The first of these properties is called *inflection*, the second *deflection*. Now the rays differ in these properties in the order in which they were named; the red being *most*, the violet *least* inflexible and deflexible. This was suspected by David Rittenhouse,* but was first demonstrated by the ingenious experiments of Mr Brougham †.

* Transf. Philad. ii.

† Phil. Tran. 1796.

322 And reflexity.

When light falls upon a visible body, some of it is reflected back; and the more polished or the whiter any surface is, the more light it reflects. The rays of light differ also in reflexity (see REFLEXITY, *Suppl.*), the red being the most, the violet the least reflexible. This discovery we owe to the same ingenious gentleman ‡.

‡ Phil. Tranf. ibid.

These properties of light constitute the subject of OPTICS; to which we refer those who wish to see them investigated. We mention them here because they prove that light is acted on by other bodies, that it is subjected to the laws of attraction, and, consequently, that it possesses *gravity*.

2. The particles of light seem also, like those of caloric, to possess the property of repelling one another; at least their rapid motion, in all directions, from luminous bodies, seems to be owing to some such property.

323 Light capable of entering bodies,

3. Light is capable of entering into bodies, and remaining in them, and of being afterwards extricated without any alteration. Father Beccaria, and several other philosophers, have shown us by their experiments, that there are a great many substances which become luminous after being exposed to the light. This property was discovered by carrying them instantly from the light into a dark place, or by darkening the chamber in which they were exposed. Most of these substances, indeed, lose this property in a very short time, but they recover it again on being exposed to the light; and this may be repeated as often as we please. We are indebted to Mr Canton for some very interesting experiments on this subject, and for discovering a composition which possesses this property in a remarkable degree. He calcined some common oyster shells in a good coal fire for half an hour, and then pounded and sifted the purest part of them. Three parts of this powder were mixed with one part of the flowers of sulphur, and rammed into a crucible which was kept red hot for an hour. The brightest parts of the mixture were then scraped off, and kept for use in a dry phial well stopped. When this composition is exposed for a few seconds to the light, it becomes sufficiently luminous to enable a person to distinguish the hour on a watch by it. After some time it ceases to shine, but recovers this property on being again exposed to the light. Light then is not only acted upon by other bodies, but it is capable of uniting with them, and afterwards leaving them without any change.

It is well known that light is emitted during combustion; and it has been objected to this conclusion, that these bodies are luminous only from a slow and imperceptible combustion. But surely combustion cannot be suspected in many of Father Beccaria's experiments, when we reflect that one of the bodies on which they were made was his own hand, and that many of the others were altogether incombustible; and the phenomena observed by Mr Canton are also incompatible with the notion of combustion. His pyrophorus shone only in consequence of being exposed to light, and lost that property by being kept in the dark. It is not exposure to light which causes substances capable of combustion at the temperature of the atmosphere to become luminous, but exposure to air. If the same temperature continues, they do not cease to shine till they are consumed; and if they cease, it is not the application of light, but of caloric, which renders them again luminous: but Canton's pyrophorus, on the contrary, when it had lost its property of shining, did not recover it by the application of heat, except it was accompanied by light. The only effect which heat had was to increase the separation of light from the pyrophorus, and of course to shorten the duration of its luminousness. Two glass globes, hermetically sealed, containing each some of this pyrophorus, were exposed to the light and carried into a dark room. One of them, on being immersed in a bason of boiling water, became much brighter than the other, but in ten minutes it ceased to give out light: the other remained visible for more than two hours. After having been kept in the dark for two days, they were both plunged into a bason of hot water; the pyrophorus which had been in the water formerly did not shine, but the other became luminous, and continued to give out light for a considerable time. Neither of them afterwards shone by the application of hot water; but when brought near to an iron heated so as scarcely to be visible in the dark, they suddenly gave out their remaining light, and never shone more by the same treatment: but when exposed a second time to the light, they exhibited over again precisely the same phenomena; even a lighted candle and electricity communicated some light to them. Surely these facts are altogether incompatible with combustion, and fully sufficient to convince us that light alone was the agent, and that it had actually entered into the luminous bodies.

It has been questioned, indeed, whether the light emitted by pyrophori be the same with that to which they are exposed. Mr Wilson has proved, that in many cases at least it is different, and in particular that on many pyrophori the blue rays have a greater effect than any other, and that they cause an extrication of red light. Mr de Grosser has shewn the same thing with regard to the diamond, which is a natural pyrophorus ‡. Still, however, it cannot be questioned that the luminousness of these bodies is owing to exposure to light, and that the phenomenon is not connected with combustion.

‡ Jour. de Phys. xx. 270.

324 And of being combined with them.

But light appears capable, not only of entering into bodies, but of combining with them chemically. The phenomena of the phosphori seem to be instances of this, and a great many facts concur to prove that light enters into the composition of oxygen gas. When vegetables grow in the light, they give out oxygen gas; but no oxygen is extricated in the dark, even though heat be applied †. From this it is evident, that the separation of this gas from plants, or perhaps the decomposition of the water which they contain, depends upon the action of light; and that as this decomposition is chemical, the light to produce it must either combine with the oxygen or the hydrogen, or at least contribute to the combination of some other substance with one or other of them. When the oxyds of gold or silver are exposed

† Priestly and Ingenhousz.

Light.

expoſed to light, they are reduced to the metallic ſtate,* and at the ſame time a quantity of oxygen gas is extricated.‡ In this caſe, it is evident that the light muſt either combine with the oxygen or the metals. If a quantity of nitric acid be expoſed for ſome time to the light, it becomes yellow, as is well known, and a quantity of oxygen gas is ſound floating on its top. If it be now carried to a dark place, the oxygen is gradually abſorbed, and the acid becomes colourleſs. In this caſe, nitric acid is decompoſed by means of light, and reſolved into *nitrous acid* and oxygen gas. The light muſt therefore have combined either with the nitrous acid or the oxygen. But no change whatever appears to have been produced in the nitrous acid; for if it be obtained in the dark by any other proceſs, it has preciſely the ſame properties. The oxygen, on the contrary, is converted into a *gas*. It is more probable, then, that the light has combined with the oxygen than with the acid. Hence there is reaſon to ſuſpect that light makes one of the ingredients of oxygen gas. Caloric has already been ſhewn to make another ingredient.

* Scheele.
‡ Bertholl*e*t.

325 Light which appears during combuſtion ſuppoſed combined with oxygen gas.

During combuſtion, a quantity of light as well as caloric is almoſt always evolved. We muſt conclude, therefore, that light makes a part of the compoſition either of the combuſtibles themſelves, or of the oxygen gas with which they unite. We have already ſhewn, that oxygen gas probably contains light; and this probability is confirmed by another fact. Subſtances may be combined with oxygen without the emiſſion of any light, provided the oxygen be not in the ſtate of a gas. If phoſphorus, for inſtance, be put into nitric acid, it attracts oxygen, and is converted into phoſphoric acid without the emiſſion of any light. Now if the light which appears during combuſtion had been combined with the combuſtible, it ought to appear in all caſes when that combuſtible is united with oxygen, whether the oxygen has previouſly been in the ſtate of a gas or not. But as this is not the caſe, we may certainly infer, that the light which appears during combuſtion is extricated, not from the combuſtible, but from the oxygen gas. And this ſeems at preſent to be the opinion of the greater number of philoſophers.

But we muſt acknowledge, that this concluſion is not without its difficulties, and difficulties, too, which, in the preſent ſtate of chemiſtry, it does not ſeem poſſible to ſurmount.

326 Difficulties attending this opinion.

In the firſt place, it is evident, that light *may* be produced during combuſtion, though the oxygen be not in the ſtate of a gas: For if nitric acid be poured upon oil of turpentine, the oil takes fire, and burns with the greateſt rapidity, and a great deal of light is emitted. This combuſtion is occaſioned by the oxygen of the acid combining with the ingredients of the oil. It follows, therefore, if the light emitted was previouſly combined with the oxygen, that oxygen muſt contain light when not in the ſtate of a gas. Mr Prouſt has ſhown that a great variety of ſimilar combuſtions may be produced. But what is very remarkable, by proper caution the very ſame combinations may be made to take place without the viſible emiſſion of any light. In that caſe they take place very ſlowly, as happens alſo when phoſphorus decompoſes nitric acid; ſo that the emiſſion or non-emiſſion of light ſeems to depend not upon the ſtate of the oxygen, ſo much as upon the rapidity or ſlowneſs of the combination. It is true, indeed, as the late Dr Hutton of Edinburgh obſerved, that light may be emitted in theſe ſlow combinations though it be not viſible: and this is very probably the caſe; but then the proof is deſtroyed that light exiſts in oxygen gas, from its not appearing during combinations in which the oxygen did not exiſt previouſly in a gaſeous ſtate.

In the ſecond place, the colour of the light emitted during combuſtion differs almoſt always according to the combuſtible. During the combuſtion of phoſphorus, tin, and zinc, the light emitted is white; during that of ſulphur and biſmuth, blue. Now if this light were united with the oxygen, why does it not appear always of the ſame colour, whatever be the combuſtible?

In the laſt place, the phenomena of phoſphori ſhew that light is capable of entering into other bodies as well as oxygen gas; and the emiſſion of light on the colliſion of two flint ſtones, when no oxygen gas can be decompoſed, is a proof of the ſame kind, which cannot be got over.

In the preſent ſtate of chemiſtry, therefore, it cannot be concluded, that the light emitted during combuſtion does not exiſt in the combuſtibles as well as in the oxygen.

327 Light heats bodies.

4. Light has the property of heating bodies. All bodies, however, are not heated by it. Thoſe which are perfectly tranſparent, or which allow all the light to paſs through them, ſuffer no alteration in their temperature. Thus light may be concentrated upon water or glaſs without producing any effect. Neither does it produce much change upon thoſe bodies (mirrors for inſtance) that reflect all or nearly all the light which falls upon them. And the ſmallneſs of the alteration of temperature is always proportional to the fineneſs of the poliſh, or, which is the ſame thing, to the quantity of light which is reflected. So that we have reaſon to conclude, that if a ſubſtance could be procured which reflected all the light that fell upon it, the temperature of ſuch a ſubſtance would not be at all affected by light falling upon it. Dr Franklin expoſed upon ſnow pieces of cloth of different colours (white, red, blue, black), to the light of the ſun, and found that they ſunk deeper, and conſequently acquired heat, in proportion to the darkneſs of their colour. Now it is well known that dark-coloured bodies, even when equally expoſed to the light, reflect leſs of it than thoſe which are light-coloured. But ſince the ſame quantity falls upon each, it is evident that dark coloured bodies muſt abſorb and retain more of it than thoſe which are light-coloured. That ſuch an abſorption actually takes place is evident from the following experiment. Mr Thomas Wedgewood placed two lumps of luminous or phoſphoreſcent marble on a piece of iron heated juſt under redneſs. One of the lumps of marble which was blackened over gave out no light; the other gave out a great deal. On being expoſed a ſecond time in the ſame manner, a faint light was ſeen to proceed from the clean marble, but none at all could be perceived to come from the other. The black was now wiped off, and both the lumps of marble were again placed on the hot iron: The one that had been blackened gave out juſt as little light as the other §. In this caſe, the light which ought to have proceeded from the luminous marble diſappeared: it muſt therefore have been ſtopped

§ *Phil. Tran.* 1792.

Light.

stopped in its passage out, and retained by the black paint. Now black substances are those which absorb the most light, and they are the bodies which are most heated by exposure to light Cavallo observed, that a thermometer with its bulb blackened stands higher than one which has its bulb clean, when exposed to the light of the sun, the light of day, or the light of a lamp*. Mr Pictet made the same observation; and took care to ascertain, that when the two thermometers were allowed to remain for some time in a dark place, they acquired precisely the same height. He observed, too, that when both thermometers had been raised a certain number of degrees, the clean one fell a good deal faster than the other‡. But it is not a small degree of heat alone which can be produced by means of light. When its rays are concentrated by a burning glass, they are capable of setting fire to combustibles with ease, and even of producing a temperature at least as great, if not greater, than what can be procured by the most violent and best conducted fires. In order to produce this effect, however, they must be directed upon some body capable of absorbing and retaining them; for when they are concentrated upon transparent bodies, or upon fluids, mere air for instance, they produce little or no effect whatever. We may conclude, therefore, in general, that in all cases when light produces heat it is absorbed.

* Phil. Tran. 1780.

‡ Sur le Feu, ch. 4.

328 Heat renders bodies luminous,

5. All bodies become luminous when their temperature is raised a certain number of degrees. No fact is more familiar than this; so well known indeed is it, that little attention has been paid to it. When a body becomes luminous by being heated in a fire, it is said in common language to be *red hot*. It follows from all the experiments hitherto made, that the temperature at which they become red hot is nearly the same in all bodies.—It seems to be pretty near 800° A red hot body continues to shine for some time after it has been taken from the fire and put into a dark place. The constant accession, then, either of light or heat is not necessary for the shining of bodies: but if a red hot body be blown upon by a strong current of air, it ceases to shine immediately§. Consequently the moment the temperature of a body is diminished by a certain number of degrees, it ceases to be luminous.

§ T. Wedgewood, Phil. Tran. 1792.

Whenever a body reaches the proper temperature, it becomes luminous, independent of any contact of air; for a piece of iron wire becomes red hot while immersed in melted lead†.

† Id. ibid.

329 Except the gases.

To this general law there is one remarkable exception. It does not appear that the gases become luminous even at a much higher temperature. The following ingenious experiment of Mr T. Wedgewood seems to set the truth of this exception in a very clear point of view. He took an earthen ware tube B (fig. 5.), bent so in the middle that it could be sunk, and make several turns in the large crucible C, which was filled with sand. To one end of this tube was fixed the pair of bellows A; at the other end was the globular vessel D, in which was the passage F, furnished with a valve to allow air to pass out, but none to enter. There was another opening in this globular vessel filled with glass, that one might see what was going on within. The crucible was put into a fire; and after the sand had become red hot, air was blown through the earthen tube by means of the bellows. This air, after passing through the red-hot sand, came into the globular vessel. It did not shine; but when a piece of gold wire E was hung at that part of the vessel where the earthen ware tube entered, it became faintly luminous. A proof, that though the air was not luminous, it had been hot enough to raise other bodies to the shining temperature.

330 Enquiry into the cause of these phenomena

6. Thus it appears that light and heat reciprocally produce each other; that the fixation of light in bodies always produces heat, and that the application of a sufficiently strong heat always occasions the extrication of light. Are heat and light, then, owing to the same cause? Does light become caloric merely by being fixed in bodies? and does caloric assume the appearance of light whenever it is extricated from them? In short, are caloric and light merely names for the same substance, called *caloric* when it is fixed in bodies, and *light* when in a state of liberty?

To these questions it may be answered, That if caloric and light were one and the same substance, they ought to produce precisely the same effects. Now this is not the case: a black body is not heated sooner by mere caloric than any other, though the contrary takes place when both are exposed to the light.* Heat cannot make growing vegetables exhale oxygen gas, though light does it almost instantaneously. When oxy-muriatic acid (a compound of oxygen and muriatic acid) is exposed to the light, a quantity of oxygen gas flies off, and nothing remains but common muriatic acid. Light then decomposes this acid; for if you wrap up a bottle in black cloth, so as to exclude light, and then expose it equally to the sun, no such decomposition takes place. Now this decomposition cannot be produced by mere caloric. If the acid be heated, it simply evaporates without being altered. Chaptal has proved (P), that the rays of light directed on certain parts of glasses, containing solutions of salts, cause them to crystallize in that part in preference to any other†. These observations have been confirmed and extended by Mr Dorthes‡. Now caloric produces no such effects, nor has the temperature any influence on the phenomenon.

* T. Wedgewood, Phil. Tran. 1792.

† Mem. Toulouse, iii.

‡ Ann. de Chim. ii. 2.

These facts are sufficient to shew that light and caloric, even when they have entered into bodies, produce different effects, and that therefore they have different properties (Q). But if the only difference between them were, that the one is in a state of liberty, the other in that

(P) Petit made the same observations in 1722. See *Memoirs of the Academy of Sciences* for that year, p. 95. and 331.

(Q) We must acknowledge, however, that the following ingenious experiments of Professor Pictet might be adduced, to prove that light and caloric possess at least *one* property in common, that of moving in straight lines.

He placed two concave mirrors of tin, of nine inches focus, at the distance of twelve feet two inches from one another. In the focus of one of them he placed a ball of iron two inches in diameter, heated so as not to be visible that of combination, the moment light entered a body it ought to be no longer light but caloric, and conſequently ought to produce preciſely the ſame effects with caloric: And ſince this is not the caſe, we are warranted ſurely to conclude that light and caloric are not the ſame, but different ſubſtances. How then does caloric occaſion the appearance of light, and light that of caloric?

331
Suppoſed owing to the mutual repulſion of light and caloric.

We have ſeen already, that there is no body in nature which does not contain caloric; and light has ſuch an influence upon every thing, it produces ſuch important changes upon the animal and vegetable kingdoms, it can be extricated from ſuch a vaſt number of bodies, that in all probability we may conclude, with regard to it alſo, that it exiſts in all, or in almoſt all, the bodies in nature. We have no means of aſcertaining either the quantity of light or of caloric that exiſts in bodies; but if we were to judge from the quantity which appears during combuſtion, we muſt reckon it very conſiderable. Now, may there not exiſt a repulſion between the particles of caloric and light? It is not eaſy, at leaſt, to ſee why light flies off during combuſtion with ſuch rapidity, if this be not the caſe. If ſuch a repulſion actually exiſts, it will follow that caloric and light cannot be accumulated in the ſame body beyond a certain proportion. If the caloric exceed, it will tend to drive off the light; if the light, on the contrary, happens to prevail, it will diſplace the caloric.

If caloric and light actually exiſt in all bodies, there muſt be an affinity between them and all other bodies; and this affinity muſt be ſo great, as to render ineffectual the repulſion which exiſts between light and caloric. Let us ſuppoſe now, that theſe two ſubſtances exiſt in all bodies in certain proportions, it will follow, that the more either of caloric or light is added to any body, the ſtronger muſt the repulſion between their particles become; and if the accumulation be ſtill going on, this repulſion will ſoon become great enough to balance their affinity for the body in which they exiſt, and conſequently will diſpoſe them to fly off. If caloric, for inſtance, be added to a body, whenever the body arrives at a certain temperature it becomes luminous, becauſe part of the light which was formerly combined with it is driven off. This temperature muſt depend partly upon the affinity between the body and caloric, and partly upon its affinity for light. Pyrophori, for inſtance, the affinity between which and light does not ſeem to be very great, become luminous at a very moderate temperature. This is the caſe with the pyrophorus of Canton. A great many hard bodies become luminous when they are expoſed to a moderate heat; fluor, for inſtance, carbonat of barytes, ſpar, ſea ſhells, and a great many others, which are enumerated by Mr Thomas Wedgewood.*

The ſame ingenious gentleman has obſerved, that gold, ſilver, copper, and iron, become luminous when heated

* *Phil. Tranſ.* 1792, p. i.

viſible in the dark; in the other was placed the bulb of a thermometer. In ſix minutes the thermometer roſe from 4° to 14° *(Reaumur)*. A lighted candle, which was ſubſtituted for the ball of iron, made the thermometer riſe in one experiment from 4,6° to 14°; in another, from 4,2° to 14,3°. In this caſe both light and heat appeared to act. In order to ſeparate them, he interpoſed between the two mirrors a plate of clear glaſs. Before the interpoſition of the glaſs, the thermometer had riſen from 2° to 12°, where it was ſtationary. After the interpoſition of the glaſs it ſunk in nine minutes to 5,7°; and when the glaſs was again removed it roſe in ſeven minutes to 11,1°; yet the light which fell on the thermometer did not ſeem at all diminiſhed by the glaſs. Mr Pictet therefore concluded, that the caloric had been reflected by the mirror, and that it had been the cauſe of the riſe of the thermometer. In another experiment, a glaſs matraſs was ſubſtituted for the iron ball, nearly of the ſame diameter with it, and containing 2044 grains of boiling water. Two minutes after a thick ſcreen of ſilk, which had been interpoſed between the two mirrors, was removed, a Fahrenheit's thermometer, which was in the other focus, roſe from 47° to $50\frac{1}{2}$; and the moment the matraſs was removed from the focus the thermometer again deſcended. On repeating the experiment, with this variation, that the bulb of the thermometer was blackened, it roſe from $51\frac{1}{2}$ to $55\frac{1}{4}$.

The mirrors of tin were now placed at the diſtance of 90 inches from each other; the matraſs with the boiling water in one of the foci, and a very ſenſible air thermometer in the other, every degree of which was equal to $\frac{1}{10}$th of a degree of Reaumur. Exactly in the middle ſpace between the two mirrors there was placed a very thin common glaſs mirror, ſuſpended in ſuch a manner that either ſide could be turned towards the matraſs. When the poliſhed ſide of this mirror was turned to the matraſs, the thermometer roſe only 0,5°; but when the ſide covered with tinfoil, and which had been blackened with ink and ſmoke, was turned toward the matraſs, the thermometer roſe 3,5°. In another experiment, when the poliſhed ſide of the mirror was turned to the matraſs, the thermometer roſe 3°, when the other ſide 9,2°. On rubbing off the tinfoil, and repeating the experiment, the thermometer roſe 18°. On ſubſtituting for the glaſs mirror a piece of thin white paſteboard of the ſame dimenſions with it, the thermometer roſe 10°. On putting a matraſs full of ſnow into one of the foci (the mirrors in this experiment were $10\frac{1}{2}$ feet diſtant from each other), the air thermometer *ſunk* ſeveral degrees, and roſe again when the matraſs was removed. When nitric acid was poured on the ſnow, the thermometer ſunk 5° or 6° lower.

Taking it for granted that theſe experiments proved the motion of caloric in ſtraight lines like light, Mr Pictet endeavoured to diſcover the velocity of its motion. For this purpoſe he placed two concave mirrors at the diſtance of 69 feet from each other; the one of tin as before, the other of plaſter gilt, and 18 inches in diameter. Into the focus of this laſt mirror he put the air thermometer, and the bullet of iron heated as before into that of the other. A few inches from the face of the tin mirror there was placed a thick ſcreen, which was removed as ſoon as the bullet reached the focus. The thermometer roſe the inſtant the ſcreen was removed without any perceptible interval: hence he concluded, that the time caloric takes in moving 69 feet is too ſhort to be meaſured. See *Pictet ſur le Feu*, chap. iii.

We

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heated in times inversely proportional to their specific calorics†. Now the specific calorics of these metals are in the following order:

† Phil. Trans. 1792, p. i.

Iron,
Copper,
Silver,
Gold.

They become luminous, therefore, when exposed to the same degree of heat, in the following order:

Gold,
Silver,
Copper,
Iron.

Now the smaller the specific caloric of any body is, the less must be the quantity of caloric necessary to raise it a given number of degrees; the sooner therefore must it arrive at the temperature at which it gives out light. It was natural to expect, then, if the emission of light from a body by the application of heat be owing to the repulsion between caloric and light, that those bodies should become luminous soonest in which that repulsion increases with the greatest rapidity; and this we see is precisely the case. The only question to be determined before drawing this conclusion is, Whether the same quantity of caloric entered all of them? That depends upon their conducting power, which, according to Ingenhousz, is in the following order:

Silver,
Gold,
Copper,
Iron.

We see, then, that this conducting power is nearly in the order in which these metals become luminous; so that the greatest quantity of caloric would enter those which become soonest luminous. Now this is just what ought to happen, provided the expulsion of light from a luminous body, by the application of heat, be owing to the repulsion between the particles of caloric and light.

The repulsion between the different rays of light and caloric does not seem to be equal: the repulsion between the blue rays and caloric seems to be greater than that between the red rays and caloric; and the repulsion between all the rays and caloric seems to be directly as their refrangibility: accordingly, when heat is applied to a body, the blue rays escape sooner, and at a lower temperature, than the red rays and others which are most refrangible. When sulphur, for instance, is burnt at a low temperature, the colour of the flame is blue; and when examined by the prism it is found to consist of the violet, indigo, blue, and sometimes of a small quantity of the green rays;* but when this substance is burnt at a high temperature the colour of the flame is white, all the rays separating together. When bodies

* Morgan, Phil. Trans. 1785.

We must observe, with regard to these experiments, that the idea that caloric can be reflected, and that it can move in straight lines like light, or that there is such a thing as *radiant heat*, to use the phrase of Lambert and Scheele, is directly contrary to the experiments of Count Rumford, formerly described; by which he shewed the incapacity of various bodies to conduct heat; for if caloric could move in straight lines through transparent mediums, it would be absurd to say that either air, or water, or oil, was a non-conductor of it. But these bodies have in fact been found to be con-conductors; and therefore it must follow unavoidably, that there is no such thing as radiant caloric. Consequently, if the experiments of Mr Pictet *can* be explained, on the supposition that light and not caloric was the agent, that alone will be sufficient to exclude them from ranking as proofs of the identity of heat and light. Now this has been done with a great deal of ingenuity by the late Dr James Hutton of Edinburgh, in his treatise on the *Philosophy of Light, Heat, and Fire.*

He had previously convinced himself, by a number of experiments, that the different species of light possessed very different degrees of intensity when measured by the eye and the thermometer. He rendered light of different colours equally intense to the eye, by varying the distance from the luminous body till he could just read by the light of it. In this way he compared the red light from a fire of coals with the white light of flame, and found, that when they were equally powerful in affording vision, the red was by far the most powerful in producing heat. When a body is heated to incandescence, it emits first the white or compound light; but as it cools, the light which it emits becomes of the red species, and this is the last which disappears. As the body cools, therefore, the power of its light to produce heat does not diminish so fast as its power to produce vision; consequently, when this last ceases entirely, the other may still in a certain degree remain. We may suppose, therefore, that the iron ball in Mr Pictet's experiments, after it had lost all light to the eye, continued still to emit rays, which, though they made no impression on that organ, had power to produce heat, and that it was these rays collected by the mirrors that raised the thermometer. What confirms this is, that when the bulb of the thermometer was blackened it rose higher than at other times; for caloric, as has been already mentioned, would have produced no such effect. As to the effect of the matrass of water, it is explained, by supposing that all bodies, raised to a certain temperature, emit rays of light, whether they have been heated red hot or not.

As to the effect of the snow in lowering the thermometer, which was certainly a very singular and unlooked for effect, Dr Hutton explains it, by supposing that all bodies emit rays of light, whatever their temperature is, and that this irradiation diminishes as their temperature diminishes. On that supposition, it is evident that the temperature of the thermometer, like that of all other bodies, is maintained partly by the irradiation of invisible light from the surrounding bodies—It must therefore, since it is placed in the focus of one of the mirrors, be affected by whatever body is placed in the focus of the other. If that body be colder than the surrounding bodies, less light will be irradiated from it and thrown upon the thermometer; consequently the thermometer will be depressed till the deficiency is supplied by some other channel.

Such is the ingenious hypothesis by which Dr Hutton has explained the experiments of Mr Pictet; and the explanation, though it is not without very considerable difficulties, must be allowed at least to be the most plausible which has hitherto been given, and to be highly deserving of being put to the test of experiment.

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bodies have continued to burn for fome time, they may be fuppofed to have loft the greater part of the moft refrangible rays; hence the red appearance of bodies, charcoal for inftance, that have burnt for fome time, the only rays which remain to feparate being the orange, yellow, and red†.

† *Morgan, Phil. Tranf.* 1785.

The blue rays feem not only to repel caloric with greater force, but likewife to have a greater affinity for other bodies than the red rays have; for they decompofe the oxyd of filver (or rather the muriat of filver) much fooner, and to a greater extent, than the red rays‡: hence we fee the reafon why the application of the blue rays to Mr Wilfon's pyrophori and to the diamond caufes an extrication of red rays.

‡ *Sennebier.*

We have feen already, that the gafes are not heated red hot by the application of heat. It would follow from this, that the gafes do not contain light: but the contrary is certain; for light is actually extricated durring the combuftion of hydrogen, and muft therefore have exifted either in the oxygen or hydrogen gas, or in both. Probably therefore the reafon that heat does not extricate light from the gafes is, that the affinity between their bafes and light is exceedingly ftrong: it would therefore require a more than ufual temperature to produce its extrication; and on account of the great dilatability of thefe gafes, which always tends to diminifh the repulfion between the caloric and light, this temperature cannot be applied. It is eafy to fee, upon the fuppofition that there exifts a repulfion between caloric and light, why the accumulation of light fhould produce heat, and why light only occafions heat in thofe bodies that abforb it.

Such is the theory of the caufe of the reciprocal extrication of light and caloric by the application of thefe fubftances refpectively to bodies, which has been propofed by feveral ingenious chemifts (R); and we acknowledge frankly, that it appears to us by far the moft plaufible of all the explanations of this phenomenon with which we are acquainted.

332
Objections to which this theory is liable.

It is not, however, beyond the reach of objections, and objections too, we are afraid, altogether incompatible with its truth. Were the repulfion between caloric and light the only caufe of the luminoufnefs of hot bodies, the continual application of heat would furely in time feparate the whole of the light which was combined with the body, and then it would ceafe to be luminous altogether; but we have no reafon to fuppofe that bodies ever ceafe to become luminous by the continued application of heat. Claveus kept melted, and confequently red hot, gold for months in a furnace; but he does not fay that its luminoufnefs was diminifhed, far lefs deftroyed; and had fuch a remarkable phenomenon taken place, certainly he would not have failed to inform us; but fo far from that, he exprefsly fays that it fuffered no alteration (S)§.

§ *Shaw's Boyle*, iii. 268.

Whether light would continue to extricate a great deal of caloric during fo long a time has never been tried: but we have no reafon for fuppofing that its power to produce that effect is ever exhaufted; for bodies, after being expofed to the fun for years, and even for ages, are juft as much heated by it as ever. But thefe effects, far from being inexhauftible, ought, according to the theory, to come very fpeedily to an end. It is certainly probable, then, as other philofophers have fuppofed, that though light and caloric are not precifely one and the fame fubftance, they are fome how or other intimately connected, and are either compofed of different proportions of the fame ingredients, or the one enters into the compofition of the other.

333
Scheele's theory of light and caloric.

One of the firft theories of this kind (for the opinion of Stahl has been already difcuffed) was formed by Mr Scheele*, one of the moft extraordinary men and greateft philofophers that ever exifted. Without the affiftance of education or of wealth, his genius burft forth with aftonifhing luftre; and at an age when moft philofophers are only rifing into notice, he had finifhed a career of difcoveries which have no parallel in the annals of chemiftry. Whoever wifhes to behold ingenuity combined with fimplicity, whoever wifhes to fee the inexhauftible refources of chemical analyfis, whoever wifhes for a model in chemical refearches—has only to perufe and to ftudy the works of Scheele (T). After a vaft number of experiments, conducted with aftonifhing ingenuity, he concluded, that caloric was compofed of a certain quantity of oxygen combined with phlogifton; that radiant heat, a fubftance which he fuppofed capable of being propagated in ftraight lines like light, and not capable of combining with air, was compofed of oxygen united with a greater quantity of phlogifton, and light of oxygen united with a ftill greater quantity. He fuppofed, too, that the difference between the rays depended upon the quantity of phlogifton: the red, according to him, contained the leaft; the violet, the moft phlogifton. By *phlogifton* Mr Scheele feems to have

* In his *Treatife on Fire.*

(R) Particularly by Dr Parr, who is faid to be the author of a paper on this fubject, publifhed in the *Exeter Memoirs*.

(S) A gentleman, to whom we mentioned this objection, obferved, that in the cafe of bodies long expofed to heat, the light, which appears to proceed from them, might, in fact, be extricated from the atmofphere by the caloric communicated to it from the heated body. This thought is new and ingenious, and might eafily be put to the teft of experiment. Some of the facts mentioned in the text are rather hoftile to it; but fhould it prove well founded, it would go far to remove moft of the difficulties in which the theory of light is at prefent involved.

(T) This Newton of chemiftry died in 1786, at the age of 44. His moral character, according to Mr Erhart and others, who were the companions of his youth, and Meffrs Gadolin, Efpling, and thofe who knew him in his latter days, was irreproachable and praife-worthy. His outward appearance was not expreffive of the great mind which lay concealed as it were under a veil. He feldom joined in the ufual converfations and amufements of fociety, having as little leifure as inclination to do fo; for what little time he had to fpare from the hurry of his profeffion (an apothecary), was conftantly filled up in the profecution of experiments. It was only when he received vifits from his friends, with whom he could converfe upon his favourite fcience, that he indulged himfelf in a little relaxation. For fuch friends he had a fincere affection, as he had alfo for thofe that lived at a diftance, and even for fuch as were not perfonally known to him. He kept up a regular correfpondence with Meffrs Erhart, Meyer, Kirwan, Crell, and feveral other chemifts. See *Crell's Life of Scheele.*

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have meant *hydrogen*. It is needlefs therefore to examine his theory, as it is now known that the combination of hydrogen and oxygen forms not caloric but water (u). The whole fabric therefore has tumbled to the ground; but the importance of the materials will always be admired, and the ruins of the ftructure fhall remain eternal monuments of the genius of the builder.

334 De Luc's theory

Mr de Luc, fo well known for his important meteorological labours, has advanced another theory*. According to him, light is a body which moves conftantly in ftraight lines, with fuch rapidity that its gravitation towards other fubftances bears no fenfible proportion to its motion. Light has the property of combining with another unknown fubftance, and the compound formed is caloric, which poffeffes very different properties from light. Caloric is conftantly defcribing helicoidal curves round an axis, which accounts for the flownefs of its apparent motion. Light produces or increafes heat, partly by increafing the expanfive power of caloric, and partly by combining with the *unknown fubftance*, and forming new caloric; caloric, on the other hand, is always decompofed when bodies become luminous. This theory is certainly ingenious, and would remove many of the difficulties which we at prefent labour under in attempting to explain the phenomena of caloric and light. It is, however, liable to other difficulties, which could not be eafily furmounted. But it is needlefs to examine thefe, as the theory itfelf is fupported by no evidence whatever, and cannot therefore be admitted.

* In his *Idées fur la Meteorologie.*

335 Hutton's theory.

Another theory has been advanced by the late Dr Hutton of Edinburgh (v); a man of undoubted genius, but of rather too fpeculative a turn of mind, and who fometimes involved himfelf in difficulties from his very ingenuity. All his writings difplay evident marks of the profound philofopher: they contain much inftruction; and even his miftakes are not without their ufe: but unfortunately his manner is fo peculiar, that it is fcarcely more difficult to procure the fecrets of fcience from Nature herfelf, than to dig them from the writings of this philofopher. He fuppofes that there are two kinds of matter, gravitating matter and light; the laft of which wants gravity, and confequently neither poffeffes magnitude (w) nor momentum. Light has the power of being fixed in bodies; and then it becomes either caloric or phlogifton, which differs in fome particulars from caloric, but in what, the Doctor does not precifely tell us.

Part of this theory we have examined already when we attempted to prove that light and caloric were different fubftances. The other part of the theory feems to involve a contradiction; for how could light become fixed in a body, unlefs it were attracted by it? and if light poffeffes attraction, it furely cannot be deftitute of gravity; for what is gravity but *attraction* (x)?

Thus, notwithftanding the ingenuity of the philofophers who have attempted to inveftigate this part of chemiftry, the connection between light and caloric is ftill unknown. We muft content ourfelves, therefore, with confidering them at prefent as diftinct fubftances, and leave the folution of the many difficulties which at prefent perplex us to the more happy labours of future enquirers.

PART II. OF COMPOUND BODIES.

TO thofe bodies, which are compofed of *two fimple fubftances* combined together, for want of a better name we have given the appellation of *compound bodies*. They may be reduced under five claffes:

1. Water;
2. Alcohol;
3. Oils;
4. Alkalies;
5. Acids.

Thefe fhall be the fubject of the five following chapters; and we fhall finifh this part of the article with fome obfervations on *Affinity*.

CHAP. I. *Of* WATER.

WATER is a well-known liquid, found in abundance in every part of the world, and abfolutely neceffary for the exiftence of animals and vegetables.

When pure, in which ftate it can be obtained only by diftillation, it is tranfparent, and deftitute of colour tafte, and fmell.

A cubic foot of water, at the temperature of 55°, weighs, according to the experiments of Profeffor Robifon of Edinburgh (fee *SPECIFIC Gravity*, Encycl.), 998,74 avoirdupois ounces, of 437,5 grains troy each, or only 1,26 ounces lefs than 1000 avoirdupois ounces; fo that rain water, at the fame temperature, will weigh pretty nearly 1000 ounces. The fpecific gravity of water is always fuppofed = 1,000, and it is made the meafure of the fpecific gravity of every other body. 336 Weight of water.

When water is cooled down to 32°, it affumes the form of ice. If this procefs goes on very flowly, the ice affumes the form of cryftalline needles, croffing each other at angles either of 60° or 120°, as Mr de Mairan has remarked; and it has been often obferved in large cryftals of determinate figures. Ice, while kept at a temperature confiderably below 32°, is very hard, and may be pounded into the fineft duft. It is elaftic. Its fpecific gravity is lefs than that of water. 337 Ice.

When

(u) This candid philofopher afterwards acknowledged, that the proofs for the compofition of water were complete; but we do not know exactly how he attempted to reconcile his theory of heat with the belief that water was compofed of oxygen and hydrogen; two opinions which are certainly incompatible.

(v) See his differtations on different fubjects of natural philofophy.

(w) Indeed Dr Hutton refufed this property to gravitating matter alfo; following, in this particular, the theory of the celebrated Bofcovich.

(x) We hope not to be accufed of difputing merely about the meaning of a word, till what is faid on this fubject in the chapter of the prefent article, which treats of *Affinity*, has been examined.

Water.

338 Steam. When water is heated to the temperature of 212°, it boils, and is gradually converted into steam. Steam is an invisible fluid like air, but of a less specific gravity. It occupies about 1200 times the space that water does. Its elasticity is so great, that it produces the most violent explosions when confined. It is upon this principle that the steam-engine has been constructed. See STEAM and STEAM-*Engine*, Encycl.

339 Boiling point of water. The phenomena of boiling are owing entirely to the rapid formation of steam at the bottom of the vessel. The boiling point of water varies according to the pressure of the atmosphere. In a vacuum water boils at 90°; and when water is confined in Papin's digester, it may be almost heated red hot without boiling.

340 Impregnated with various salts. The mixture of various salts with water affect its boiling point considerably. Mr Achard made a number of experiments on that subject: the result of which may be seen in the following tables‡.

‡ *Transf. Berlin*, 1785.

CLASS I. *Salts which do not affect the Boiling Point.*

Sulphat of copper.

CLASS II. *Salts which raise the Boiling Point.*

A saturated solution of	Raises the boiling point
Muriat of soda	10,35°
Sulphat of soda	5,6
Sulphat of potass	0,9
Nitrat of potass	3,5
Boracic acid	2,2
Carbonat of soda	2,35

This augmentation varies with the quantity of salt dissolved. In general, it is the greater the nearer the solution approaches to saturation.

CLASS III. *Salts which lower the Boiling Point.*

Borax,	In a small quantity, lowers the boiling point - - - - -	1,350°
	Saturated solution of, - -	0,22
Sulphat of magnesia,	In a small quantity,	1,47
	Saturated solution of	1,1
Alum,	A very small quantity of, - -	0,0
	A greater quantity, - -	0,7
	A saturated solution of, -	0,0
Sulphat of lime,	in any proportion,	2,02
Sulphat of zinc,	in any proportion,	0,45
Sulphat of iron,	in any proportion,	0,22
Acetite of lead,	in any proportion,	1,24

CLASS IV.

Muriat of ammonia,	Small quantity of, lowers the boiling point, - - - -	0,45
	Saturated solution of, raises do.	9,79
Carbonat of potass,	Small quantity of, lowers do. -	0,45
	Saturated solution of, raises do.	11,2

341 Water compressible. Water was once supposed to be incompressible; but the contrary has been demonstrated by Mr Canton. The Abbé Mongez made a number of experiments, long after that philosopher, on the same subject, and obtained similar results.

342 Opinion about its nature. Water was believed by the ancients to be one of the four elements of which every other body is composed; and, according to Hippocrates, it was the substance which nourishes and supports plants and animals. That water was an unchangeable element continued to be believed till the time of Van Helmont, who made plants grow for a long time in pure water: From which experiment it was concluded, that water was convertible into all the substances found in vegetables.—Mr Boyle having digested pure water in a glass vessel hermetically sealed for above a year, obtained a quantity of earthy scales; and concluded, in consequence, that he had converted it partly into an earth.* He obtained the same earth by distilling water in a tall glass vessel over a slow fire†. Margraf repeated the experiment with the same result, and accordingly drew the same conclusion. But the opinion of these philosophers was never very generally received. The last person who embraced it was probably Mr Waselton, who published his experiments on the subject in the Journal de Physique for 1780. Mr Lavoisier had proved, as early as 1773, that the glass vessels in which the distillation was performed lost a weight exactly equal to the earth obtained. Hence it follows irresistibly, that the appearance of the earth, which was silica, proceeded from the decomposition of the vessels; for glass contains a large proportion of silica. It has been since shown by Dr Priestley, that water always decomposes glass when applied to its surface for a long time in a high temperature.

* Shaw's Boyle, iii. 417.
† *Ibid*, i. 267.

343 History of the discovery of its composition. We have formerly mentioned, that water is composed of oxygen and hydrogen. This great discovery has contributed more perhaps than any other to the advancement of the science of chemistry, by furnishing a key for the explanation of a prodigious number of phenomena. The evidence, therefore, on which it rests, and the objections which have been made to it, deserve to be examined with peculiar attention.

The first person probably who attempted to discover what was produced by burning hydrogen gas was Scheele. He concluded, that during the combustion oxygen and hydrogen combined, and that the product was caloric.

In 1776 Macquer, assisted by Sigaud de la Fond, set fire to a bottle full of hydrogen gas, and placed a saucer above the flame, in order to see whether any fuliginous smoke would be produced. The saucer remained perfectly clean; but it was moistened with drops of a clear liquid, which they found to be pure water ‡.

‡ *Macquer's Dictionary*. art. *Gas inflammable*.

Next year Bucquet and Lavoisier exploded oxygen and hydrogen gas, and made an attempt to discover what was the product; about the nature of which they had formed different conjectures. Bucquet had supposed that it would be carbonic acid gas; Lavoisier, on the contrary, suspected that it would be sulphuric or sulphurous acid. What the product was they did not discover; but they proved that no carbonic acid gas was formed, and consequently that Mr Bucquet's hypothesis was ill founded ||.

|| *Mem. Par.* 1781. 470.

In the beginning of the year 1781, Mr Warltire, at the request of Dr Priestley, fired a mixture of these two gases contained in a copper vessel; and observed, that after the experiment the weight of the whole was diminished. Dr Priestley had previously, in the presence of Mr Warltire, performed the same experiment in a glass vessel. This vessel became moist in the inside, and was covered with a sooty substance §, which Dr Priestley afterwards supposed to be a part of the mercury used in filling the vessel*.

§ *Priestley*, v. 395.
* *Phil. Transf.* lxxiv. 332.

In the summer of 1781, Mr Henry Cavendish, who had been informed of the experiments of Priestley and Warltire, Water

Warltire, set fire to 500,000 grain measures of hydrogen gas, mixed with about $2\frac{1}{4}$ times that quantity of common air. By this process he obtained 135 grains of pure water. He also exploded 19,500 grain measures of oxygen gas with 37,000 of hydrogen gas, and obtained 30 grains of water, containing in it a little nitric acid. From these experiments he concluded that water was a compound.—Mr Cavendish must therefore be considered as the real discoverer of the composition of water. He was the first who ascertained that water was produced by firing oxygen and hydrogen gas, and the first that drew the proper conclusion from that fact. Mr Watt, indeed, had also drawn the proper conclusion from the experiments of Dr Priestley and Mr Warltire, and had even performed a number of experiments himself to ascertain the fact, before Mr Cavendish had communicated his; but he had been deterred from publishing his theory by some experiments of Dr Priestley, which appeared contrary to it †. He has therefore a claim to the merit of the discovery; a claim, however, which does not affect Mr Cavendish, who knew nothing of the theory and experiments of that ingenious philosopher.

† Phil. Transf. lxxv. 330.

Meanwhile, in the winter 1781-2, Mr Lavoisier, who had suspected, that when oxygen and hydrogen gas were exploded, sulphuric or sulphurous acid was produced, made an experiment in order to ascertain the fact, at which Mr Gingembre assisted. They filled a bottle, capable of holding six pints (French), with hydrogen gas, to which they set fire, and then corked the bottle, after pouring into it 2 oz. (French) of lime water. Through the cork there passed a copper tube, by means of which a stream of oxygen gas was introduced to support the flame. Though this experiment was repeated three times, and instead of lime water a weak solution of alkali and pure water were substituted, they could not observe any product whatever ‡. This result astonished Mr Lavoisier exceedingly: he resolved, therefore, to repeat the experiment on a larger scale, and if possible with more accuracy. By means of pipes furnished with stop-cocks, he put it in his power to supply both gases as they should be wanted, that he might be enabled to continue the burning as long as he thought proper.

‡ Mem. Par. 1781 p. 470

The experiment was made by Lavoisier and la Place on the 24th of June 1783, in the presence of Messrs le Roi, Vandermonde, several other academicians, and Sir Charles Blagden, who informed them that Mr Cavendish had already performed it, and that he had obtained water.* They continued the inflammation till all their stock of gases was wasted, and obtained about 295 grains of water, which, after the most rigid examination, appeared to be perfectly pure. From this experiment Lavoisier concluded, that water was composed of oxygen and hydrogen. Mr Monge soon after performed the same experiment, and obtained a similar result: and it was soon after repeated again by Lavoisier and Meusnier on a scale sufficiently large to put the fact beyond doubt.*

* Ibid. p. 472.

* Ibid. p. 474.

Water.

344 Proofs of the composition of water.

The proofs that water is a compound are of two kinds; it has been actually composed, and it has been decomposed.

345 Experiment of Lavoisier and Meusnier.

With regard to the composition of water, we shall relate the celebrated experiment made by Lavoisier and Meusnier in the month of February 1785, in the presence of a numerous deputation from the academy of sciences, and so many other spectators, that it may be considered as having been performed in public. Every precaution was taken to ensure success. The gases had been prepared with care, and held for some time over a solution of potass, in order to deprive them of any acidity which they might accidentally contain; and before entering into the glass globe where they were to be burnt, they were made to pass over newly calcined potass, to deprive them of the water which they might happen to retain in solution. The hydrogen gas had been obtained by passing steam through iron at a white heat; the oxygen gas was procured from the red oxyd of mercury. The combustion took place in a large glass globe, into which the gases were admitted by means of tubes furnished with stop-cocks; and the most ingenious contrivances were employed to ascertain exactly the quantities of each which were consumed (Y). The whole machine is described at large by Mr Meusnier in the Memoires of the Academy of Sciences for 1782.

The quantities of gas employed, after deducting the 432 grains of residuum which were not consumed, were 2794,76 grains of oxygen gas, and 471,125 of hydrogen gas. After taking from these 32,25 grains, = the humidity of which the oxygen gas was deprived by the calcined potass, and 44,25 grains, = the weight which the hydrogen lost by the same process, there remains altogether 3188,4 grains of gas.

The quantity of water obtained amounted to 3219 grains; the specific gravity of which was to distilled water as 1,0051 to 1. This quantity was 30 grains more than the gas employed. The difference, no doubt, was owing to a small error in estimating the weight of the gases; which indeed it is extremely difficult to avoid, as the weight is altered by the smallest difference of temperature. This water had a slight smell, and a taste sensibly acid; it reddened slightly blue paper, and effervesced with the carbonat of potass. 1152 grains of that water being saturated with potass, and evaporated to dryness, left 20 grains of a salt which melted on the fire like nitre. It follows from this experiment, that the quantity of acid contained in the whole water would not have been quite sufficient to have formed 56 grains of nitre.

The residuum weighed, as has been already observed, 432 grains; its volume was equal to 444 grains of oxygen gas; it was diminished by nitrous gas (Z) precisely as gas would be which contained 0,24 parts of oxygen; it rendered lime water somewhat turbid, which indicated the presence of carbonic acid gas.

From the comparison of the weights, and volumes of the gases consumed, it was concluded that water consists

(Y) A variety of instruments have been invented by the French chemists for that purpose. These instruments they have denominated *Gazometers*.

(Z) This gas shall be afterwards described. It has the property of absorbing almost instantaneously the oxygen gas with which it comes into contact. It is therefore often used, in order to discover how much oxygen gas exists in any mixture.

Water.

346 Experiment of Le Fevre de Gineau.

* Journ. de Phys. 1788, p. 457.

fists of 0,85 parts, by weight, of oxygen, and 0,15 of hydrogen.

This experiment was soon after repeated by Mr le Fevre de Gineau upon a still larger scale, and in the presence of a great number of spectators. It continued for no less than 12 days, and was performed with the most rigorous exactness of which experiments of that nature will admit.*

The oxygen gas employed, which had been procured from the black oxyd of manganese, occupied the space of 35085,1 cubic inches, and weighed 18298,5 gr.

The hydrogen gas was obtained by dissolving iron in diluted sulphuric acid. Its volume was 7496,7 cubic inches, and its weight 4756,3 grains.

	Grains.
The two gases, therefore, amounted to -	23054,8
From which taking the residuum after combustion, which amounted to - -	2831,0
There remains for the quantity consumed, -	20223,8
The water found in the glass globe after the combustion amounted to - -	20139,0
And there were carried off by the residuum, -	54,0
In all, - -	20193,0

Which is just 30 grains less than the weight of the gases which disappeared, or $\frac{1}{674}$ part of their weight. This difference arose from the same difficulties which attended the experiment of Lavoisier. As the errors are on different sides, we are warranted to conclude that this was the case, and that it was not owing to any real difference between the gases and the product.

The water was examined in the presence of Messrs Lavoisier, le Roi, Monge, Berthollet, Bayen, and Pelletier. Its specific gravity was to that of distilled water as 1,001025 to 1. It contained no sulphuric nor muriatic acids; yet it had an acid taste, and converted vegetable blues to a red. 6606 grains of it required for saturation 36 grains of carbonat of potass, and furnished by evaporation 26,5 grains of crystals of nitre. The whole water, therefore, would have required 109,7 grains of carbonat of potass for saturation.

This water affected lime water a little; and it was found, that the residuum of the gas contained some carbonic acid gas. This residuum formed a nineteenth part of the volume of the two gases employed, and an eighth of their weight. It contained 462 grains of carbonic acid gas, or about $\frac{1}{6}$ part; the rest was azotic gas, with about $\frac{1}{12}$ of oxygen.

This experiment gave the proportions of oxygen and hydrogen in water as follows:

Oxygen, - - -	,848
Hydrogen, - - -	,152
	1,000

This is so near the determination of Mr Lavoisier, that it must be considered as a very strong confirmation of it.

347 Experiment of Seguin, Fourcroy, and Vauquelin.

In the year 1790, another similar experiment was performed by Seguin, Fourcroy, and Vauquelin, in the presence of a number of commissioners appointed by the academy of sciences. Every precaution was taken to ascertain the quantity of gas employed with the utmost exactness, and to exclude all atmospherical air as completely as possible.

Water.

The hydrogen gas was procured by dissolving zinc in sulphuric acid diluted with 7 parts of water. The oxygen gas was obtained by distilling oxy-muriat of potass (A).

The quantity of hydrogen gas employed amounted to 862,178 grains troy. The quantity of oxygen gas amounted to 13475,198 cubic inches (French). Its purity was such, that it contained three cubic inches of azotic gas in the 100. The whole gas, therefore, contained 404,256 cubic inches. There were likewise in the glass vessel in which the combustion took place 15 cubic inches (French) of atmospheric air, which consisted of 11 cubic inches of azotic and four of oxygen gas. So that the whole oxygen gas employed amounted to 13074,942 cubic inches; and it contained besides 415,256 cubic inches of azotic gas. They ascertained by experiment, that a cubic inch of this oxygen gas, thus diluted with $\frac{3}{100}$ of azot, weighed ,4040 of a grain troy. Now, according to the experiments of Lavoisier, a cubic inch (French) of azotic gas weighs only ,3646 of a grain troy. Consequently the weight of pure oxygen gas is greater than ,4040; and by calculation they shewed it to amount to ,4051 of a grain troy. The weight of the whole oxygen gas employed, therefore, was 5296,659 grains troy; and that of the azotic gas mixed with it 151,402 grains troy.

The combustion continued 185 hours; and during all that time our philosophers never quitted the laboratory. The flame was exceedingly small, and the heat produced by no means great. This was owing to the very small stream of hydrogen, which was constantly flowing into the vessel.

The water obtained amounted to 5943,798 grains troy, or 12 oz. 7 dwts. and 15,798 grains. It exhibited no mark of acidity, and appeared in every respect to be pure water. Its specific gravity was to that of distilled water as 18671 to 18670; or nearly as 1,000053 to 1.

The residuum of gas in the vessel after combustion amounted to 987 cubic inches (French); and on being examined, was found to consist of the following quantities of gases:

Azotic gas, - - - - -	467 cubic inches.
Carbonic acid gas, - - -	39
Oxygen gas, - - - - -	465
Hydrogen gas, - - - -	16
Total, .	987

The Weight of which is as follows:

Azotic gas, - - - - -	170,258 gr. troy.
Carbonic acid gas, - - -	23,306
Oxygen gas, - - - - -	188,371
Hydrogen gas, - - - -	0,530
Total, -	382,465

Now the weight of the whole gases employed was, - - - -	6310,239 gr. troy.
That of the water obtained, and of the residuum, - - - -	6326,263
Or, - - - - - - - - -	16,024 grains

more than had been employed. This small quantity must

(A) A salt composed of oxy-muriatic acid and potass.

Water.

must have been owing to common air remaining in the tubes and other parts of the apparatus, in spite of all the precautions that were taken to prevent it; if it did not rather proceed from unavoidable errors in their valuations.

	Gr. Troy.
The quantity of azotic gas introduced was	151,178
The quantity found in the residuum was	170,258
There was therefore a surplus of - -	19,080 gr.

As sufficient precautions had been taken to prevent the introduction of carbonic acid gas, the quantity found in the residuum must have been formed during the process. There must therefore have been a small quantity of carbon introduced. Now zinc often contains carbon, and hydrogen has the property of dissolving carbon: probably, then, the carbon was introduced in this manner. The carbonic acid found in the residuum amounted to 23,306 grains, which, according to Lavoisier's calculation, is composed of 8,958 grains of carbon, and 14,348 grains of oxygen.

Substracting these 8,958 grains of carbon, and the ,530 of a grain of hydrogen, which remained in the vessel, from the total of hydrogen introduced, there will remain 852,690 grains for the hydrogen that disappeared.

Substracting the 14,348 grains of oxygen which entered into the composition of the carbonic acid, and the residuum of oxygen, which amounted to 188,371 grains, the quantity of oxygen that disappeared will amount to 5093,940 grains.

Hydrogen that disappeared, - -	852,690 gr. troy.
Oxygen, - - - - -	5093,940
Total, -	5946,630
Quantity of water obtained, -	5943,798
Which is less than the gases consumed by . - - -	2,832 grains*.

* Ann. de Chim. viii. 325.

Such are the principal experiments upon which the opinion is founded that water is a compound. Let us examine them, and see whether they are sufficient to establish that opinion. The circumstances which chiefly claim our attention, and which have been chiefly insisted on, are these:

348 Objections to the composition of water examined.

1. The whole of the gases was not consumed.

2. In the residuum were found several substances which were not introduced, and which must therefore have been formed during the combustion.

3. The water obtained was seldom perfectly pure. It generally contained some nitric acid.

4. As only part of the gases were consumed, and as all gases contain water in them, might not the gas which disappeared have been employed in forming the other substances found in the residuum? and might not the water obtained have been merely what was formerly dissolved in the gases, and which had been precipitated during the experiment?

That the whole of the gases was not consumed, will not surprise us, if we recollect that it is impossible for that to take place, allowing them to be perfectly pure, except they be mixed in precisely the proper proportions, and not even then, except every particle of them could be raised to the proper temperature. Now how can this be done in experiments of that nature?

But how is it possible to procure a large quantity of gas completely pure? and supposing it were possible, how can every particle of atmospheric air be excluded? In the last experiment, notwithstanding every precaution, 15 cubic inches (French) were admitted; and there is reason to believe, from the results, that the quantity was even considerably greater than this. But if any atmospheric air be admitted, there must be a residuum of azotic gas.

In the first experiment it had been previously ascertained that the oxygen gas employed contained $\frac{1}{12}$th of azotic, or about 233,05 grains; and the residuum contained at most 329,1 grains, or 96,05 grains more than what had for certain pre-existed in the gases.

In the second experiment, the azot in the residuum, amounted at most to $\frac{1}{6}$th of the oxygen gas employed. But the oxygen was procured from the black oxyd of manganese, which always yields a quantity of azot as well as of carbonic acid. It has been ascertained, that the azot, mixed with oxygen gas procured in that manner, often exceeds $\frac{1}{5}$th.

In the third experiment, the azotic gas found in the residuum amounted to 170,258 grains; and the quantity contained in the gases before combustion amounted to 151,178 grains: the surplus, therefore, amounted to 1908 grains.

Now, is it not much more probable that these inconsiderable quantities of azot, which, in the last experiment amounted to no more than $\frac{1}{311}$ part by weight of the whole gas employed, pre-existed in the gases before the combustion began, though their extreme minuteness prevented them from being discovered, than that they were formed during the experiment? a supposition which is directly contradicted by a great number of well ascertained facts.

As to the carbonic acid gas, which in the second experiment amounted to $\frac{1}{40}$th of the gases employed, it was evidently derived from the manganese, which almost constantly contains it. And when carbonic acid is once mixed with oxygen, it is difficult to separate it by means of lime water, except a large quantity be used, as Mr Cavendish has well observed. The reason is that oxygen gas has the property of dissolving carbonic acid, as Mr Welter has remarked†. Mr le Fevre de Gineau ascertained by experiment that 1870 cubic inches of oxygen gas which did not affect lime water, lost between $\frac{1}{13}$th and $\frac{1}{20}$th of its weight when washed in *milk of lime*(B).

† Ann. de Chim. iii. 91.

In a second experiment, he previously washed the two gases in milk of lime, and the residuum after combustion contained *no* carbonic acid gas. In a third experiment he washed only the oxygen, and obtained products equally free from carbonic acid. It is certain, then, that the *carbonic acid* is but an accidental mixture. As to the carbonic acid of the third experiment above related, which amounted only to $\frac{1}{131}$ part of the gases employed, the source of it has been already pointed out.

As

(B) Lime mixed with water till it is of the thickness of *milk*, or rather of *cream*.

Water.

As to the nitric acid, the quantity of nitre obtained in Mr Lavoisier's experiment, was 56 grains; which, according to Mr Kirwan's calculation, contain 30,156 grains of nitric acid, a quantity considerably less than $\frac{1}{100}$th part of the gases which disappeared. In the second experiment, the nitre obtained amounted to 80,7 grains; which according to Kirwan, contain 43,456 grains of nitric acid, or less than $\frac{1}{170}$th part of the gases consumed. Now, as nitric acid is composed of oxygen and azot, both of which were present in the vessel, it is easy to see how it was produced. And that its production is merely accidental, and not necessary, is evident from the last experiment in which no nitric acid was formed. It has been ascertained, indeed, that the formation of this acid during these experiments is quite arbitrary. It never is formed when the combustion goes on so slowly as to produce but little heat, as Seguin has ascertained*; because oxygen and azot do not combine, except at a high temperature. Nor is it formed even at a high temperature, as Mr Cavendish has proved, except there be a deficiency of hydrogen†; because hydrogen has a stronger affinity for oxygen than azot has.

* Ann. de Chim. ix. 48.

† Phil. Transf. 1784.

The quantity of water obtained in the first experiment was just 30 grains more than the weight of the gases which had disappeared: the water obtained in the second, was precisely 30 grains less than the gases consumed: and in the third experiment the difference was only 16 grains. The quantities of gas operated upon were large; in all of the experiments several thousand grains, and in one of them above 20 thousand. Now, how is it possible that the water produced should correspond so exactly with the gases consumed (for the differences are so small as not to merit any attention), unless the water had been formed by the combination of these gases?

Dr Priestley, however, who made a great many experiments on this subject, drew from them a very different conclusion; and thought he had proved, that during the combustion the two gases combined, and that the combination was nitric acid. This theory was adopted, or rather it was suggested by Mr Keir, who has supported it with a great deal of ingenuity†.

† Keir's Dictionary, art. Nitrous Acid.

Let us examine these experiments of Dr Priestley*, and see whether they warrant the conclusions he has drawn from them. The gases were exploded in vessels of copper. He found that the quantity of water obtained was always *less* than that of the gases which he had used. He obtained also a considerable quantity of nitric acid. In the experiment made on the largest quantity of the gases, and from which he draws his conclusions, the quantity of liquid obtained amounted to 442 grains. This liquid was examined by Mr Keir. It was of a green colour, 72 grains of brown oxyd of copper were deposited in it, and it contained a solution of nitrat of copper (copper combined with nitric acid). Mr Keir analysed this liquor: It consisted of pure water and nitrat of copper; and Mr Keir concluded that the nitric acid formed amounted to $\frac{1}{10}$th of the oxygen gas employed. Mr Berthollet, however, has shewn, that it could not have amounted to more than $\frac{1}{41}$ part§. Let us suppose, however, that it amounted to $\frac{1}{20}$. A quantity of oxygen and hydrogen gas has disappeared: What is become of them? They have combined, says Dr Priestley, and formed nitric acid. This nitric acid is only $\frac{1}{20}$ of their weight: Dr Priestley supposes, however, that it contains the whole oxygen and hydrogen that existed in these gases, and that all the rest of the weight of these gases was owing to a quantity of water which they had held in solution. Oxygen gas, then, (for we shall neglect the hydrogen, which Dr Priestley was not able to bring into view at all) is composed of one part of oxygen, and 19 of water. Where is the proof of this? Dr Priestley informs us, that he ascertained by experiment, that half the weight of carbonic acid gas was pure water. Supposing the experiment accurate (c), what can be concluded from it? Surely to bring it forward in proof, that oxygen gas consists of $\frac{19}{20}$ parts, or almost wholly of water, is downright trifling. It is impossible, therefore, from Dr Priestley's experiments, allowing his suppositions and conjectures their utmost force, to account for the disappearing of the two gases, or the appearance of the water, without admitting that this liquid was actually composed of oxygen and hydrogen. If we add to this, that no oxygen gas has hitherto (as far as we know at least) been procured absolutely free from some admixture of azot, and that his oxygen was always procured either from red oxyd of lead, or from black oxyd of manganese, or red oxyd of mercury, all of which substances yield a considerable proportion of azot; that in one experiment in which he observes that his oxygen was *very pure*, as it had been obtained from red oxyd of mercury, Mr Berthollet(d) ascertained by actually making the experiment, that part of the *very same* oxyd which Dr Priestley had employed yielded a gas, $\frac{1}{3}$d of which was azot*; if we add, that it has been proved beyond the possibility of doubt, and to Dr Priestley's own satisfaction, that nitric acid is composed of oxygen and azot—we shall find it no difficult matter to explain the origin of that acid in Dr Priestley's experiments: and if we recollect that in Seguin's experiment, upon a much larger scale indeed than Dr Priestley's, no nitric acid at all was formed, it will be impossible for us to believe for a moment that the compound formed by oxygen and hydrogen is nitric acid. Thus Dr Priestley's

* Phil. Transf. 1788.

§ Ann. de Chim. iii. 86.

* Ann. de Chim. iii. 94.

(c) He informs us that the carbonat of barytes does not yield its carbonic acid by means of heat (this Dr Hope has shewn to be a mistake); but that, when the vapours of water are passed over it, the gas is disengaged: and he determines by the water missing how much has combined with the gas. According to him, 60 grains of water enter into the composition of 147 grains of gas. But, besides assigning too small a weight to the gas, he forgot that its temperature was high, and that therefore it was capable of combining with much more water than in its usual state: nor did he ascertain whether more of this water was deposited on the vessels; and yet, by neglecting this precaution, Morveau has shewn that Mr Kirwan, in a similar experiment, obtained a result nine times greater than it ought to have been. *Encycl. Method. Chim.* art. *Air*.

(d) Mr Berthollet had supplied Dr Priestley with the oxyd. He had received two ounces of it from Mr Le Blanc, one of which he sent to Dr Priestley, and the other he reserved.

Water.

ley's experiments rather confirm than deftroy the theory of the compofition of water. We obtain from them, however, one curious piece of information, that the prefence of copper increafes the quantity of nitric acid formed. This curious fact, with a variety of others of a fimilar nature, will perhaps afterwards claim our attention; but at prefent we muft confider another theory which this phenomenon fuggefted, and which was firft propofed, we believe, by Mr de la Metherie (E).

Had the French chemifts, it has been faid, employed copper veffels in their experiments, they would have obtained three times the quantity of nitric acid. This acid, therefore, muft in their experiments have been decompofed, after having been formed, for want of a bafe to combine with; and the azot which appeared in the refiduum was owing to this decompofition. Hydrogen and oxygen, therefore, do not form water, but azot (F). Let us examine the experiment of Mr Le Fevre by this theory, as the quantity of azot was accurately afcertained. The nitric acid obtained amounted to 43,456 grains; three times that quantity is 130,368 grains, into which 23054 grains of gas were converted; which is impoffible. Or even fuppofing that the decompofition had been going on during the whole experiment, which is directly contrary to Dr Prieftley's experiments, and which there is no reafon whatever to fuppofe, but every reafon againft—ftill the whole azot amounted only to $\frac{1}{8}$th of the quantity of gas employed, allowing this gas to have contained no azot, which was evidently not the cafe. It appears, then, that this hypothefis, even if it could be admitted, would be totally inadequate to account for the phenomena. But if we were to examine it by Mr Seguin's experiment, its abfurdity would be ftill more glaring. In that experiment the azotic gas amounted to only 19 grains, and the quantity of gas which difappeared was 5946 grains: fo that were the hypothefis true, oxygen and hydrogen gas would confift of one part of oxygen and hydrogen and 312 parts of water; a fuppofition fo enormoufly abfurd, that it is impoffible for any perfon even to advance it.

It is impoffible, therefore, for the phenomena which attend the combuftion of oxygen and hydrogen gas to be accounted for in any way confiftent with common fenfe, except we fuppofe that water is formed.

349 Decompofition of water.

But the experiments above related, conclufive as they appear, are not the only ones by which this important fact has been afcertained. Meffrs Van Trooftwyk and Dieman, affifted by Mr Cuthbertfon, filled a fmall glafs tube, $\frac{1}{8}$th of an inch in diameter and 12 inches long, with diftilled water. One end of this tube was fealed hermetically; but, at the fame time, a fmall gold wire had been paffed through it. Another wire paffed thro' the open end of the tube, and could be fixed at greater or fmaller diftances from the firft wire. By means of these wires, they made a great number of electrical explofions pafs through the water. Bubbles of air appeared at every explofion, and collected at the top of the tube. When electric fparks were paffed through this air, it exploded and difappeared almoft completely. It muft therefore have confifted of a mixture of oxygen and hydrogen gas, and this gas muft have been formed by the decompofition of the water: for they had taken care to deprive the water before hand of all its air, and they ufed every precaution to prevent the accefs of atmofpherical air; and, befides, the quantity of gas produced did not diminifh, but rather increafed, by continuing to operate a number of times upon the fame water, which could not have been the cafe had it been merely air diffolved in water: nor would atmofpherical air have exploded and left only a very fmall refiduum, not more than $\frac{1}{80}$th part. They had taken care alfo to prove that the electric fpark did not contribute to form hydrogen gas; for on paffing it through fulphuric and nitric acids, the product was not hydrogen, but oxygen gas†.

† Journ. de Phyf. xxxv. 369.

Thefe experiments have been fince repeated by Dr Pearfon, affifted by Mr Cuthbertfon. He produced, by means of electricity, quantities of gas from water, amounting to 56,5488 cubes of $\frac{1}{10}$th of an inch each; on nitrous gas being added to which, it fuffered a diminution of bulk, and nitrous acid appeared to have been formed; It muft therefore have contained oxygen gas. When oxygen gas was added to the remainder, and an electric fpark paffed through it, a diminution took place precifely as when oxygen and hydrogen gas are mixed: It muft therefore have contained hydrogen. When an electric fpark was paffed through the gas thus produced from water, the gas difappeared, being no doubt converted into water*.

* Nicholfon's Journal, i. 242.

Such are the proofs by which the compound nature of water is afcertained; and we do not believe that any phyfical fact whatever can be produced which is fupported by more complete evidence.

But what becomes of the caloric which was previoufly combined with thefe gafes? It paffes through the veffel and is loft, and its weight is too inconfiderable to make any fenfible variation in the quantity of the product. If we were to judge from analogy, we would conclude, that the oxygen and hydrogen, while in the ftate of gas, are probably fomewhat lighter than after they are condenfed into water; but the difference, if it exifts, can fcarcely be fenfible.

350 Combination and affinity of water.

Water is capable of combining with a vaft number of fubftances: all bodies, indeed, which are foluble in water form a chemical union with it.

Its affinity for other bodies is doubtlefs various, tho' we have no method of afcertaining this difference, except

(E) Another favourite theory of La Metherie was, that gafes themfelves are deftitute of gravity, and that they owe their whole weight to the water with which they are combined: that during combuftion the water of the two gafes is depofited; and that the gafes themfelves efcape through the veffel and are loft. He complains bitterly that this theory had never been noticed by his antagonifts; as if it were neceffary to refute a hypothefis which is not fupported by any proof whatever, and as if it had not been proved that oxygen increafes the weight of metals, and confequently poffeffes gravity.

(F) This, as has been formerly explained, was the original opinion of Dr Prieftley; to which, though he does not explain himfelf fully, he evidently ftill adheres. There is then no difference between his theory and this, except what relates to the decompofition of the nitric acid.

Alcohol. cept in thofe bodies which have no affinity, or but a very fmall affinity, for each other; and it is only in a few even of thefe that this difference can be afcertained. If muriat of barytes be poured into lime water, the lime is precipitated, owing, no doubt, to the fuperior affinity of the muriat for water. Several very curious inftances of the affinity of different falts for water have been mentioned by Mr Quatremere Dijonval. When the folutions of nitrat of lime and nitrat of magnefia in water are mixed together, the nitrat of magnefia is precipitated. Muriat of magnefia is alfo precipitated by muriat of lime, and fulphat of magnefia by fulphat of lime: fo that it would feem that the falts which have magnefia for their bafis, have a lefs affinity for water than thofe whofe bafis is lime‡.

‡ *Journ. de Phyf.* xvii.

Water has the property of diffolving oxygen gas. If a quantity of common air be confined for fome time above water, the whole of the oxygen is abforbed, and nothing but the azotic gas remains. This fact was firft obferved by Mr Scheele.

Chap. II. *Of* Alcohol.

351 Difcovery of alcohol.

Wine has been known from the earlieft ages. The Scriptures inform us, that Noah planted a vineyard and drank wine; and the heathen writers are unanimous in afcribing the invention of this liquor to their earlieft kings and heroes. Beer, too, feems to have been difcovered at a very remote period. It was in common ufe in Egypt in the time of Herodotus*. Tacitus informs us, that it was the drink of the Germans†. Whether the ancients had any method of procuring ardent fpirits from thefe or any other liquors, does not appear. The Greeks and Romans feem to have been ignorant of ardent fpirits altogether, at leaft we can difcover no traces of any fuch liquor in their writings. But among the northern nations of Europe, intoxicating liquors were in ufe from the earlieft ages. Whether thefe liquors refemble the beer of the Germans, we do not know. It is certain at leaft, that the method of procuring ardent fpirits by diftillation was known in the dark ages; and it is more than probable that it was practifed in the north of Europe much earlier. They are mentioned exprefsly by Thaddæus, Villanovanus, and Lully‡.

* Lib. ii. n. 77.

† *De Morib. Germ.* ch. xxiii.

‡ *Berg.* 4th. art. ii. 4.

352 Method of procuring it.

Ardent fpirits, fuch as brandy, for inftance, rum, and whifky, confift almoft entirely of three ingredients, water, *alcohol* or *fpirit of wine*, to which they owe their ftrength, and a fmall quantity of a peculiar oil, to which they owe their flavour.

The alcohol may be feparated from the water by the following procefs. Into the whifky or other ardent fpirit a quantity of potafs is to be put, which has juft immediately before been expofed for about half an hour in a crucible to a red heat, in order to deprive it of moifture. Potafs in this ftate has a ftrong attraction for water; it accordingly combines with the water of the fpirit, and the folution of potafs thus formed finks to the bottom of the veffel, and the alcohol, which is lighter, fwims over it, and may eafily be decanted off; or, what is perhaps better, the folution of potafs may be drawn off from below it by means of a ftop-cock placed at the bottom of the veffel. It is impoffible to fix the quantity of potafs which ought to be ufed, becaufe that muft depend entirely on the ftrength of the fpirit; but it is of no confequence though the potafs employed be a little more than enough. The alcohol thus obtained contains a little potafs diffolved, which may be feparated by diftilling it in a water bath with a very fmall heat. The alcohol paffes over, and leaves the potafs behind. It is proper not to diftil to drynefs. This procefs is firft mentioned by Lully. Alcohol may be obtained in the fame manner from wine and from beer; which liquids owe their ftrength entirely to the quantity of that fubftance which they contain.

353 Its properties.

Alcohol is a tranfparent liquor, colourlefs like water, of a pleafant fmell, and a ftrong penetrating agreeable tafte.

It is exceedingly fluid, and has never been frozen, though it has been expofed to a cold fo great that the thermometer ftood at —69°*.

* At *Hudfon's Bay*.

Its fpecific gravity when pure is about 0,800.

It is exceedingly volatile, boiling at the temperature of 176°; in which heat it affumes the form of an elaftic fluid, capable of refifting the preffure of the atmofphere, but which condenfes again into alcohol when that temperature is reduced. In a vacuum it boils at 56°, and exhibits the fame phenomena: fo that were it not for the preffure of the atmofphere, alcohol would always exift in the form of an elaftic fluid, as tranfparent and invifible as common air. This fubject was firft examined with attention by Mr Lavoifier†. The fact, however, had been known long before.

† *Journ. de Phyf.* 1785.

Alcohol has a ftrong affinity for water, and is mifcible with it in all proportions. The fpecific gravity of all the different mixtures, in every proportion, and in all the different degrees of temperature, from 32 to 100°, has been lately afcertained with great accuracy by Sir Charles Blagden and Mr Gilpin. But as a very full account of thefe interefting experiments has been given in the Encyclopædia in the article Spirituous *Liquors*, we do not think ourfelves at liberty to repeat it here.

354 Opinions concerning its compofition.

If alcohol be fet on fire, it burns all away with a blue flame, without leaving any refiduum. Boerhaave obferved, that when the vapour which efcapes during this combuftion is collected in proper veffels, it is found to confift of nothing but water. Junker had made the fame remark: and Dr Black fufpected, from his own obfervations, that the quantity of water obtained, if properly collected, exceeded the weight of the alcohol confumed. This obfervation was confirmed by Lavoifier; who found that the water produced during the combuftion of alcohol exceeded the alcohol confumed by about $\frac{1}{8}$th part*.

* *Mem. Par.* 1781. p. 493.

Different opinions were entertained by chemifts about the nature of alcohol. Stahl thought that it was compofed of a very light oil, united by means of an acid to a quantity of water. According to Junker, it was compofed of phlogifton, combined with water by means of an acid. Cartheufer, on the other hand, affirmed, that it contained no acid, and that it was nothing elfe than pure phlogifton and water. But thefe hypothefes were mere affertions fupported by no proof whatever. Lavoifier was the firft who attempted to analyfe it.

355 Lavoifier's analyfis.

He fet fire to a quantity of alcohol in clofe veffels, by means of the following apparatus: BCDE (fig. 6.) is a veffel of marble filled with mercury. A is a ftrong glafs veffel placed over it, filled with common air, and capable of containing about 15 pints (French). Into this veffel is put the lamp R filled with alcohol, the

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weight of which has been exactly determined. On the wick of the lamp is put a small particle of phosphorus. The mercury is drawn up by suction to the height IH. This glass communicates by means of the pipe LK with another glass vessel S filled with oxygen gas, and placed over a vessel of water T. This communication may be shut up at pleasure by means of the stop-cock M.

Things being thus disposed, a crooked red hot iron wire is thrust up through the mercury, and made to touch the phosphorus. This instantly kindles the wick, and the alcohol burns. As soon as the flame begins to grow dim, the stop-cock is turned, and a communication opened between the vessels S and A; a quantity of oxygen gas rushes in, and restores the brightness of the flame. By repeating this occasionally, the alcohol may be kept burning for some time. It goes out, however, at last, notwithstanding the admission of oxygen gas.

The result of this experiment, which Mr Lavoisier repeated a great number of times, was as follows:

The quantity of alcohol consumed amounted to 76,7083 grains troy.

The oxygen gas consumed amounted to 266,82 cubic inches, and weighed 90,506 grains troy.

The whole weight of the substances consumed, therefore, amounted to 167,2143 grains.

After the combustion, there were found in the glass vessel 115,41 cubic inches of carbonic acid gas, the weight of which was 78,1192 grains troy. There was likewise found a considerable quantity of water in the vessel, but it was not possible to collect and weigh it. Mr Lavoisier, however, estimated its weight at 89,0951 grains: as he concluded, with reason, that the whole of the substances employed were still in the vessel. Now the whole contents of the vessel consisted of carbonic acid gas and water; therefore the carbonic acid gas and water together must be equal to the oxygen gas and alcohol which had been consumed.

But 78,1192 grains of carbonic acid gas contain, according to Mr Lavoisier's calculation†, 55,279 grains of oxygen: 90,506 grains, however, of oxygen gas had disappeared; therefore 35,227 grains must have been employed in forming water.

† *Mem. Par.* 1781.

35,227 grains of oxygen gas require, in order to form water, 6,038 grains of hydrogen gas; and the quantity of water formed by this combination is 41,265 grains. But there were found 89,095 grains of water in the glass vessel; therefore 47,83 grains of water must have existed ready formed in the alcohol.

It follows from all these data, that the 76,7083 grains of alcohol, consumed during the combustion, were composed of

22,840 Carbon,
6,038 Hydrogen,
47,830 Water.

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76,7 *.

* *Ibid.* 1784.

Such were the consequences which Mr Lavoisier drew from his analysis. He acknowledged, however, that there were two sources of uncertainty, which rendered his conclusions not altogether to be depended upon. The first was, that he had no method of determining the quantity of alcohol consumed, except by the difference of weight in the lamp before and after combustion; and that therefore a quantity might have evaporated without combustion, which, however, would be taken into the sum of the alcohol consumed. But this error could not have been great; for if a considerable quantity of alcohol had existed in the state of vapour in the vessel, an explosion would certainly have taken place. The other source of error was, that the quantity of water was not known by actual weight, but by calculation.

356 Ingredients of alcohol.

To this we may add, that Mr Lavoisier was not warranted to conclude from his experiment, that the water found in the vessel, which had not been formed by the oxygen gas used, had existed in the alcohol in the state of water: he was intitled to conclude from his data, that the ingredients of that water existed in the alcohol before combustion; but not that they were actually combined in the state of water, because that combination might have taken place, and in all probability did partly take place, during the combustion. It follows, therefore, from Mr Lavoisier's experiments, that alcohol, supposing he used it perfectly pure, which is not probable, is composed of

0,2988 parts carbon,
0,1840 parts hydrogen,
0,5172 parts oxygen.

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1,0000

But it gives us no information whatever of the manner in which these ingredients are combined. That alcohol contains oxygen, has been proved by a very ingenious set of experiments performed by Messrs Fourcroy and Vauquelin. When equal parts of alcohol and sulphuric acid are mixed together, a quantity of caloric is disengaged, sufficient to elevate the temperature of the mixture to 190°. Bubbles of air are emitted, the liquor becomes turbid, assumes an opal colour, and at the end of a few days a deep red. When examined, the sulphuric acid is found to have suffered no change; but the alcohol is decomposed, partly converted into water and partly into ether, a substance which we shall describe immediately. Now, it is evident that the alcohol could not have been converted into water unless it had contained oxygen*.

* *Nicholson's Journal*, i. 391.

When equal parts of sulphuric acid and alcohol are mixed together and heat applied, the mixture boils at 208°, and a liquid equal to half the weight of the alcohol comes over into the receiver. This liquid is *ether*.

357 Ether.

Ether is obscurely hinted at in some of the older chemical authors, but little attention was paid to it till a paper appeared in the Philosophical Transactions for 1730, written by a German, who called himself *Frobenius* (G), containing a number of experiments on it. In this paper it first received the name of *ether*.

358 Its properties.

Ether is limpid and colourless, of a very fragrant smell, and a hot pungent taste. Its specific gravity is 0,7394. It is exceedingly volatile, boiling in the open air at 98° and in a vacuum at —20°. Were it not therefore for the pressure of the atmosphere, it would always exist in a gaseous state. Ether unites with water in the proportion of ten parts of the latter to one of the

(G) The name was supposed to have been feigned.

Alcohol.

the former.* It is exceedingly inflammable, and when kindled in the ftate of vapour burns with rapidity, or rather explodes, if it be mixed with oxygen gas.

* Count de Lauraguais.

359 Theory of its formation.

Chemifts entertained various opinions refpecting the nature of ether. Macquer fuppofed, that it was merely alcohol deprived by the acid of all its water. But it was generally believed that the acid entered partly into its compofition. Since the nature of acids has become better known, a great number of philofophers have fuppofed that ether is merely alcohol combined with a quantity of oxygen furnifhed by the acid. The real compofition of this fingular fubftance has been lately afcertained by the experiments of Fourcroy and Vauquelin.

" A combination (fay they) of two parts of fulphuric acid and one part of alcohol elevates the temperature to 201°, becomes immediately of a deep red colour, which changes to black a few days afterwards, and emits a fmell perceptibly ethereal.

" When we carefully obferve what happens in the combination of equal parts of alcohol and concentrated fulphuric acid expofed to the action of caloric in a proper apparatus, the following phenomena are feen :

" 1. When the temperature is elevated to 208°, the fluid boils, and emits a vapour which becomes condenfed by cold into a colourlefs, light, and odorant liquor, which from its properties has received the name of *ether*. If the operation be properly conducted, no permanent gas is difengaged until about half the alcohol has paffed over in the form of ether. Until this period there paffes abfolutely nothing but ether and a fmall portion of water, without mixture of fulphurous or of carbonic acid.

" 2. If the receiver be changed as foon as the fulphurous acid manifefts itfelf, it is obferved that no more ether is formed, but the fweet oil of wine, water, and acetous acid, without the difengagement hitherto of a fingle bubble of carbonic acid gas. When the fulphuric acid conftitutes about four-fifths of the mafs which remains in the retort, an inflammable gas is difengaged, which has the fmell of ether, and burns with a white oily flame. This is what the Dutch chemifts have called *carbonated hydrogen gas*, or *olefiant gas*, becaufe when mixed with the oxy-muriatic acid it forms oil. At this period the temperature of the fluid contained in the retort is elevated to 230° or 234°.

" 3 When the fweet oil of wine ceafes to flow, if the receiver be again changed, it is found that nothing more paffes but fulphurous acid, water, carbonic acid gas ; and that the refiduum in the retort is a black mafs, confifting for the moft part of fulphuric acid thickened by carbon.

" The feries of phenomena here expofed will juftify the following general inductions :

" 1. A fmall quantity of ether is formed fpontaneoufly and without the affiftance of heat, by the combination of two parts of concentrated fulphuric acid and one part of alcohol.

" 2. As foon as ether is formed, there is a production of water at the fame time ; and while the firft of thefe compofitions takes place, the fulphuric acid undergoes no change in its intimate nature.

" 3. As foon as the fulphurous acid appears, no more ether is formed, or at leaft very little ; but then there paffes the fweet oil of wine, together with water and acetous acid.

" 4. The fweet oil of wine having ceafed to come over, nothing further is obtained but the fulphurous and carbonic acids, and at laft fulphur, if the diftillation be carried to drynefs.

Alcohol.

" The operation of ether is therefore naturally divided into three periods : the firft, in which a fmall quantity of ether and water are formed without the affiftance of heat ; the fecond, in which the whole of the ether which can be obtained is difengaged without the accompaniment of fulphurous acid ; and the third, in which the fweet oil of wine, the acetous acid, the fulphurous acid, and the carbonic acid, are afforded. The three ftages have no circumftance common to all, but the continual formation of water, which takes place during the whole of the operation.

" The ether which is formed without the affiftance of caloric, and the carbon which is feparated without decompofition of the fulphuric acid, prove that this acid acts on alcohol in a manner totally different from what has hitherto been fuppofed. It cannot, in fact, be affirmed, that the acid is altered by the carbon, becaufe daily experience fhews that no fenfible attraction takes place between thefe two bodies in the cold ; neither can it be affected by the hydrogen ; for in that cafe fulphurous acid would have been formed, of which it is known that no trace is exhibited during this firft period. We muft therefore have recourfe to another fpecies of action, namely, the powerful attraction exercifed by the fulphuric acid upon water. It is this which determines the union of the principles which exift in the alcohol, and with which the concentrated acid is in contact : but this action is very limited if the acid be fmall in quantity ; for an equation of affinity is foon eftablifhed, the effect of which is to maintain the mixture in a ftate of repofe.

" Since it is proved that ether is formed in the cold by the mixture of any quantities of alcohol and fulphuric acid, it is evident that a mafs of alcohol might be completely changed into ether and vegetable acid by ufing a fufficient abundance of fulphuric acid. It is equally evident that the fulphuric acid would not by this means undergo any other change than that of being diluted with a certain quantity of water. This obfervation proves, that alcohol contains oxygen, becaufe water cannot exift without this principle, which muft be afforded by the alcohol only, fince the fulphuric acid fuffers no decompofition.

" We muft not, however, imagine, from thefe facts, that ether is alcohol minus oxygen and hydrogen. Its properties alone would contradict this ; for a quantity of carbon proportionally greater than that of the hydrogen is at the fame time feparated. It may, in fact, be conceived, that the oxygen, which in this cafe combines with the hydrogen to form water, not only faturated that hydrogen in the alcohol, but likewife the carbon. So that, inftead of confidering ether as alcohol minus hydrogen and oxygen, we muft, by keeping an account of the precipitated carbon and the fmall quantity of hydrogen contained in the water which is formed, regard it as alcohol plus hydrogen and oxygen.

" The foregoing are the effects produced by a combination of alcohol and fulphuric acid, fpontaneoufly produced without foreign heat. Let us in the next place, obferve, how this combination is effected when caloric is added. The phenomena are then very different, though fome of the refults are the fame.

" In

Alcohol.

"In the first place we must observe that a combination of sulphuric acid and alcohol in equal parts does not boil at less than 207 degrees of temperature, while that of alcohol alone boils at 176. Now since ebullition does not take place till the higher temperature, it is clear that the alcohol is retained by the affinity of the sulphuric acid, which fixes it more considerably. Let us also consider, that organic bodies, or their immediate products, exposed to a lively brisk heat, without the possibility of escaping speedily enough from its action, suffer a partial or total decomposition, according to the degree of temperature. Alcohol undergoes this last alteration when passed through an ignited tube of porcelain. By this sudden decomposition it is converted into water, carbonic acid and carbon. The reason, therefore, why alcohol is not decomposed when it is submitted alone to heat in the ordinary apparatus for distillation, is, that the temperature at which it rises in vapours is not capable of effecting the separation of its principles; but when it is fixed by the sulphuric acid or any other body, the elevated temperature it undergoes, without the possibility of disengagement from its combination, is sufficient to effect a commencement of decomposition, in which ether and water are formed, and carbon is deposited. Nothing more therefore happens to the alcohol in these circumstances than what takes place in the distillation of every other vegetable matter in which water, oil, acid and coal are afforded.

"Hence it may be conceived that the nature of the products of the decomposition of alcohol must vary according to the different degrees of heat; and this explains why at a certain period no more ether is formed but the sweet oil of wine and acetous acid. In fact, when the greatest quantity of the alcohol has been changed into ether, the mixture becomes more dense, and the heat which it acquires previous to ebullition is more considerable. The affinity of the acid for alcohol being increased, the principles of this acid become separated; so that, on the one hand, its oxygen seizes the hydrogen and forms much water, which is gradually volatilized; while, on the other, the ether retaining a greater quantity of carbon, with which at that temperature it can rise, affords the sweet oil of wine. This last ought therefore to be considered as an ether containing an extraordinary portion of carbon, which gives it more density, less volatility, and a lemon yellow colour.

"During the formation of the sweet oil of wine, the quantity of carbon which is precipitated is no longer in the same proportion as during the formation of ether.

"What we have here stated concerning the manner in which ether is formed by the simultaneous action of the sulphuric acid and heat, appears so conformable to truth, that nearly the same effects may be produced by a caustic fixed alkali. In this case also a kind of ether and a sweet oil of wine are volatilized, and coal is precipitated. It is therefore only by fixing the alcohol that the sulphuric acid permits the caloric to operate a sort of decomposition. It may also be urged as a proof of this assertion, that the sulphuric acid, which has served to make ether as far as the period at which the sweet oil of wine begins to appear, is capable of saturating the same quantity of alkali as before its mixture with the alcohol‡."

‡ Nicholson's Jour. i. 391.

Ether may also be obtained by means of several other acids. The different liquids thus formed are distinguished by prefixing the name of the acid used in the process. Thus the ether above described is called *sulphuric ether*; that obtained by means of nitric acid, *nitric ether*, and so on. There are several minute shades of difference between these various ethers, which have not yet been properly enquired into.

360 Substances soluble in alcohol.

Alcohol is capable of dissolving a great many bodies. A considerable number of these, with the quantities soluble, is exhibited in the following tables.

I. *Substances dissolved in large quantities.*

Names of the Substances.	Temperature.	240 parts of alcohol dissolve.
Nitrat of cobalt	54,5°	240 parts
copper	54,5	240
alumina	54,5	240
magnesia	180,5	694
Muriat of zinc	54,5	240
alumina	54,5	240
magnesia	180,5	1313
iron	180,5	240
copper	180,5	240
Acetite of lead	113	
copper*		
Benzoic acid	135,5	
Sulphat of magnesia		
Nitrat of zinc decomposed		
iron decomposed		
bismuth decomposed		

* Withering, Phil. Trans. lxxii. 336.

II. *Substances dissolved in small Quantities.*

Names of the Substances.	240 parts of alcohol at the boiling temperature dissolve.
Muriat of lime	240 parts
Nitrat of ammonia	214
Oxy-muriat of mercury	212
Succinic acid	177
Acetite of soda	112
Nitrat of silver	100
Refined sugar	59
Boracic acid	48
Nitrat of soda	23
Acetite of copper	18
Muriat of ammonia	17
Arseniat of potass	9
Acidulated oxalat of potass	7
Nitrat of potass	5
Muriat of potass	5
Arseniat of soda	4
Barytes	
Strontites	
White oxyd of arsenic	3
Tartat of potass	1
Phosphorus	
Nitrat of lead*	
lime*	
Muriat of mercury†	
Carbonat of ammonia*	

* Id. ibid.
† Macquer, ibid.

III. *Subſtances inſoluble with Alcohol.*

Sugar of milk,	Sulphat of ſoda,
Borax,	magneſia,
Tartar,	Sulphite of ſoda,
Alum,	Tartrite of ſoda and
Sulphat of ammonia,	potaſs,
lime,	Phoſphoric acid,
barytes*,	Nitrat of lead,
iron (green),	mercury,
copper,	Muriat of lead,
ſilver,	ſilver‡,
mercury,	Common ſalt,
zinc,	Carbonat of potaſs,
potaſs,	ſoda.

* *Withering, Phil. Tranſ.* lxxii. 336.

‡ *Macquer, ibid.*

Theſe have been chiefly borrowed from tables which Mr de Morveau publiſhed in the *Journal de Phyſique* July 1785, and which were drawn up for the moſt part from the experiments deſcribed in Wenzel's Treatiſe on Affinities.

361 Its affinities.

The affinities of alcohol are very imperfectly known. Thoſe ſtated by Bergman are as follows:

Water,
Ether,
Volatile oil,
Sulphurets of alkalies.

Chap. III. *Of* Oils.

362 Diſcovery of oil.

Oil, which is of ſuch extenſive utility in the arts, was known at a very remote period. It is mentioned in Geneſis, and during the time of Abraham was even uſed in lamps*. The olive was very early cultivated, and oil extracted from it in Egypt. Cecrops brought it from Sais, a town in Lower Egypt, where it had been cultivated from time immemorial, and taught the Athenians to extract oil from it. In this manner the uſe of oil became known in Europe. But the Greeks ſeem to have been ignorant of the method of procuring light by means of lamps till after the ſiege of Troy; at leaſt Homer never mentions them, and conſtantly deſcribes his heroes as lighted by torches of wood.

* *Gen.* xv. 17.

† *Herodot.* lib. ii. 59, and 62.

Oils are divided into two claſſes, *Fixed* and *Volatile;* each of which is diſtinguiſhed by peculiar properties.

363 Fixed oils.

I. The fixed oils, called alſo *fat* or *expreſſed* oils, are numerous, and are obtained, partly from animals and partly from vegetables by ſimple expreſſion. As inſtances, we ſhall mention whale oil or train oil, obtained from the blubber of the whale; olive oil, obtained from the fruit of the olive; lintſeed oil, and almond oil, obtained from lintſeed and almond kernels. Fixed oils may alſo be obtained from poppy ſeeds, hemp ſeeds, beech maſt, and many other vegetable ſubſtances.

All theſe oils differ from each other in ſeveral particulars, but they alſo poſſeſs many particulars in common. Whether the oily principle in all the fixed oils is the ſame, and whether they owe their differences to accidental ingredients, is not yet completely aſcertained, as no proper analyſis has hitherto been made; but it is exceedingly probable, as all the oils hitherto tried have been found to yield the ſame products. In the preſent ſtate of our knowledge, it would be uſeleſs to give a particular deſcription of all the fixed oils, as the differences between them have not even been accurately aſcertained. We ſhall content ourſelves, therefore, with giving the characters which diſtinguiſh fixed oils in general, and an analyſis of one oil, by way of ſpecimen.

364 Their properties.

Fixed oils are inſoluble in alcohol, which diſtinguiſhes them from volatile oils. They are alſo inſoluble in water.

They have an unctuous feel, are tranſparent while fluid, are deſtitute of ſmell, and have a mild inſipid kind of taſte.

They are all ſuſceptible of becoming ſolid by expoſure to a ſufficient degree of cold. Olive oil and almond oil freeze at 10½ degrees‡.

‡ *Chaptal's Chemiſtry, Engliſh tranſ.* iii. 43.

They are capable of being converted into vapour by heat: but require for that purpoſe a temperature conſiderably ſuperior to that of boiling water. Olive oil boils at 600°, and moſt of the fixed oils hitherto tried require nearly the ſame degree of heat.

When in the ſtate of vapour, they take fire on the approach of an ignited body, and burn with a yellowiſh white flame. It is upon this principle that candles and lamps burn. The tallow or oil is firſt converted into the ſtate of vapour in the wick, it then takes fire, and ſupplies a ſufficient quantity of heat to convert more oil into vapour, and this proceſs goes on while any oil remains. The wick is neceſſary to preſent a ſufficiently ſmall quantity of oil at once for the heat to act upon. If the heat were ſufficiently great to keep the whole oil at the temperature of 600°, no wick would be neceſſary, as is obvious from oil catching fire ſpontaneouſly when it has been raiſed to that temperature.

365 Analyſis of olive oil.

Mr Lavoiſier analyſed olive oil, by burning it in preciſely the ſame apparatus as that which he employed for analyſing alcohol.

The quantity of oil conſumed amounted to 15,79 grains troy.

The quantity of oxygen gas amounted to 50,86 gr. troy. The whole amount therefore of the ſubſtances conſumed during the combuſtion is 66,65 grains troy.

The carbonic acid obtained amounted to 44.50 gr. There was alſo a conſiderable quantity of water, the weight of which could not be accurately aſcertained: but as the whole of the ſubſtances conſumed were converted into carbonic acid gas and water, it is evident, that if the weight of the carbonic acid be ſubtracted from the weight of theſe ſubſtances, there muſt remain preciſely the weight of the water. Mr Lavoiſier, accordingly concluded, by calculation, that the weight of the water was 22,15 grains. Now the quantity of oxygen in 44,50 grains of carbonic acid gas is 32,04 grains, and the oxygen in 22,15 grains of water is 18,82 grains: both of which taken together amount to 50,86 grains, preciſely the weight of the oxygen gas employed. There does not appear therefore to be any oxygen in olive oil.

The quantity of carbon in 44,50 grains of carbonic acid gas is 12,47 grains; and the quantity of hydrogen in 22,15 grains of water is 3,32 grains; both of which, when taken together, amount to 15,79 grains, which is the weight of the oil conſumed.

It follows, therefore, from this analyſis, that 15,79 grains of olive oil are compoſed of

12,47 Carbon,
3,32 Hydrogen.

Olive

Oils.

Olive oil therefore is compoſed of about

79 Carbon,
21 Hydrogen.

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100*

* Mem. Par. 1784. and Jour. de Phyſ. for 1787, July.

In what manner theſe ſubſtances are combined, cannot be learned from this analyſis. Whether they combine directly, and ſaturate each other in that proportion, as is moſt probable—or whether the hydrogen is combined previouſly with a part of the carbon, and that compound combining with a certain quantity of carbon, forms oil, is altogether uncertain. Yet theſe queſtions are of the utmoſt importance; and till the method of ſolving them be diſcovered, we never can acquire any preciſe ideas about the conſtituent parts of a great number of ſubſtances, which, though formed ultimately of the ſame ingredients, differ very much in their properties from one another; as wax and oil; alcohol, ſugar, and ether.

366 Rancidity.

When fixed oils are expoſed to the atmoſphere, they become thick, acquire a brown colour, and a peculiarly unpleaſant ſmell: they are then ſaid to be *rancid*. When oil is poured upon water, ſo as to form a thin layer on its ſurface, and is in that manner expoſed to the atmoſphere, theſe changes are produced much ſooner, the oil becomes thicker, and aſſumes an appearance very much reſembling wax. Berthollet, who firſt examined theſe phenomena with attention, aſcribed them to the action of light: but Sennebier obſerved, that no ſuch change was produced on the oil though ever ſo long expoſed to the light, provided atmoſpherical air was excluded; but that it took place on the admiſſion of oxygen gas, whether the oil was expoſed to the light or not †. It cannot be doubted, then, that it is owing to the combination of oxygen. All ſubſtances that are capable of ſupplying that principle, the metallic oxyds, for inſtance, and ſeveral of the acids, produce the ſame effect upon oils; and it is a known fact, that oil is capable of reducing many of the metallic oxyds to the metallic ſtate, and conſequently that it has a ſtronger affinity for oxygen.

† Ann. de Chim. xi. 89.

Mr Chaptal has ſuppoſed that oils become rancid merely becauſe they contain a quantity of mucilage, with which the oxygen combines, and that when oxygen combines with fixed oils, it produces a different effect, converting them into what is called *drying oils*.

It is certain that oils contain a quantity of mucilage; but ſome change is evidently produced on the oils themſelves by rancidity; for no agitation in water is capable of reſtoring them to their former ſtate, although water deprives them of their mucilage. *Drying oils*, ſo called

367 Drying oils.

becauſe they are capable of *drying* completely when ſpread out, a property which renders them uſeful in painting, ſeem, as Sennebier obſerves, to be completely deprived of mucilage; for, in order to render an oil drying, it muſt be boiled, which evaporates or decompoſes all the mucilage: they ſeem alſo to loſe part of their hydrogen ‡.

‡ Berthollet.

368 Fixed oils diſſolve ſulphur.

Fixed oils are capable of diſſolving ſulphur at their boiling temperature. The ſolution is very fetid, owing to a partial decompoſition of the oil. Hydrogen gas flies off, having a quantity of ſulphur diſſolved in it. When the ſolution cools, the ſulphur cryſtallizes.

369 And phoſphorus.

Fixed oils diſſolve phoſphorus. The ſolution is luminous, from the ſlow combuſtion of the phoſphorus.

Fixed oils are capable of combining with many of the metallic oxyds. The compounds are called *metallic ſoaps*. Several of the oxyds are decompoſed by being boiled in oils.

Fixed oils combine alſo with the alkaline earths and with alumina. The compounds are called *earthy ſoaps*.

370 Their affinities.

The affinities of the oils are as follows.

Lime,	Nitric acid,
Barytes,	Muriatic,
Fixed alkalies,	Sulphurous,
Magneſia,	Sulphuric,
Ammonia,	Acetous,
Oxyd of mercury,	Sulphur,
Other metallic oxyds (H),	Phoſphorus (I)
Alumina.	

371 Volatile oils.

II VOLATILE OILS, called alſo *eſſential oils*, are all obtained from vegetables. They have a ſtrong aromatic ſmell, and a pungent acrid taſte. They are ſo volatile, that they may be diſtilled by the heat of boiling water. They are ſoluble in alcohol, but not in water. They evaporate on the application of heat, without leaving any ſtain behind them, which is not the caſe with the fixed oils. By this teſt, accordingly, it is eaſy to diſcover whether they have been adulterated with any of the fixed oils. Let a drop of the volatile oil fall upon a ſheet of writing paper, and then apply a gentle heat to it. If it evaporates without leaving any ſtain upon the paper, the oil is pure; but if it leaves a ſtain, it has been contaminated with ſome fixed oil or other.

Volatile oils are very numerous, and differ from one another, in fluidity and weight, in their freezing point, and in ſeveral other particulars. Little attention has been paid to the greateſt part of them, becauſe few of them have been found of any uſe. The principal quality for which they are valued is their odour. Some of them are obtained by expreſſion, as oil of bergamot, lemons, oranges; others by diſtillation, as oil of pepper-mint, thyme, lavender, &c. It would be uſeleſs, even if it were poſſible, to give a particular deſcription of all the volatile oils.

372 Their properties.

They are more inflammable than the fixed oils; a quality which they owe to their volatility. As far as experiments have hitherto been made, they ſeem to conſiſt of carbon and hydrogen; but nothing is known concerning the proportions of theſe ingredients. They thicken when expoſed to the air, probably by combining with oxygen, and form *reſins* (K).

When

(H) Their order not well aſcertained.

(I) The firſt column was aſcertained by Berthollet. The laſt is to be conſidered as unconnected with the firſt. On account of the affinity of theſe two claſſes of bodies for each other, it has not been poſſible to diſcover which of them has the greateſt affinity for oil.

(K) Reſins are concrete vegetable juices; the diſtinguiſhing property of which is inſolubility in water and ſolubility in alcohol. *Common reſin*, or *roſin*, from which they derive their name, is one of them, and ſealing wax conſiſts almoſt entirely of another.

Alkalies.

When expofed to cold, or when kept for a long time, fome of them depofite cryftals refembling the acid of benzoin (L).

They diffolve fulphur, and form what have been called *balfams of fulphur*.

They are capable of combining with moft of the fubftances that unite with fixed oils. Their affinities, which certainly differ from thofe of fixed oils, have not yet been properly afcertained.

CHAP. IV. *Of* ALKALIES.

373 Properties of alkalies.

SUBSTANCES poffeffed of the following properties are called *alkalies*:

1. Incombuftible.
2. Capable of converting vegetable blues to a green.
3. A hot cauftic tafte.
4. Very foluble in water, even when combined with carbonic acid.

There are three alkalies, *potafs*, *foda*, *and ammonia*. The two firft are called *fixed* alkalies, becaufe a very violent heat is neceffary to volatilize them; the laft is called *volatile* alkali, becaufe it very eafily affumes a gafeous form, and is confequently diffipated by a very moderate degree of heat.

SECT. I. *Of Potafs.*

374 Method of procuring potafs.

IF a fufficient quantity of wood be burnt to afhes, and thefe afhes be afterwards wafhed repeatedly with water till it comes off free from any tafte, and if this liquid be filtrated and evaporated to drynefs, the fubftance which remains behind is *potafs*; not, however, in a ftate of purity, for it is contaminated with feveral other fubftances; but fufficiently pure to exhibit many of its properties. In this ftate, it occurs in commerce under the name of *potafh*. It may be purified confiderably, by putting it in a crucible, keeping it red hot for fome time; then diffolving it in water, filtrating it, and evaporating it again to drynefs. By the following method it may be obtained nearly pure: Mix together equal quantities of nitre and carbon, and put them by little and little into a red hot crucible. They burn with a vivid flame, and leave behind them a quantity of potafs. This is to be diffolved in water, filtrated, and evaporated to drynefs. Or potafs may be obtained by burning tartar wrapt up in brown paper and placed in a crucible (M).

The potafs procured by thefe laft proceffes is exceedingly white; is it not, however, quite pure; for it is combined with a fubftance which blunts all its properties confiderably. This fubftance is carbonic acid gas; from which it may be feparated by diffolving it, and mixing with it an equal quantity of lime made into a pafte with water. The lime has a greater affinity for carbonic acid gas, and therefore combines with it; and the pure potafs remains diffolved in the water, and may be feparated from the lime by filtrating the mixture. This procefs, however, muft be performed in clofe veffels; for there is a little carbonic acid gas in the atmofphere, which would again combine with the potafs if it were allowed to ftand expofed to the air.

It is then to be evaporated till a thick pellicle appears on its furface, and afterwards allowed to cool; and all the cryftals which have formed are to be feparated, for they confift of foreign falts. The evaporation is then to be continued in an iron pot; and, during the procefs, the pellicle which forms on the furface is to be carefully taken off with an iron fkimmer. When no more pellicle appears, and when the matter ceafes to boil, it is to be taken off the fire, and muft be conftantly agitated while cooling with an iron fpatula. It is then to be diffolved in double its own weight of cold water. This folution is to be filtered and evaporated in a glafs retort till it begins to depofite regular cryftals. If the mafs confolidates ever fo little by cooling, a fmall quantity of water is to be added, and it muft be heated again. When a fufficient number of cryftals have been formed, the liquor which fwims over them, and which has affumed a very brown colour, muft be decanted off, and kept in a well-clofed bottle till the brown matter has fubfided, and then it may be evaporated as before, and more cryftals obtained. The cryftals may then be diffolved in pure water. By this procefs, which was invented by Mr Lowitz of Peterfburgh,* potafs may be obtained in a ftate of the greateft purity. The fhape of its cryftals is very different, according to the way in which they have been produced. When allowed to form in the cold, they are octahedrons in groups, and contain 0.43 of water: When formed by evaporation on the fire, they affume the figure of very thin tranfparent blades of extraordinary magnitude, which, by an affemblage of lines croffing each other in prodigious numbers, prefent an aggregate of cells or cavities, commonly fo very clofe, that the veffel may be inverted without lofing one drop of the liquid which it contains †.

* *Nicholfon*, i. 164.

† *Ibid.*

Pure potafs is fo exceedingly corrofive, that when applied to any part of the body, it deftroys it almoft inftantaneoufly. On account of this property, it has been called *cauftic*, and is often ufed by furgeons under the name of the *potential cautery*, to open abfceffes, and deftroy ufelefs or hurtful excrefcences.

375 Black's difcovery of the caufe of its caufticity.

As potafs is never obtained at firft in a ftate of purity, but always combined with carbonic acid, it was long before chemifts underftood to what the changes produced upon it by lime were owing. According to fome, it was deprived of a quantity of mucilage, in which it had formerly been enveloped; while, according to others, it was rendered more active by being more comminuted. At laft, in 1756, Dr Black publifhed the celebrated experiments which we have fo often mentioned; in which he proved, by the moft ingenious and fatisfactory analyfis, that the *potafs* which the world had confidered as a fimple fubftance, was really a compound,

(L) See a paper by Margueron on this fubject, *Ann. de Chim.* xxi. 174.

(M) That potafs was known to the ancient Gauls and Germans, cannot be doubted, as they were the inventors of foap, which, Pliny informs us, they compofed of afhes and tallow. Thefe afhes (for he mentions the afhes of the beech tree particularly) were nothing elfe but potafs; not, however, in a ftate of purity. *Plinii, lib.* xviii. *c.* 51. The κονια, too, mentioned by Ariftophanes and Plato, appears to have been a ley made of the fame kind of afhes.

Alkalies.

compound, consisting of potass and carbonic acid; that lime deprived it of this acid; and that it became more active by becoming more simple.

376 Meyer's theory.

While Dr Black was thus occupied in Scotland, Mr Meyer was employed in Germany in the same researches; from which, however, he drew very different conclusions. His Essays on Lime appeared in 1764. Pouring into lime water a solution of potass *(carbonat of potass)*, he obtained a precipitate, which he found not to differ from lime-stone. The alkali had therefore deprived the lime of its causticity and its active properties; and these very properties it had itself acquired. From which he concluded, that the causticity of lime was owing to a particular acid with which it had combined during its calcination. The alkali deprived the lime of this acid, and therefore had a stronger affinity for it. To this acid he gave the name of *acidum pingue* or *causticum*. It was, according to him, a subtile elastic mixt, analogous to sulphur, approaching very nearly to the nature of fire, and actually composed of an acid principle and fire. It was expansible, compressible, volatile, astringent, capable of penetrating all vessels, and was the cause of causticity in lime, alkalies, and metals. This theory was exceedingly ingenious, and it was supported by a vast number of new and important facts. But notwithstanding the reputation and acknowledged genius and merit of its author, it never gained many followers; because the true theory of causticity, which had been already published by Dr Black, soon became known on the continent; and, notwithstanding some opposition at first, soon carried conviction into every unprejudiced mind. Even Mr Meyer himself readily acknowledged its truth and importance, though he did not at first, on that account, give up his own theory.

When potass is exposed to the action of fire, it first becomes soft, and melts into a transparent liquid at the commencement of ignition.

When exposed to the air, it attracts moisture very fast, and is soon converted into a liquid. It attracts, at the same time, carbonic acid gas, for which it has a very strong affinity. It is impossible, then, to keep potass in a state of purity, except in very close vessels.

377 Sulphuret of potass.

It unites readily with sulphur, and forms *sulphuret of potass*. This compound may be formed two ways; either by melting the ingredients together, or by boiling them in water, and then filtrating the solution. Sulphuret of potass when dry, in which state it is obtained by the first process, is of a brown colour. It is soluble in water, and very soon attracts moisture.

While dry it produces no change upon the air of the atmosphere, as Messrs Dieman, Van Trooftwyck, Nieuwland, and Bondt, ascertained by experiment*. But when moistened with water, it very soon absorbs all the oxygen gas which happens to be in the vessel in which it is inclosed, and leaves nothing but azotic gas. This fact was first observed by Scheele, and induced him to use sulphuret of potass for an *eudiometer*, or instrument to measure the quantity of oxygen contained in any given portion of atmospheric air.

* Ann. de Chim. xiv. 294.

If sulphuret of potass be allowed to remain moist, and in contact with the atmosphere, it is gradually converted into sulphat of potass by the sulphur combining with oxygen, and forming sulphuric acid. At the same time the sulphuret emits a fetid smell, which is known to be the odour of sulphurated hydrogen gas. The sulphuret then decomposes the water with which it is mixed. Very little sulphurated hydrogen gas, however, is emitted, except an acid (the sulphuric, for instance) be poured upon the mixture, and then it is given out very copiously. The reason of this is, that there is an affinity between the potass and this gas. Accordingly it is retained by the potass after it is formed. But as the acids have a much stronger affinity for potass, as soon as any of them is poured in, the gas is obliged to separate‡.

‡ Ibid.

If liquid sulphuret of potass be kept in close vessels, it is not decomposed except in part; because as soon as the alkali is saturated with the sulphurated hydrogen gas, the action of the sulphur on the water is at an end*. The explanation of the action of this sulphuret on the atmosphere, which the Dutch chemists above-mentioned give from these data, is as follows:

* Ibid.

Sulphuret of potass decomposes water; sulphurated hydrogen gas is formed, and absorbed by the alkali. This gas has a strong affinity for oxygen, which it absorbs from the atmosphere: the hydrogen combines with this oxygen, and forms water; and the sulphur is again precipitated, or rather left combined with the potass. Water is again decomposed by the attraction of the sulphur for oxygen; new sulphurated hydrogen gas is again formed; again absorbed; again attracts oxygen gas; and is again decomposed. And this process goes on till the whole of the sulphur has combined with oxygen, and consequently till the sulphuret is converted into a sulphat†.—The only part of this theory which requires confirmation is the action of sulphurated hydrogen gas on oxygen gas, and the consequent formation of water. And this they have rendered not improbable, by shewing that sulphurated hydrogen gas combined with alkali has the property of absorbing oxygen gas from the atmosphere‡.

† Ibid.

‡ Ibid. p. 305.

378 Phosphuret of potass.

Potass unites with phosphorus by fusion, and forms a phosphuret of potass. Little is known concerning its properties, except that it produces phosphurated hydrogen gas.

Potass seems also capable of combining with carbon.

Potass does not combine with the metals; but it unites with many of their oxyds.

When a solution of potass is boiled upon silica recently procured, it dissolves part of it. As the solution cools, it assumes the appearance of a jelly, even though previously diluted with 17 times its own weight of water*.

* Bergman, ii. 32.

379 Glass.

When equal parts of silica and potass are melted together, they combine and form *glass*. A substance which, whether we consider its hardness, beauty, and transparency, its amazing ductility while hot, or the difficulty of decomposing it, must be allowed to be one of the most useful compounds ever invented by man.

When the quantity of potass is double or triple that of the silica, the glass is soluble in water, and forms what is called *liquor silicum*.

Potass seems also capable of combining in the same manner with barytes, lime, magnesia, and alumina; but these combinations have never been examined with attention. Lime, however, is often added to the materials for making glass, and is supposed to increase its hardness and solidity.

The metallic oxyds have the property of rendering glass more fusible, and of communicating various colours

Alkalies. lours to it; they accordingly very often make a part of its composition. The colours communicated by these oxyds will appear from the following table:

Metallic Oxyds.	Colour communicated to Glass.
Oxyd of gold and tin,	Purple.
Silver,	Yellow or golden.
Iron,	Pale green.
Lead,	Colourless.
Zinc,	White.
Antimony,	Green (N).
Arsenic,	White.
Cobalt,	Blue.
Nickel,	Blue (O)
Manganese,	Red.
Tungsten,	Colourless.
Molybdenum,	Colourless.
Uranium,	Grey (opake).
Titanium,	White (opake).
Tellurium,	White.
Chromum,	Green.

380 Soap. Potass combines readily with fixed oils, and forms the compound known by the name of *soap*.

381 Potass, whether a compound. Potass has never yet been decomposed. Several chemists, indeed, have conjectured, that it was a compound of lime and azot; and some persons have even endeavoured to prove this by experiment; but none of their proofs are at all satisfactory. We ought, therefore, in strict propriety, to have assigned it a place in the first part of this article: but this would have separated the alkalies from each other, and would have introduced a confusion into the article, which would have more than counterbalanced the logical exactness of the arrangement. Besides, we are certain, from a variety of facts, that all the alkalies are compounds: One of them has actually been decompounded; and the other two have been detected in the act of formation, though the ingredients which compose them have not hitherto been discovered.

Whether potass contains lime is a different question. Were we to judge from analogy, we should suppose, that the four alkaline earths, and the three alkalies, possess one common principle. They have a great number of common properties, and perhaps ought to be classed altogether under the name of *alkalies*.

That azot enters into the composition of all these bodies, as Fourcroy has conjectured, is far from improbable. One alkali, as we shall soon see, actually contains azot. But no conclusion can be drawn till future discoveries have lifted off the veil which at present obstructs our view.

382 Its affinities. The affinities of potass are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Phosphoric,
Oxalic,
Tartarous,
Arsenic,
Succinic,
Citric,
Formic,
Lactic,
Benzoic,
Sulphurous,
Acetous,
Saccholactic,
Boracic,
Nitrous,
Carbonic,
Prussic,
Oil,
Sulphur,
Phosphorus,
Water.

The place of the metallic oxyds has not yet been ascertained.

Sect. II. *Of Soda.*

Soda, called *mineral alkali*, because it is found in the earth, was known to the ancients under the names of *νιτρον* and *nitrum* (P). It was long confounded with potass: and perhaps was never properly distinguished from it till Du Hamel published a paper on the subject in 1736.

383 Properties of soda. Its properties, while pure, are precisely the same with those of potass, excepting only that its affinity for other bodies is not so strong; it does not, therefore, require any particular description. We ought to mention, however, that it differs from potass in one particular; potass attracts moisture in the air, but soda parts with it, and when exposed to the atmosphere, soon crumbles down into a dry powder.

It is capable of combining with all the substances with which potass unites; but it forms compounds possessed, in general, of very different properties from those of the compounds into which potass enters.

It is reckoned more proper than potass for forming glass and soap.

Some chemists have supposed that it is composed of magnesia and azot; but their proofs are insufficient.

The order of its affinities is the same with that of potass.

Sect. III. *Of Ammonia.*

384 Discovery of ammonia. Ammonia (Q), volatile alkali, or *hartshorn*, as it is called in commerce, is mentioned as early as the 15th century. Both Basil Valentine and Raymond Lully described the methods of procuring it. Dr Black was the first who distinguished pure ammonia from the carbonat of ammonia, or ammonia combined with carbonic acid; and Dr Priestley first discovered the method of obtaining it in a state of complete purity.

To obtain pure ammonia, mix common sal ammoniac with three parts of slacked lime; apply heat; and receive

(N) If the glass be made with soda.

(O) But reddish if the glass be formed of soda. *Klaproth.*

(P) The *νιτρον* of the Athenians was evidently the same substance; and so was the נתר of the Hebrews.

(Q) We have adopted this word, which is Dr Black's, because we think it preferable to *ammoniac* or *ammoniaca*, the words proposed and used by the French chemists.

ceive the product in a vessel filled with mercury, standing in a bason of mercury. A gas comes over, which is pure ammonia*. This gas is transparent like common air, and is not condensed by cold.

* Priestley on Air, iii. 371

385
Its properties.

Its specific gravity is 0,000732. It is to common air as 600 to 1000†.

† Kirwan on Phlog. p. 28

It has a very strong but not unpleasant smell. Animals cannot breathe it without death. When a lighted candle is let down into this gas it goes out three or four times successively; but at each time the flame is considerably enlarged by the addition of another flame of a pale yellow colour, and at last this flame descends from the top of the vessel to the bottom‡.

‡ Priestley, ii. 381.

Water absorbs this gas with avidity. It disappears almost instantly on the introduction of a little water. From an experiment of Dr Priestley, it appears that water saturated with this gas is of the specific gravity 1,1435‖.

‖ Ibid. p. 372.

This water acquires the smell of ammonia. It has a very strong disagreeable taste, and converts vegetable colours to a green.

Ammonia in the state of gas has no effect upon sulphur or phosphorus. Carbon absorbs it; probably because it contains water. Neither hydrogen nor azot produce any alteration on it¶.

¶ Ibid. p. 377.

Alcohol and ether absorb it in considerable quantity*.

* Ibid.

386
Its component parts.

Dr Priestley discovered, that when electric explosions were made to pass through this gas, its bulk was gradually augmented to thrice the space which it formerly occupied. It was then mostly converted into hydrogen gas. He discovered too that heat produced the very same effect†. These experiments prove that hydrogen enters as an ingredient into the composition of ammonia.

† Ibid. 389.

Mr Scheele observed, that when ammonia was treated with the oxyds of manganese, gold, or mercury, the oxyds were reduced; the ammonia disappeared; and nothing remained but a quantity of azotic gas. These facts induced Bergman to conjecture, that ammonia was composed of hydrogen and azot: a conjecture which has been fully confirmed by the experiments of Berthollet.

This ingenious chemist observed, that if oxy-muriatic acid and ammonia be mixed, an effervescence takes place; azot is disengaged, a quantity of water formed, and the oxy muriatic acid is converted into common muriatic acid. Now the substances mixed were ammonia and oxy-muriatic acid, which is composed of oxygen and muriatic acid; the products were, muriatic acid, azot, and water, which is composed of oxygen and hydrogen. The oxygen of the water was furnished by the acid; the other products must have been furnished by the ammonia which has disappeared. Ammonia, therefore, must be composed of azot and hydrogen. Mr Berthollet proved, that ammonia was composed of these ingredients by a number of other experiments. For instance, if the oxyd of copper be heated in contact with ammoniacal gas, it is restored to the metallic state; the ammonia disappears, a quantity of water is formed, and azotic gas is disengaged. It follows from Mr Berthollet's experiments, that ammonia is composed of 121 parts of azot, and 29 of hydrogen‡. According to Dr Austin it is composed of 121 parts of azot, and 32 of hydrogen*.

‡ Mem. Par. 1785.

* Phil. Tran. 1788.

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Formation of ammonia.

After the composition of ammonia had been thus ascertained, it became a question of some consequence, Whether it could be formed artificially? Dr Austin accordingly mixed hydrogen and azotic gas together in the proper proportions, and endeavored to make them combine by the application of heat by electricity, and by cold; but he found, that while these two substances were in a gaseous state, they could not be combined by any method which he could devise. It could not be doubted, however, that the combination often takes place when these bodies are presented to each other in a different form. Dr Priestley† and Mr Kirwan‡ had actually produced it, even before its composition was known. Accordingly he found, that when tin is moistened with nitric acid, and after being allowed to digest for a minute or two, a little potass or lime is added, ammonia is immediately exhaled*. In that case, the nitric acid, and the water which it contains are decomposed; the oxygen of each unites with the tin, and reduces it to the state of an oxyd; and at the same time the hydrogen of the water combines with the azot of the acid, and forms ammonia, which is driven off by the stronger affinity of the potass or lime. Dr Austin succeeded also in forming ammonia by several other methods. He introduced into a glass tube filled with mercury a little azotic gas, and then put into the gas some iron filings moistened with water. The iron decomposes the water and combines with its oxygen, and the hydrogen, meeting with azot at the moment of its admission, combines with it, and forms ammonia. This experiment shews, that the gaseous state of the azot does not prevent its combination with hydrogen.

† On Air, ii. 41.

‡ On Hepatic Air, § iii.

* Dr Austin.

388
Sulphuret of ammonia.

Ammonia may be combined with sulphur by mixing together two parts of muriat of ammonia (ammonia combined with muriatic acid), two parts of lime, and one part of sulphur, and distilling; a yellow liquor is obtained which contains sulphuret of ammonia. It is capable of crystallizing.

The phosphuret of ammonia is unknown.

Ammonia is capable of combining with several of the metallic oxyds, particularly copper.

It combines with fixed oils, and forms *soap*.

The order of its affinities is precisely the same with that of the fixed alkalies.

Chap. V. *Of* Acids.

Substances possessed of the following properties are denominated *acids*.

389
Properties of acids.

1. When applied to the tongue, they excite that sensation which is called *sour*, or *acid*.

2. They change the blue colours of vegetables to a red. The vegetable blues employed for this purpose are generally tincture of litmus and syrup of violets or of radishes, which have obtained the name of *reagents* or *tests*. If these colours have been previously converted to a *green* by alkalies, the acids restore them again.

3. They unite with water in almost any proportion.

4. They combine with all the alkalies, and most of the metallic oxyds and earths, and form with them those compounds which are called *neutral salts*.

It must be remarked, however, that every acid does not possess all these properties; but all of them possess a sufficient number of them to distinguish them from other substances. And this is the only purpose which artificial definition is meant to answer.

Paracelsus believed that there was only one acid principle

390 *Theories about the acid principle.*

ciple in nature which communicated taſte and ſolubility to the bodies in which it was combined. Beccher embraced the ſame opinion; and added to it, that this acid principle was a compound of earth and water, which he conſidered as two elements. Stahl adopted the theory of Beccher, and endeavoured to prove, that his acid principle was ſulphuric acid; of which, according to him, all the other acids were mere compounds. But his proofs were only conjectures or vague experiments, from which nothing could be deduced. Neverthelеſs, his opinion, like every other which he advanced in chemiſtry, continued to have ſupporters for a long time, and was even countenanced by Macquer. At laſt its defects began to be perceived, Bergman and Scheele declared openly againſt it; and their diſcoveries, together with thoſe of the French chemiſts, notwithſtanding the ill-natured attempts of Monnet to ſupport it, demonſtrated the falſehood of both parts of the theory, by ſhewing that ſulphuric acid did not exiſt in the other acids, and that it was not compoſed of water and earth, but of ſulphur and oxygen.

The opinion however, that acidity is owing to ſome principle common to all the ſalts, was not abandoned. Wallerius, Meyer and Sage, had advanced different theories in ſucceſſion about the nature of this principle; but as they were founded rather on conjecture and analogy than direct proof, they obtained but

391 *Lavoiſier's theory.*

few advocates. At laſt Mr Lavoiſier, by a number of ingenious and accurate experiments, proved, that ſeveral combuſtible ſubſtances when united with oxygen, form acids; that a great number of acids contain oxygen; and that when this principle is ſeparated from them, they loſe their acid properties. He concluded, therefore, that the acidifying principle is oxygen, and that acids are nothing elſe but combuſtible ſubſtances combined with oxygen, and differing from one another, according to the nature of the combuſtible baſe. This concluſion has been confirmed by every ſubſequent obſervation. All the acids hitherto analyſed contain oxygen, *one*, perhaps excepted, *the Pruſſic acid*, which poſſeſſes properties ſo different from the reſt, that it might, without great impropriety, be placed in a diſtinct claſs. It is probable, therefore, that thoſe acids which it has not yet been poſſible to decompoſe conſiſt of oxygen combined with a combuſtible baſe: but till this analyſis has actually been accompliſhed, the theory of Mr Lavoiſier cannot be conſidered as completely demonſtrated (R).

392 *Liſt of the acids.*

The acids at preſent known amount to about 39, moſt of which have been examined within theſe 30 years. Their names are as follows:

1. Sulphuric acid,	8. Phoſphorous,
2. Sulphurous,	9. Boracic,
3. Nitric,	10. Fluoric,
4. Nitrous,	11. Carbonic,
5. Muriatic,	12. Acetic,
6. Oxy-muriatic,	13. Acetous,
7. Phoſphoric,	14. Oxalic,
15. Tartarous,	28. Pyrotarous,
16. Citric,	29. Pruſſic,
17. Malic,	30. Formic,
18. Lactic,	31. Sebacic,
19. Saccholactic,	32. Bombic,
20. Gallic,	33. Zoonic,
21. Benzoic,	34. Arſenic,
22. Succinic,	35. Tungſtic,
23. Camphoric,	36. Molybdic,
24. Suberic,	37. Chromic,
25. Laccic,	38 Platinic,
26. Pyromucous,	39. Stannic,
27. Pyrolygnous,	

Theſe acids ſhall form the ſubject of the following ſections.

SECT. I. *Of Sulphuric Acid.*

SULPHUR combines with two different quantities of oxygen: with the ſmaller quantity it forms *ſulphurous acid*; with the larger, *ſulphuric acid*. The laſt of theſe is the ſubject of the preſent ſection.

393 *Diſcovery of ſulphuric acid.*

The ancients were acquainted with ſome of the compounds into which ſulphuric acid enters; *alum*, for inſtance, and *green vitriol*: but they appear to have been ignorant of the acid itſelf. It is firſt mentioned in the works of Baſil Valentine, which were publiſhed about the end of the 15th century.

It was for a long time obtained by diſtilling *green vitriol*, a ſalt compoſed of ſulphuric acid, and green oxyd of iron; hence it was called *oil of vitriol*, and afterwards *vitriolic acid*. Another method of obtaining it was by burning ſulphur under a glaſs bell; hence it was called alſo *oleum ſulphuris per campanam*. The French chemiſts, in 1787, when they formed a new chemical nomenclature, gave it the name of *ſulphuric acid*.

394 *Method of procuring it.*

At preſent it is generally procured by burning a mixture of ſulphur and nitre in chambers lined with lead. The theory of this proceſs requires no explanation. The nitre ſupplies a quantity of oxygen to the ſulphur, and the air of the atmoſphere furniſhes the reſt. The acid thus obtained is not quite pure, containing a little potaſs, ſome lead, and perhaps alſo nitric and ſulphurous acids. Theſe acids may be driven off by applying for ſome time a gentle heat, and afterwards the ſulphuric acid itſelf may be diſtilled over pure.

395 *Its component parts.*

It appears from an experiment of Mr Berthollet, that ſulphuric acid contains 63,2 parts of ſulphur, and 36,8 of oxygen. He aſcertained, in the firſt place*, that nitre is totally decompoſed by being heated with ¼th of ſulphur. He then mixed together 288 grains of nitre, and 72 of ſulphur; and after expoſing them to a ſufficient heat, he found 12 grains of ſulphur ſublimed, and 228 grains of ſulphat of potaſs†. But the ſum of the ingredients was 360 grains; conſequently 120 grains had been diſſipated. All this loſs muſt have been ſuffered by the acid of the nitre, for the heat was too ſmall to ſeparate any of the alkali. According to Mr Kirwan 288 grains of nitre contain 132,96 of alkali,

* *Mem. Par.* 1781. 232.

† *Mem. Par.* 1782. 603.

(R) This theory has been carried ſo far by ſome chemiſts, that they have conſidered it as a concluſive proof, that oxygen did not enter into the compoſition of a body, if they could ſhew that the body was not an acid. Thus, according to them, *water* cannot contain oxygen, becauſe water is not an *acid*.—But ſurely no theory, however ingenious and ſatisfactory, can for a moment be put in competition with experiment. The ways of Nature are not as our ways, nor her thoughts as our thoughts.

Sulphuric Acid.

kali, and 155,04 of acid. 155,04—120 = 35,04 = quantity of oxygen furnifhed by the nitre to convert 60 grains of fulphur into acid.

396 Its properties.

Sulphuric acid is a liquid, fomewhat of an oily confiftence, tranfparent and colourlefs as water, without any fmell, and of a very ftrong acid tafte. When applied to animal or vegetable fubftances, it very foon deftroys their texture.

It always contains a quantity of water; part of which, however, may be driven off by the application of a moderate heat. This is called *concentrating the acid.* When as much concentrated as poffible, its fpecific gravity is 2,000.

It changes all vegetable blues to a red, except indigo.

According to Erxleben, it boils at 546°; according to Bergman, at 572°.

397 Its cryftals.

When expofed to a fufficient degree of cold it cryftallizes or freezes; and after this has once taken place, it freezes again by the application of a much inferior cold. Morveau froze it at —4°; it affumed the appearance of frozen fnow. After the procefs began it went on in a cold not nearly fo intenfe. The acid melted flowly at 27,5°; but it froze again at the fame temperature, and took five days to melt in the temperature of 43° ‡. Chaptal, who manufactured this acid, once obferved a large glafs veffel full of it cryftallized at the temperature of 48°. Thefe cryftals were in groups, and confifted of flat hexahedral prifms, terminated by a fix-fided pyramid. They felt hotter than the furrounding bodies, and melted on being handled.* Chaptal has obferved, that fulphuric acid, in order to cryftallize, muft not be too concentrated. This obfervation has been extended a good deal further by Mr Keir. He found, that fulphuric acid, of the fpecific gravity of 1,780, froze at 45°; but if it was either much more or much lefs concentrated, it required a much greater cold for congelation †.

‡ *Encycl. Method. Chim.* i. 376.

* *Journ. de Phyf.* xxxi. 473.

† *Phil. Tranf.* lxxvii. Part ii.

398 Its affinity for water.

Sulphuric acid has a very ftrong attraction for water, Neumann found, that when expofed to the atmofphere it attracted 6,25 times its own weight. Mr Gould found, that 180 grains of acid, when expofed to the atmofphere, attracted 68 grains of water the firft day, 58 the fecond, 39 the third, 23 the fourth, 18 the fifth, and at laft only 5, 4, 3, 4, 3, &c. The 28th day the augmentation was only half a grain.* The affinity therefore between fulphuric acid and water, as is the cafe in general with other fubftances, becomes weaker the nearer they approach to faturation. He does not fpecify the fpecific gravity of his acid; but as it only attracted 3,166 times its own weight, it could not have been very concentrated.

* *Phil. Tranf.* 1684.

When fulphuric acid is mixed with water, a great quantity of caloric is evolved. A mixture of equal parts of thefe liquids caufes a heat almoft equal to that of boiling water. Lavoifier and De la Place found, that when 2,625 lbs troy of fulphuric acid, of the fpecific gravity 1,87058, was mixed with 1,969 lbs. troy of water, as much caloric was evolved as melted 4,1226 pounds troy of ice, or as much caloric as the acid and water would have given out had they been heated without mixture to 155,9° †. This caloric is owing chiefly, if not folely, to the increafe of denfity in the water; for when equal quantities of fulphuric acid and water are mixed together, the fpecific gravity is much greater than the mean; and it has been formerly fhewn, that whenever bodies become denfer they give out caloric.

† *Mem. Par.* 1780.

399 Strength of fulphuric acid of various denfities.

Since there is fuch a ftrong affinity between fulphuric acid and water, and fince the denfity of the mixture is different from the mean denfity of the ingredients, it becomes a problem of the greateft importance to determine how much of the ftrongeft fulphuric acid that can be prepared exifts in any given quantity of fulphuric acid of inferior fpecific gravity, and which confequently confifts of a determinate quantity of this ftrong acid diluted with water.

This problem has been folved by Mr Kirwan ‡. He took fulphuric acid of the fpecific gravity 2,000, which is the ftrongeft that can be procured, for his ftandard, and the point was to determine how much of this ftandard acid exifted in a given quantity of acid of inferior denfity.

‡ *Irifh Tranf.* iv.

He concluded, from a number of experiments with fulphuric acid, of the fpecific gravities 1,8846, 1,8689, 1,8042, 1,7500 (for he could not procure an acid of the fpecific gravity 2,000 at the temperature of 60°, in which his experiments were performed), that when equal parts of ftandard acid and water are mixed, the denfity is increafed by $\frac{1}{75}$th part of the whole mixture. Then, by applying a formula given by Mr Poujet (s), he calculated, that the increafe of denfity, on mixing different

(s) Mr Poujet undertook the examination of the fpecific gravity of alcohol mixed with different quantities of water. He took for his ftandard alcohol whofe fpecific gravity was 0,8199, at the temperature of 65,75°. He then formed ten mixtures; the firft containing nine meafures of alcohol and one of water, the fecond eight meafures of alcohol and two of water, and fo on till the laft contained only one meafure of alcohol and nine of water. He took care that each of thefe meafures fhould contain equal bulks, which he afcertained by weight, obferving that a meafure of water was to a meafure of alcohol as 1 to 0,8199. Thus 10000 grains of water and 8199 of alcohol formed a mixture containing equal bulks of each. From the fpecific gravity of each of thefe mixtures he difcovered how much they had diminifhed in bulk in confequence of mixture, by the following method.

Calling A the real fpecific gravity of any of the mixtures; B its fpecific gravity found by calculation, fuppofing no diminution of bulk; n the number of meafures compofing the whole mafs; $n - x$ the number to which it is reduced in confequence of mutual penetration—it is evident, fince the increafe of denfity does not diminifh the weight of the whole mafs, that $nB = \overline{n - x} \times A$. Therefore $x = \frac{A - B}{A} \times n$, or (making $n = 1$) $= \frac{A - B}{A}$. $\frac{A - B}{A}$ is therefore the diminution of volume produced by the mixture.

The

Sulphuric Acid.

different quantities of ſtandard acid and water, was as in the following table:

Number of parts of water.	Number of parts of ſtandard acid.	Augmentation of denſity.
5	95	0,0252
10	90	0,0479
15	85	0,0679
20	80	0,0856
25	75	0,0699
30	70	0,1119
35	65	0,1213
40	60	0,1279
45	55	0,1319
50	50	0,1333

The firſt 50 numbers of the following table were formed by adding theſe augmentations to the ſpecific gravity of the above mixture found by calculation, and taking the arithmetical mean for the intermediate quantities. The remaining numbers were formed from actual obſervation. He found by the firſt part of the table, that 100 parts of acid, of the ſpecific gravity 1,8472, contained 88,5 parts ſtandard, conſequently 400 grains of this acid contain 354 grains ſtandard. He took ſix portions of this acid, each containing 400 grains, and added to them as much water as made them contain reſpectively 48, 46, 44, 42, 40, 38 grains ſtandard. The quantity of water to be added in order to produce this effect, he found by the following method. Suppoſe $x =$ the quantity of water to be added to 400 parts of acid, that the mixture may contain 48 *per cent*, of ſtandard acid. Then $400 + x : 354 :: 100 : 48$, and conſequently $x = 337{,}5$. After finding the ſpecific gravity of theſe, the half of each was taken out, and as much water added; and thus the ſpecific gravities, correſponding to 24, 23, 22, 21, 20, 19, were found. Then ſix more portions, of 400 grains each, were taken, of the ſpecific gravity 1,8393, and the proper quantity of water added to make them contain 36, 34, 32, 30, 28, 26 *per cent.* of ſtandard. Their ſpecific gravities were found, the half of them taken out, and as much water added; and thus the ſpecific gravity of 18, 17, 16, 15, 14, and 13 found. Care was taken, after every addition of water, to allow the ingredient ſufficient time to unite.

The laſt 11 numbers were only found by analogy; obſerving the ſeries of decrement of the four laſt numbers before them.

Table

The following table contains the reſult of Mr Poujet's experiments, calculated according to that formula; the whole volume or n being $= 1$.

Meaſures of Water.	Meaſures of Alcohol.	Diminution of the whole volume = 1 by experiment.	By calculation.
1	9	0,0109	0,0103
2	8	0,0187	0,0184
3	7	0,0242	0,0242
4	6	0,0268	0,0276
5	5	0,0288	
6	4	0,0266	0,0276
7	3	0,0207	0,0242
8	2	0,0123	0,0184
9	1	0,0044	0,0103

It is evident, from this table, that the diminution of the bulk of the mixture follows a regular progreſſion. It is greateſt when the meaſures of water and alcohol are equal, and diminiſhes as it approaches both ends of the ſeries. Mr Poujet accounts for this by conceiving the alcohol to be diſſolved in the water, which retains a part of it in its pores, or abſorbs it. The quantity abſorbed ought to be in the ratio of that of the ſolvent and of the body diſſolved, and each meaſure of water will retain a quantity of alcohol proportional to the number of meaſures of alcohol in the mixture. Thus in a mixture formed of nine meaſures of alcohol and one of water, the water will contain a quantity of alcohol $= 9$; in one of eight meaſures of alcohol and two of water, the water will contain a quantity of alcohol $= 8$. Therefore the diminution of bulk in each mixture is in a ratio compounded of the meaſures of alcohol and water which form it; in the above table, as 1×9, 2×8, 3×7, 4×6, &c. And in general, taking the diminution of bulk when the meaſures of both liquids are equal for a conſtant quantity, and calling it, c, calling the number of meaſures n, the number of meaſures of alcohol x, the increaſe of denſity

Sulphuric Acid.

TABLE *of the Quantity of Standard Sulphuric Acid, Specific Gravity* 2,000 *in Sulphuric Acid of inferior Density, Temperature* 60.

100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid
2,000	100	1,6217	67	1,2847	34
1,9859	99	1,6122	66	1,2757	33
1,9719	98	1,6027	65	1,2668	32
1,9579	97	1,5932	64	1,2589	31
1,9439	96	1,5840	63	1,2510	30
1,9299	95	1,5748	62	1,2415	29
1,9168	94	1,5656	61	1,2320	28
1,9041	93	1,5564	60	1,2210	27
1,8914	92	1,5473	59	1,2101	26
1,8787	91	1,5385	58	1,2009	25
1,8660	90	1,5292	57	1,1918	24
1,8542	89	1,5202	56	1,1836	23
1,8424	88	1,5112	55	1,1746	22
1,8306	87	1,5022	54	1,1678	21
1,8188	86	1,4933	53	1,1614	20
1,8070	85	1,4844	52	1,1531	19
1,7959	84	1,4755	51	1,1398	18
1,7849	83	1,4666	50	1,1309	17
1,7738	82	1,4427	49	1,1208	16
1,7629	81	1,4189	48	1,1129	15
1,7519	80	1,4099	47	1,1011	14
1,7416	79	1,4010	46	1,0955	13
1,7312	78	1,3875	45	1,0896	12
1,7208	77	1,3741	44	1,0833	11
1,7104	76	1,3663	43	1,0780	10
1,7000	75	1,3586	42	1,0725	9
1,6899	74	1,3473	41	1,0666	8
1,6800	73	1,3360	40	1,0610	7
1,6701	72	1,3254	39	1,0555	6
1,6602	71	1,3149	38	1,0492	5
1,6503	70	1,3102	37	1,0450	4
1,6407	69	1,3056	36	1,0396	3
1,6312	68	1,2951	35	1,0343	2

400 Quantity of real acid in strong sulphuric acid.

But we have no reason to suppose that sulphuric acid, at the density 2,000, is free from all mixture of water; so far from that, we know for certain that it contains a considerable proportion; for when it is combined with other bodies, barytes, for instance, or potass, there is a considerable quantity of water which remains behind, and does not enter into the combination. Now, is it possible to determine what would be the density of sulphuric acid, supposing it to be deprived of all water, or at least of all water except what is necessary for its existence as an acid? or to determine, how much real acid exists in a given quantity of standard acid?

Homberg first attempted to answer this question. It was afterwards undertaken by Bergman, and Wenzel, and Wiegleb. They do not inform us of the quantity of water contained in a given weight of acid, but they put it in our power to find it, by informing us how much real acid is necessary to saturate a given quantity of potass. Their respective experiments give the following numbers:

	Hom.	Berg.	Wenzel.	Wiegleb.
100 parts of potass require	38,3	78,5	82,63	101,92

Homberg used carbonat of potass, and did not take into consideration the carbonic acid driven off by the sulphuric. When this is taken in, his number should be 54 instead of 38,3.

Now to discover the quantity of real acid in any sulphuric acid mixture, we have only to find out how much potass it would require for saturation. The differences between the above results are so great, that there was reason to suspect their accuracy. Mr Kirwan therefore attempted to ascertain the density of pure sulphuric acid by another method, and he rated it at 4,226. As this method has been already described in the article CHEMISTRY *(Encycl.)*, we cannot enter upon it here. At any rate, it would be unnecessary, as many of the principles upon which Mr Kirwan went were erroneous, as Mr Morveau* and Mr Keir‡ have sufficiently shewn; and Mr Kirwan with his usual candour has accordingly abandoned it, and adopted another method which is not liable to the same exceptions. He dissolved 1523,5 grains

* *Encycl. Method.* art. *Affinité.*
‡ *Keir's Dictionary,* art. *Acid.*

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density or diminution of bulk z; we shall have $c : z :: \frac{n}{2} \times \frac{n}{2} : \overline{n-x} \times x$, and $z = \frac{4c}{n^2} \times \overline{nx - x^2}$, or (making $n = 1$) $= 4cx - 4cx^2$.

The diminution of bulk, calculated according to this formula, make the last column of the above table. They correspond very well with experiment, while the measures of alcohol are more than those of water, but not when the reverse is the case. This Mr Poujet thinks is owing to the attraction which exists between the particles of water, and which, when the water is considerable compared with the alcohol, resists the union of the water with the alcohol.

By the formula $z = \frac{4cnx - 4cx^2}{n^2}$, the quantity of alcohol of the standard may be determined in any mixture where the alcohol exceeds the water.

Let the number of measures, or the whole mass	$= 1$
The measures of alcohol	$= x$
The diminution of bulk at equal measures	$= c$
The diminution of bulk of a mixture containing x measures of alcohol	$= 4cx - 4cx^2$
The specific gravity of water	$= a$
The specific gravity of the alcohol	$= b$
The specific gravity of the unknown mixture	$= y$

Then

Sulphurous Acid.

grains of pure carbonat of potash, dried in a red heat, in distilled water. The whole weighed 4570 grains. He took 360 grains of this mixture, which contained 120 grains of carbonat of potash, and saturated it with pure sulphuric acid of the specific gravity 1,565, which, according to the above table, contained 61 *per cent.* of standard acid. The acid required for saturating the solution of potash amounted to 130 grains, and contained therefore 79 of standard. The carbonic acid disengaged was 34 grains, and consequently the quantity of alkali was 120 -- 34 = 86 grains. The solution being turbid, was diluted with 3238 grains of water. Its specific gravity was then 1,013 at the temperature of 60°. The weight of the whole was 3694 grains. Forty-five grains of sulphat of potash (potash combined with sulphuric acid) dissolved in 1017 grains of distilled water, have the same specific gravity at the same temperature; from whence it follows, that the proportion of salt in each was equal. But in the last solution the quantity of salt was $\frac{1}{23,6}$ of the whole; therefore the quantity of salt in the first was $\frac{3694}{23,6} = 159,52$ grs. Now of this weight 86 grains were alkali; the remainder, therefore, which amounts to 70,52 grains, must be acid. But the quantity of standard acid employed was 79 grains; of this there were $8\frac{1}{2}$ grains, which did not enter into the combination, and which must have been pure water: 79 parts of standard acid, therefore, contain at least 8,5 parts of water, and consequently 100 parts of standard acid contain 10,75 parts of water. It only remains now to consider how much water sulphat of potash contains. Mr Kirwan thinks it contains none, because it loses no weight in any degree of heat below ignition, and even when exposed to a red heat for half an hour it hardly loses a grain. This is certainly sufficient to prove, at least, that it contains very little water; and consequently we may conclude, with Mr Kirwan, that 100 parts of sulphuric acid, of the specific gravity 2,000, are composed pretty nearly of 89,25 of pure acid and 10,75 of water. This method used by Mr Kirwan is nearly the same with that proposed by Mr Keir*.

* *Keir's Dictionary*, art. *Acid.*

It seems even possible to obtain sulphuric acid free from all the water that may not be necessary to its acid state. When it is procured by distillation from green vitriol, if the receiver be changed after the process has gone on for some time, a quantity of acid is obtained in a solid form, or crystallized. This, as Morveau has shewn, is sulphuric acid deprived of the water with which it is usually combined. When this *glacial* acid, as it has been called, is exposed to the air, it rises in white fumes, and is soon dissipated. This singular effect is produced by its violent attraction for the water which exists in atmospheric air. When thrown into water, it seizes it with violence; a great deal of caloric is evolved, sufficient, if the quantity of water be not too great, to elevate the whole in vapours†.

† *Encycl. Method. Chim.* i. 590.

401 Action of this Acid on other bodies.

Sulphuric acid is capable of decomposing alcohol and oils; and when assisted by heat, it decomposes also some of the metallic oxyds which contain the greatest quantity of oxygen; as red oxyd of lead, black oxyd of manganese. It decomposes likewise all the sulphurets and phosphurets which have an alkaline or earthy basis.

It oxydates iron, zinc, and manganese, in the cold. By the assistance of heat it oxydates silver, mercury, copper, antimony, bismuth, arsenic, tin, and tellurium. At a boiling heat it oxydates lead, cobalt, nickel, molybdenum. It does not act upon gold, platinum, tungsten, nor titanium.

It unites readily with all the alkalies, the alkaline earths, alumina, and jargonia, and with most of the metallic oxyds, and forms salts denominated *sulphats*. Thus the combination of sulphuric acid and soda is called *sulphat of soda*; the compound of sulphuric acid and lime, *sulphat of lime*, and so on. It does not act upon silica nor adamanta:

402 Its affinities.

The affinities of sulphuric acid are as follows ‡:

Barytes,
Strontites*,
Potash,
Soda,
Lime,
Magnesia,
Ammonia,
Alumina,
Jargonia †?
Oxyd of zinc,
——— iron,
——— manganese,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— bismuth,
Oxyd

‡ See *Bergman* and *Lavoisier*.
* *Dr Hope, Transf. Edin.* iv.
† *Vauquelin, Ann. de Chim.* xxiii 208.

Then since the increase of density does not change the weight of the whole, $\overline{1-x} \times a + b\,x = \overline{1-4cx+4cx^2} \times y$.

$$\text{Hence } x = 0,5 - \frac{a-b}{8cy} + \sqrt{\frac{a-y}{4cy} + \left(\frac{a-b}{8cy} - 0,5\right)}$$

$$y = \frac{a - ax + bx}{1 - 4cx + 4cx^2}$$

And making $a = 1$, $b = 0,8199$, $c = 0,0288$

$$x = 0,5 - \frac{0,1801}{0,2304y} + \sqrt{\frac{1-y}{0,1152y} + \left(\frac{0,1801}{0,2304y} - 0,5\right)}$$

$$y = \frac{1 - 0,1801\,x}{1 - 0,1152x + 0,1152x^2}.$$ See *Irish Transf.* III

Sulphurous Acid.

Oxyd of antimony,
——— arſenic,
——— mercury,
——— ſilver,
——— gold,
——— platinum,
Oil,
Water,

Sect. II. *Of Sulphurous Acid.*

403 Component parts of ſulphurous acid.

Sulphurous acid is compoſed of ſulphur and oxygen combined: the proportions have not been aſcertained; but the fact itſelf, and that the quantity of oxygen is leſs than what enters into ſulphuric acid, has been proved beyond the poſſibility of doubt. Neither can it be doubted, though the fact has not been attended to, that in this acid the ſulphur and oxygen mutually ſaturate each other, and that ſulphuric acid is not compoſed of ſulphur and oxygen, but of ſulphurous acid and oxygen. Phoſphorus is capable of decompoſing ſulphuric acid, by the aſſiſtance of heat, of ſeizing a quantity of its oxygen, and converting it into ſulphurous acid; but upon ſulphurous acid it has no effect whatever*. The affinity of phoſphorus, therefore, for oxygen is leſs than that of ſulphur; yet it is capable of taking oxygen from ſulphuric acid. Is it not evident from this, that ſulphuric acid is compoſed of ſulphurous acid and oxygen? and that ſulphur has a ſtronger affinity for oxygen than ſulphurous acid has? For if both the acids were compoſed directly of ſulphur and oxygen, it would follow from experiment, that the affinity of phoſphorus for oxygen was both ſtronger and weaker than that of ſulphur, which would be abſurd (20).

* *Fourcroy* and *Vauquelin.*

404 Its diſcovery.

Sulphurous acid has been known ſince the time of Stahl. Scheele firſt diſcovered the method of obtaining it in quantities; and Dr Prieſtley firſt procured it in a ſtate of purity; for Scheele's acid was diſſolved in water.

405 Method of procuring it.

Stahl's method of procuring ſulphurous acid was to burn ſulphur at a low temperature, and expoſe to its flames cloth dipped in a ſolution of potaſs. By this method he obtained a combination of potaſs and ſulphurous acid: for at a low temperature ſulphur forms by combuſtion only ſulphurous acid. On this ſalt Scheele poured a quantity of tartarous acid, and then applied a gentle heat. The ſulphurous acid is in this manner diſplaced, becauſe its affinity for potaſs is not ſo ſtrong as that of tartarous acid; and it comes over into the receiver diſſolved in water. It is now commonly procured by mixing with ſulphuric acid, oil, greaſe, metals, or any other ſubſtance that has a ſtronger affinity for oxygen than ſulphurous acid, and applying a heat ſufficient to diſtil over the ſulphurous acid as it forms. Mr Berthollet has found, that ſugar is the beſt ſubſtance to employ for this purpoſe.

Dr Prieſtley poured a little oil on ſulphuric acid, applied heat, and received the product in a glaſs jar filled with mercury. It was ſulphurous acid free from all ſuperfluous water, and in a gaſeous form.

406 Its properties.

In this ſtate it is colourleſs and inviſible like common air. It is incapable of maintaining combuſtion; nor can animals breathe it without death. It has a ſtrong and ſuffocating odour. It is this odour which burning ſulphur exhales. Its ſpecific gravity, according to Bergman is 0,00246†; according to Lavoiſier, 0,00251‡. Clouet and Monge found, that by the application of extreme cold it is converted into a liquid.

† On *Elective Attract.* § 13.
‡ *Chemiſtry Appendix.*

Dr Prieſtley diſcovered, that when a ſtrong heat is applied to this acid in cloſe veſſels, a quantity of ſulphur is precipitated, and the acid is converted into ſulphuric*. Berthollet obtained the ſame reſult; but Fourcroy and Vauquelin could not ſucceed†.

* On *Air*, ii. 330.
† *Nicholſon's Journal*, i. 313.

Water abſorbs this acid with avidity. According to Dr Prieſtley, 1000 grains of water at the temperature 54,5°, abſorb 39,6 grains of this acid. The ſpecific gravity of water ſaturated with ſulphurous acid is 1,040‡. Water in the ſtate of ice abſorbs it very rapidly, and is inſtantly melted. Water ſaturated with this acid can be frozen without parting with any of it. When water, which has been ſaturated with this acid at the freezing temperature, is expoſed to the heat of 65,25°, it is filled with a vaſt number of bubbles, which continually increaſe and riſe to the ſurface. Theſe bubbles are a part of the acid ſeparating from it. It freezes a few degrees below 32°‖.

‡ *Berthollet, Ann. de Chim.* ii. 56.
‖ *Fourcroy* and *Vauquelin, Nicholſon, ibid.*

Sulphuric acid abſorbs it at zero; but allows great part of it to eſcape at 32°*.

* *Ibid.*

It reddens tincture of turnſole; but deſtroys the colour of ſyrup of violets.

It is decompoſed by hydrogen and carbon, and ſulphurated hydrogen gas, when aſſiſted by heat†.

† *Ibid.*

Oxygen gas gradually converts it into ſulphuric acid; but this change does not take place unleſs water be preſent.

It does not ſeem capable of oxydating any of the metals except iron, zinc, and mangane ſe.

When in the ſtate of gas it is abſorbed by oils and ether.

When glaſs tubes, filled with ſulphurous acid in the ſtate of gas, are expoſed to a ſtrong heat, a quantity of ſulphur precipitates, and the reſt of the acid is converted into the ſulphuric.

407 Its combinations,

It combines with the alkalies, alkaline earths, and alumina, and many of the metallic oxyds, and forms neutral ſalts, known by the name of *ſulphites.*

408 And affinities.

Its affinities, as far as they have been inveſtigated, are as follows:

‡ *Ibid.*

Barytes,
Lime,
Potaſs,
Soda,
Magneſia, }
Ammonia, }
Alumina.

Jargonia*?

(21) Might we not with greater propriety explain theſe phænomena by the well known principle, that in proportion to the ſaturation of any chemical agent with another to which it has an affinity does the force of that affinity leſſen. The phoſphorus then might have a greater affinity for oxygen than the ſulphur has when ſaturated beyond a certain degree, and would of conſequence deprive it of oxygen till it reduced to this point, but after this it could deprive it of no more. T. P. S.

Nitric Acid.

Jargonia* ?
Metallic oxyds,
Water.

* Vauquelin, Ann. de Chim. xxii. 208.

Sect. III. *Of Nitric Acid.*

There are three different substances composed of azot and oxygen, *nitric acid*, *nitrous acid*, and *nitrous gas*. The first contains most oxygen, the last contains least.

409 Discovery of nitric acid. Nitric acid seems to have been first obtained in a separate state by Raymond Lully, who was born at Majorca in 1235. He procured it by distilling a mixture of nitre and clay. Basil Valentine, who lived in the 15th century, describes the process minutely, and calls the acid *water of nitre*. It was afterwards denominated *aqua fortis*, and *spirit of nitre*. The name *nitric acid* was first given it in 1787 by the French chemists.

410 Method of procuring it. Nitric acid is generally obtained in large manufactories by distilling a mixture of nitre (T) and clay; but the acid procured by this process is weak and impure. Chemists generally prepare it by distilling three parts of nitre and one of sulphuric acid in a glass retort. This method was first used by Glauber. When obtained in this manner it contains some nitrous acid which may be expelled by the application of a very gentle heat§.

§ Scheele.

Nitric acid is one of the most important instruments of analysis which the chemist possesses; nor is it of inferior consequence when considered in a political or commercial view, as it forms one of the most essential ingredients of gunpowder. Its nature and composition accordingly have long occupied the attention of philosophers. We shall endeavour to trace the various steps by which its component parts were discovered.

411 Discovery of its component parts. As nitre is often produced upon the surface of the earth, and never except in places which have a communication with atmospheric air, it was natural to suppose that air, or some part of the air, entered into the composition of nitric acid. Mayow having observed, that nitre and atmospherical air were both possessed of the property of giving a red colour to the blood, and that air was deprived of this property by combustion, and respiration—concluded that nitre *contained that part of the air which supported combustion, and was necessary for respiration.*

Dr Hales, by applying heat to nitric acid, and what he called *Walton mineral*, obtained a quantity of air possessed of singular properties. When atmospherical air was let into the jar which contained it, a reddish turbid fume appeared, a quantity of air was absorbed, and the remainder became transparent again*. Dr Priestley discovered that this air could only be obtained from nitric (U) acid; and therefore called it *nitrous air*. He found, that when this gas was mixed with oxygen gas, nitrous acid was reproduced. Here, then, we find, that oxygen is a part of the nitric acid, and consequently that Mayow's affirmation is verified.

* Veget. Statics, ii. 284.

Dr Priestley, however, explained this fact in a different manner. According to him, nitrous gas is composed of nitrous acid and phlogiston. When oxygen is added, it separates this phlogiston, and the acid of course is precipitated. This hypothesis was adopted by Macquer and Fontana; and these three philosophers endeavoured to support it with their usual ingenuity. But there was one difficulty which they were unable to surmount. When the two gases are mixed in proper proportions, almost the whole assumes the form of nitric acid; and the small residuum ($\frac{1}{14}$th part), in all probability, or rather certainly, depends on some accidental impurity in the oxygen gas. What then becomes of the oxygen and phlogiston? Dr Priestley supposed that they formed carbonic acid gas: but Mr Cavendish proved, that when proper precautions are taken, no such acid appears†.

† Phil. Trans. 1784.

Dr Priestley had procured his nitrous gas by dissolving metals in nitric acid; during the solution of which a great deal of nitrous gas escapes. He supposed that nitrous gas contained phlogiston, because the metal was oxydated (and consequently, according to the then received theory, must have lost phlogiston) during its formation. Mr Lavoisier proved, that this supposition was ill-founded, by the following celebrated experiment‡. To 945 grains of nitric acid (specific gr. 1,316) he added 1104 grains of mercury. During the solution 273,234 cubic inches of nitrous gas were produced. He then distilled the salt, (oxyd of mercury), which had been formed to dryness. As soon as it became red hot it emitted oxygen gas, and continued to do so till almost the whole of the mercury was revived: The quantity of oxygen emitted was 287,742 cubic inches. All that had happened, therefore, during the solution of the mercury, was the separation of the acid into two parts; nitrous gas which flew off, and oxygen, which united with the metal (X).

‡ Mem. Par. 1776, p. 673.

Mr Lavoisier concluded, therefore, that the whole of the nitrous gas was derived from the nitric acid: that nitric acid is composed of oxygen and nitrous gas; and that the proportions are nearly 64 parts by weight of nitrous gas, and 36 of oxygen gas.

But there was one difficulty which Mr Lavoisier acknowledged he could not remove. The quantity of oxygen obtained by decomposing nitric acid was often much greater than what was necessary to saturate the nitrous gas. Mr de Morveau attempted to account for this, but without success§. Nitrous gas itself was evidently a compound: but the difficulty was to discover the ingredients. Mr Lavoisier concluded from an experiment made by decomposing nitre by means of charcoal, that it contained azot: and several of Dr Priestley's experiments led to the same result. But what was the other ingredient?

§ Encycl. Method. Chim. Acide Nitrique.

Mr Cavendish had observed, while he was making experiments on the composition of water, that some nitric acid was formed during the combustion of oxygen and hydrogen gas, and that its quantity was increased by adding a little azot to the two gases before the explosion. Hence he concluded, that the formation of the acid was owing to the accidental presence of

(T) Nitre is composed of nitric acid and potass.

(U) Or nitrous acid: for at the period of Dr Priestley's discovery (1772) they were not accurately distinguished.

(X) We have already mentioned, in a preceding note, that this experiment was first made by Mr Bayen. See Part I. chap. iii. of this Article.

of azotic gas. To verify this conjecture, he passed an electrical shock through a quantity of common air enclosed in a glass tube: the air was diminished, and some nitric acid formed. He repeated the experiment, by mixing together oxygen and azotic gas; and found, that when they bore a certain proportion to each other, they were totally convertible into nitric acid. In one experiment, the proportion of azot to oxygen (in bulk) was as 416 to 914; in another, as 1920 to 4860*.

These experiments were immediately repeated by Messrs Van Marum and Van Trooftyk, and with nearly the same result.

The most convenient method of performing them is the following: Take a glass tube, the diameter of which is about the sixth part of an inch, through the cork that shuts one end of which let a small metallic conductor pass with a ball at each end. Fill this tube with mercury, and plunge its open end into a bason of mercury: then put into it a mixture of 0,13 of azotic and 0,87 of oxygen gas, till it occupies three inches of the tube; and introduce a solution of potass till it fill half an inch more. Then, by means of the conductor, make electrical explosions (from a very powerful machine) to pass through the tube till the air is as much diminished as possible. Part of the potass will be found converted into nitre. Mr Cavendish actually saturated the potass with this acid. Mr Van Marum did not, though a good deal more gas had disappeared than in the experiments of Mr Cavendish. This difference evidently depends on the quantity of potass contained in a given weight of the solution. The solution which Mr Van Marum used was no doubt stronger than that which Mr Cavendish employed.

Dr Priestley had observed several years before these experiments were made, that atmospherical air was diminished by the electric spark, and that during the diminution, the infusion of turnsole became red; but he concluded merely, that he had precipitated the acid of the air. Landriani, who thought, on the contrary, that carbonic acid gas was formed, enounced the alteration of lime-water by it as a proof of his opinion. It was to refute this notion that Mr Cavendish undertook his experiments. He has since that time repeated them with the same success§.

It cannot be doubted, then, that nitric acid is composed of azot and oxygen; for the objections of Dr Priestley have been considered while we were treating of water. Consequently nitrous gas must also be composed of the same ingredients. According to Lavoisier, nitric acid is composed of four parts, by weight, of oxygen and one part of azot.

412 Its properties.

Nitric acid is liquid, colourless, and transparent; but the affinity between its component parts is so weak, that the action of light is sufficient to drive off a part of its oxygen in the form of gas; and thus, by converting it partly into nitrous acid, to make it assume a yellow colour. Its taste is exceedingly acid and peculiar. It is very corrosive, and tinges the skin of a yellow colour, which does not disappear till the epidermis comes off.

It has a strong affinity for water, and has never yet been obtained except mixed with that liquid. When concentrated, it attracts moisture from the atmosphere, but not so powerfully as sulphuric acid. It also produces heat when mixed with water, owing evidently to the concentration of the water.

* Phil. Trans. 1783.

§ Phil. Trans. 1788.

413 Its strength at different specific gravities.

The specific gravity of the strongest nitric acid that can be procured is, according to Rouelle, 1,583; but at the temperature of 60° Mr Kirwan could not procure it stronger than 1,5543.

Taking this acid for the standard, Mr Kirwan has calculated how much of it exists in nitric acid of inferior density. His determination may be seen in the following table, which was formed precisely in the same manner as that formerly given of the strength of sulphuric acid.

100 parts at the specific gravity	contain of standard acid	100 parts at the specific gravity	contain of standard acid	100 parts at the specific gravity	contain of standard acid
1,5543	100	1,4018	70	1,2586	44
1,5295	95	1,3975	69	1,2525	43
1,5183	94	1,3925	68	1,2464	42
1,5070	93	1,3875	67	1,2419	41
1,4957	92	1,3825	66	1,2374	40
1,4844	91	1,3775	65	1,2291	39
1,4731	90	1,3721	64	1,2209	38
1,4719	89	1,3671	63	1,2180	37
1,4707	88	1,3621	62	1,2152	36
1,4695	87	1,3571	61	1,2033	35
1,4683	86	1,3521	60	1,2015	34
1,4671	85	1,3468	59	1,1963	33
1,4640	84	1,3417	58	1,1911	32
1,4611	83	1,3366	57	1,1845	31
1,4582	82	1,3315	56	1,1779	30
1,4553	81	1,3264	55	1,1704	29
1,4524	80	1,3212	54	1,1639	28
1,4471	79	1,3160	53	1,1581	27
1,4422	78	1,3108	52	1,1524	26
1,4373	77	1,3056	51	1,1421	25
1,4324	76	1,3004	50	1,1319	24
1,4275	75	1,2911	49	1,1284	23
1,4222	74	1,2812	48	1,1241	22
1,4171	73	1,2795	47	1,1165	21
1,4120	72	1,2779	46	1,1111	20
1,4069	71	1,2687	45	1,1040	19

Now, how much water does nitric acid contain, the density of which is 1,5543?

414 Quantity of real acid contained in concentrated nitric acid.

Mr Kirwan dried a quantity of crystallized carbonat of soda in a red heat, and dissolved it in water in such a proportion, that 367 grains of the solution contained 50,05 of alkali. He saturated 367 grains of this solution with 147 grains of nitric acid, the specific gravity of which was 1,2754, and which therefore by the preceding table contained 45,7 *per cent.* of acid standard. The carbonic acid driven off amounted to 14 grains. On adding 939 grains of water, the specific gravity of the solution at the temperature of 58,5°, was 1,0401. By comparing this with a solution of nitrat of soda, of the same density, precisely in the manner described formerly under sulphuric acid, he found, that the salt contained in it amounted to $\frac{1}{16,901}$ of the whole. There was an excess of acid of about two grains. The weight of the whole was 1439 grains: The quantity of salt consequently was $\frac{1439}{16,901} = 85,142$ grains. The quantity of alkali was $50,05-14 = 36,05$. The quantity of

Nitric Acid.

of ſtandard acid employed was 66,7. The whole of which amounted to 102,75 grains; but as only 85,142 grains entered into the compoſition of the ſalt, the remaining 17,608 muſt have been pure water mixed with the nitric acid. But if 66,7 of ſtandard acid contain 17,608 of water, 100 parts of the ſame acid muſt contain 26,38*.

* *Iriſh Tranſ.* iv.

Onehundred parts of ſtandard nitric acid, therefore, is compoſed of 73,62 parts of pure nitric acid and 26,38 of water. But as Mr Kirwan has not proved that nitrat of ſoda contains no water, perhaps the proportion of water may be greater. He has rendered it probable, however, that nitrat of ſoda contains very little water.

415 Its action on other bodies,

Nitric acid is decompoſed by a great variety of ſubſtances. When poured upon oils, it ſets them on fire. This is occaſioned by a decompoſition both of the acid and oil. The oxygen of the acid combines with the carbon, and with the hydrogen of the oils, and at the ſame time lets go a quantity of caloric. Hence we ſee that the oxygen which enters into the compoſition of the nitric acid ſtill contains a great deal of caloric; a fact which is confirmed by a great number of other phenomena. The combuſtion of oils by this acid was firſt taken notice of by Borrichius and Slare; but it is probable that Homberg communicated it to Slare. In order to ſet fire to the fixed oils, it muſt be mixed with ſome ſulphuric acid; the reaſon of which ſeems to be, that theſe oils contain *water*, which muſt be previouſly removed. The ſulphuric acid combines with this water, and allows the nitric acid, or rather the oil and nitric acid together, to act. The drying oils do not require any ſulphuric acid: they have been boiled, and conſequently deprived of all moiſture. It ſets fire alſo to charcoal, provided it be perfectly dry. This fact was firſt obſerved by Prouſt, and afterwards confirmed by the Dijon academicians. It ſets fire alſo to zinc, biſmuth and tin, if it be poured on them in fuſion, and to filings of iron, if they be perfectly dry‡. In all theſe caſes, the acid is decompoſed. Sulphurated hydrogen gas alſo takes fire, and burns with a ſtrong flame by means of this acid†.

‡ *Prouſt, Dijon Academicians,* and *Cornette.*
† *Tromſdorff.*

It is capable of oxydating all the metals except gold, platinum (x), and titanium. It appears, from the experiments of Scheffer, Bergman, Sage, and Tillet, that nitric acid is capable of diſſolving (and conſequently of oxydating) a very minute quantity, even of gold.

416 Its combinations,

Nitric acid combines with alkalies, alkaline earths, alumina and jargonia, and with the oxyds of metals, and forms compounds which are called *nitrats*. It does not act upon ſilica nor adamanta.

417 And affinities.

The order of its affinities is as follows:

Barytes,
Potaſs,
Soda,
Strontites*,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia† ?
Metallic oxyds, in the ſame order as for ſulphuric acid.
Water.

* *Dr Hope.*
† *Vauquelin, Ann. de Chim.* xxii. 208.

Nitrous Acid.

Sect. IV. *Of Nitrous Acid.*

418 Component parts of nitrous acid.

If oxygen gas be mixed with nitrous gas, a quantity of red fumes appear, which are readily abſorbed by water. Theſe red fumes are *nitrous acid*.

If a glaſs veſſel containing nitric acid be inverted into another veſſel containing the ſame acid, and expoſed to the light, the inverted glaſs will become partly full of oxygen gas, and at the ſame time part of the nitric acid is converted into nitrous acid*. It follows, from this experiment, that nitrous acid contains leſs oxygen than nitric acid. Lavoiſier has calculated that it contains ſomewhat leſs than three parts of oxygen to one of azot.

* *Scheele, Crell's Annals* 1786.

419 Its properties.

Nitrous acid is of a brown or red colour, exceedingly volatile, and emitting a very ſuffocating, and ſcarcely tolerable odour. When to this acid concentrated, a fourth part by weight of water is added, the colour is changed from red to a fine green; and when equal parts of water are added, it becomes blue†. Dr Prieſtley obſerved, that water impregnated with this acid in the ſtate of vapour, became firſt blue, then green, and laſtly yellow. A green nitrous acid became orange-coloured while hot, and retained a yellow tinge when cold. A blue acid became yellow on being heated in a tube hermetically ſealed. An orange-coloured acid, by long keeping became green, and afterwards of a deep blue; and when expoſed to air reſumed its original colour. Theſe colours ſeem to depend upon the concentration of the acid.

† *Bergman.*

Dr Prieſtley found that water abſorbed great quantities of this acid in the ſtate of vapour, and that when ſaturated, its bulk was increaſed one-third.

In the ſtate of vapour, it is abſorbed rapidly by oils. Whale oil, by abſorbing it, became green, thick and heavier. It gradually decompoſed the acid, retained the oxygen, and emitted the azot in the ſtate of gas‡.

‡ *Prieſtley,* iii. 111.

It is abſorbed by ſulphuric acid, but ſeemingly without producing any change; for when water is poured into the mixture, the heat produced expels it in the uſual form of red fumes§. The only ſingular circumſtance attending this impregnation is, that it diſpoſes the ſulphuric acid to cryſtallize*. This fact, firſt obſerved by Dr Prieſtley in 1777 (y), was afterwards confirmed by Mr Cornette.

§ *Ibid.* p. 144.
* *Ibid.* p. 156.

Nitrous

(x) Nitre however acts upon platinum, as Mr Tennant has proved. *Phil. Tranſ.* 1797. Morveau had made the ſame obſervation in the *Elemens de Chimie de l'Academie de Dijon.*

(y) Bernhardt, however, relates, in 1765, that once, when he was diſtilling a mixture of ten pounds of nitre with an equal quantity of calcined vitriol, which he had put into a retort, to which was fitted an adapter between the retort and the receiver, which contained a quantity of water—he obſerved a conſiderable quantity of a white cryſtalline ſalt formed in the adapter, while the liquid acid paſſed as uſual into the receiver. This ſalt was very volatile, ſmoked ſtrongly when it was expoſed to the air, and exhaled a red vapour; it burnt, to a black coal, wood, feathers or linen, as ſulphuric acid does; and where a piece of it fell, it evaporated in form of a blood-red vapour till the whole of it diſappeared. Half an ounce of theſe cryſtals diſſolved in water with ſputtering

Nitrous Acid.

Nitrous acid appears capable of combining with most of the bodies with which nitric acid unites. The salts which it forms are called *nitrites*.

Its affinities have never been accurately examined. Bergman supposes them the same with those of nitric acid.

Of Nitrous Gas.

420 Discovery of nitrous gas.

Nitrous gas was first obtained by Dr Hales, but its properties were discovered by Dr Priestley. It may be procured by dissolving metals in nitric or nitrous acid, and catching the product by means of a pneumatic apparatus.

As nitrous acid is formed by combining nitrous gas and oxygen, it is evident that nitrous gas contains less oxygen than nitrous acid. According to Lavoisier, it is composed of two parts of oxygen and one of azot.

421 Its properties.

Nitrous gas is elastic, and invisible like common air. It extinguishes light, and instantly kills all those animals that are obliged to breathe it. Its specific gravity, according to Mr Kirwan, is 0,001458 ‡.

Dr Priestley found that water was capable of absorbing about one-tenth of nitrous gas, and that by the absorption it acquired an astringent taste §. Water parts with all the nitrous gas it has imbibed on being frozen †.

‡ *On Phlogiston*, p. 28.

§ *Priestley*, I. 365.

† *Ibid.* p. 407.

Neither phosphorus nor sulphur seem capable of decomposing nitrous gas.

Mr Linck, professor at Rostoc, found, that three parts of nitrous gas and two of hydrogen gas, obtained by sulphuric acid and iron, are scarcely, or not at all, diminished when exposed to day-light over water. Common air is not more diminished by this admixture kept a long time: but the mixture itself of these two gases is diminished by the addition of new portions of nitrous gas. Mr Linck concludes, from this observation, that part of the oxygen of the nitrous gas combined with the hydrogen and formed water, and that the remaining oxygen and azot formed a mixture similar to the air of the atmosphere. Mr Vauquelin had previously made the same observation. The affinity of hydrogen, therefore, for oxygen is greater than that of azot.*

* *Nicholson's Jour.* ii. 72.

Oils imbibe nitrous gas with avidity, and decompose it.

Nitric acid absorbs a vast quantity of it, and is by that means converted into nitrous acid.—Sulphuric acid also absorbs it.

The most important property of nitrous gas is that of combining instantly with oxygen gas, and forming nitrous acid, which is instantly absorbed by water. This property induced Dr Priestley to use nitrous gas as a test of the purity of common air. He mixed together equal bulks of these substances, and judged of the purity of the air by the diminution of bulk. The apparatus used for this purpose, which consists of a graduated tube, has been called a *eudiometer*. This eudiometer has been greatly improved by Fontana, but it is still liable to uncertainty in its application. Perhaps the best eudiometer is sulphuret of potass, which, as Morveau has discovered, absorbs, on the application of heat, the whole oxygen in a given bulk of air almost instantaneously.

422 The eudiometer.

Muriatic Acid.

Dr Priestley found, that nitrous gas was decomposed by passing electric explosions through it.

Let us now consider in what manner oxygen and azot are combined in the three substances which have been just described.

423 Manner in which azot and oxygen are combined.

It can hardly be conceived that azot is capable of combining with three different proportions of oxygen, and of being saturated with each: it is surely much more probable, that in nitrous gas the oxygen and azot saturate each other directly and completely; that nitrous acid is composed of nitrous gas and oxygen, and nitric acid of nitrous acid and oxygen. And this supposition is confirmed by considering that the strength of affinity by which the oxygen is retained in each of these substances is very different. Some substances, as light, are capable of decomposing nitric acid, by seizing some of its oxygen, and of converting it into nitrous acid; but they have no effect whatever upon nitrous acid or nitrous gas. Others, as bismuth, copper, phosphorus, and sulphur, are capable of decomposing both nitric and nitrous acids, but are incapable of altering nitrous gas: And others, again, as carbon, zinc, and iron, are capable of decomposing all the three. Every body which is capable of decomposing nitrous acid is capable also of decomposing nitric acid; and every body that decomposes nitrous gas is capable also of decomposing the other two. But the reverse of this is not true. The affinity of oxygen, then, for azot, nitrous gas, and nitrous acid, is different: oxygen has a stronger affinity for azot than it has for nitrous gas, and a stronger affinity for nitrous gas than for nitrous acid. But if all these bodies were direct combinations of azot and oxygen, how could this difference of affinity take place? Is it reasonable to suppose, that a substance has a stronger affinity for one proportion of any other body than for another proportion? or that, if such a difference existed, the strongest affinity should not always prevail? Mix together nitric acid and nitrous gas in proper proportions, and the whole mixture is converted into nitrous acid: but mix nitrous and nitric acids together, and no change whatever is produced. In the first case, is it not evident that the affinity of nitrous gas for oxygen is greater than that of nitrous acid; that therefore it decomposes the nitric acid, deprives it of oxygen, and leaves it in the state of nitrous acid? But, in the second case, no change can take place, because nitric acid is composed of nitrous acid and oxygen; and it would be absurd to suppose, that *nitrous acid* has a stronger affinity for oxygen than *nitrous acid* has. But were azot and oxygen capable of uniting in various proportions, why should not a mixture of nitric and nitrous acids, or of nitrous gas and nitrous acid, form new substances? And why are the only substances which appear in decompositions nitrous acid and nitrous gas? Surely these reasons are sufficient to shew us, that these bodies are combined in the following manner:

Azot

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ing and hissing, like that of a red hot iron dipped in water, and formed a green nitrous acid. Some of this salt being put into a bottle which was not well stopped, entirely vanished. These crystals were evidently the same with Dr Priestley's. See *Keir's Dictionary*.

Azot and Oxygen } form nitrous gas;
Nitrous gas and oxygen } form nitrous acid;
Nitrous acid and oxygen } form nitric acid. (22)

Perhaps there may be even more links in the chain than we are aware of. The dephlogiſticated nitrous air of Dr Prieſtley, which Dieman and Van Trooſtwyck have lately proved to be compoſed of 37 parts of oxygen and 63 of azot, and of which little more is known than that it ſupports flame, is noxious to animals, abſorbed by water, and only obtained by means of ſubſtances capable of decompoſing nitrous gas—perhaps this *air* is compoſed directly of oxygen and azot, nitrous gas of this air and oxygen, and ſo on. There may be even links ſtill farther back than that.

Sect. V. *Of Muriatic Acid.*

424 Diſcovery of muriatic acid.

Muriatic acid appears to have been known to Bazil Valentine; but Glauber was the firſt who extracted it from common ſalt by means of ſulphuric acid. Common ſalt is compoſed of muriatic acid and ſoda, for which laſt ſubſtance ſulphuric acid has a ſtronger affinity. This acid was firſt called *ſpirit of ſalt*, afterwards *marine acid*, and now, pretty generally, *muriatic acid* ‡.

‡ From *muria*.

It is ſometimes prepared by mixing one part of common ſalt with ſeven or eight parts of clay, and diſtilling the mixture. The clay, in this inſtance, is ſuppoſed to act chiefly by means of the ſulphuric acid which it always contains (z): But this ſubject ſtill requires farther elucidation. By theſe proceſſes, muriatic acid is obtained diſſolved in water. Dr Prieſtley diſcovered, that by applying heat to this ſolution, and receiving the product in veſſels filled with mercury, a gas was procured; which gas is muriatic acid in a ſtate of purity.

425 Its properties.

Muriatic acid gas is inviſible and elaſtic, like common air. It deſtroys life and extinguiſhes flame. A candle, juſt before it goes out in it, burns with a beautiful green, or rather light blue flame; and the ſame flame appears when it is firſt lighted again.*

The ſpecific gravity of muriatic acid in the ſtate of gas is, according to Mr Kirwan †, 0,002315, which is nearly double that of common air.

Water abſorbs this gas with avidity. Ten grains of water are capable of abſorbing ten grains of the gas. The ſolution thus obtained occupies the ſpace of 13,3 grains of water nearly. Hence its ſpecific gravity is 1,500, and the denſity of the pure muriatic acid in it is 3,03* (A).

As muriatic acid can only be uſed conveniently when diſſolved in water, it is of much conſequence to know how

* *Prieſtley*, ii. 293.

† *Iriſh Tranſ.* IV.

* *Kirwan, Iriſh Tranſ.* vol. iv.

(22) To account for theſe phenomena, we would again appeal to the principle of the affinity of two ſubſtances leſſening in proportion to their mutual ſaturation. As the nitric acid is nitrogen *ſaturated* with oxygen, nitrous acid nitrogen combined with a leſs portion of oxygen, and nitrous air nitrogen combined with a ſtill leſs portion of oxygen, it would be eaſy on this principle to account for a body which partially decompoſed nitric acid not effecting the other two combinations, and it would follow from the ſame principles that any ſubſtance which would decompoſe nitrous air would decompoſe both the others. When we mix nitric acid with nitrous air it forms nitrous acid, ſo it ſhould according to this explanation. The nitrogen in the nitrous air being combined with a ſmaller portion of oxygen, has a ſtronger affinity for oxygen than the nitrogen in nitric acid has: It therefore partially decompoſes the nitric acid, combines with part of its oxygen, thus reduces it to the ſtate of nitrous acid while it paſſes on to the ſame ſtate itſelf, and then their affinity for oxygen being equal, the decompoſition ceaſes and they form an homogeneous acid. But, ſays he, nitric and nitrous acids undergo no change when mixed. How does he know that no change is made? Have the two acids ever been mixed and then ſeparated without any change having taken place in them? If they have, and the nitrous acid made uſe of did not nearly approach to the ſtate of nitric acid, it will at leaſt be a plauſible though not a concluſive argument. But where is he to fix his firſt ſtep, or the point of ſaturation? It already appears that nitrous air is not oxygen and nitrogen, but it is the *dephlogiſticated nitrous air* of Dr Prieſtley united to oxygen. If by any proceſs this is partially decompoſed, it will then appear that it is not nitrogen combined with oxygen, but the new combination of theſe gaſes which remains and oxygen. Thus, however ſmall a portion of oxygen we may find combined with nitrogen, we are to take it for granted that it is ſaturated. Theſe too are the arguments on which he founds his theory of the oxyd of a metal which contains the ſmalleſt portion of oxygen being ſaturated and that the other oxyds of it are but a combination of oxygen to the compound. Thus the grey oxyd of lead would be with him lead ſaturated with oxygen, the yellow oxyd the grey oxyd combined with oxygen, and the red oxyd, the yellow oxyd oxygenated. I muſt confeſs I cannot ſee the force of his obſervations. He has not, as far as I can ſee, adduced a ſingle argument to prove that the oxygen does not unite immediately to the metal, which is certainly a much more rational idea than to ſuppoſe it unites to the oxyd. T. P. S.

(z) Morveau has ſhown, that even alumina contains ſulphuric acid, provided a precipitation, on adding muriat of barytes, be a ſufficient teſt.

(A) For let D = the denſity of a mixture; m the weight of the denſer ingredient; d its denſity; l the weight of an equal bulk of water; and m', d', and l', the ſame elements of the rarer: Then $D = \frac{m+m'}{l+l'}$. In the above caſe, $m+m' = 20$, and $l+l' = 13{,}3$. Then $D = \frac{20}{13{,}3} = 1{,}5$. Now to find the ſpecific gravity of the condenſed how much pure acid is contained in a given quantity of liquid muriatic acid of any particular density.

426 Quantity of it contained in acids of various densities.

Now the specific gravity of the purest muriatic acid that can easily be procured and preserved, is 1,196; it would be needless, therefore, to examine the purity of any muriatic acid of superior density. Mr Kirwan calculated that muriatic acid, of the density 1,196, contains $\frac{49}{100}$ parts of acid of the density 1,500, which he took for the standard; then, by means of experiments, he formed the following table:

100 parts, at the specific gravity	contain of standard acid	100 parts, at the specific gravity	contain of standard acid	100 parts, at the specific gravity	contain of standard acid
1,196	49	1,147	37	1,1036	26
1,191	48	1,1414	36	1,0984	25
1,187	47	1,1396	35	1,0942	24
1,183	46	1,1358	34	1,0910	23
1,179	45	1,1320	33	1,0868	22
1,175	44	1,1282	32	1,0826	21
1,171	43	1,1244	31	1,0784	20
1,167	42	1,1206	30	1,0742	19
1,163	41	1,1168	29	1,0630	16
1,159	40	1,1120	28	1,0345	10
1,155	39	1,1078	27	1,0169	5
1,151	38				

Muriatic acid (for this solution of the acid in water is always called by that name) is generally of a pale yellow colour, owing, as Dr Priestley supposed, to some earthy matter dissolved in it; but much more probably to its having absorbed a quantity of oxygen, for which it has a strong affinity. Indeed, that this is the cause appears evidently from Dr Priestley's own observations; for it was destroyed only by those bodies which had a stronger affinity for oxygen. It is very volatile, as might be expected, constantly emitting white fumes of a peculiar and unpleasant odour.

427 Its action on other bodies.

Muriatic acid is capable, by the assistance of heat, of oxydating the following metals: Iron, tin, lead, zinc, bismuth, cobalt, nickel, manganese, antimony, arsenic. Several of these, as iron, for instance, it oxydates even without the assistance of heat.

At a boiling heat, it oxydates silver and copper. It has no action on gold, platinum, mercury, tungsten, molybdenum, tellurium, titanium. Its action on uranium has not been tried.

In the state of gas, it appears to decompose alcohol and oils by its affinity for water.*

It is capable of dissolving a little sulphat and fluat † of lime, and arseniat of mercury.

It combines with the alkalies, alkaline earths, alumina, and jargonia, and with most of the metallic oxyds, and forms neutral salts, known by the name of *muriats*.

* *Priestley*, II. 281.

† See sect. ix.

Morveau first shewed, that this acid, in the state of gas, neutralized putrid miasmata, and by that means destroyed their bad effects. In 1773, the cathedral of Dijon was so infected by putrid exhalations, that it was deserted, after several unsuccessful attempts to purify it. Application was made to Mr Morveau to see whether he knew any method of destroying these exhalations. He poured two pounds of sulphuric acid on six pounds of common salt, contained in a glass capsule, which had been placed on a few live coals in the middle of the church. He withdrew precipitately, and shut all the doors. The muriatic acid gas soon filled the whole cathedral, and could even be perceived at the door. After 12 hours, the doors were thrown open, and a current of air made to pass through to remove the gas. This destroyed completely every putrid odour ‡.

428 Destroys putrid miasmata.

† *Jour. de Phys.* i. 436.

429 Its affinities.

The affinities of muriatic acid are as follows:

Barytes,
Potass,
Soda,
Strontites ‡,
Lime,
Magnesia,
Ammonia,
Alumina,
Jargonia,*
Metallic oxyds as in sulphuric acid,
Water.

‡ *Dr Hope*.

* *Vauquelin Ann. de Chim.* xxii. 208.

Sect. VI. *Of Oxy-muriatic Acid.*

430 Discovery and preparation of oxy-muriatic acid.

Put into a glass retort one part of the black oxyd of manganese and three parts of muriatic acid; place it in a sand-bath in such a manner that the liquor which rises up into the neck of the retort may fall back again into the vessel; and apply a small receiver, with a little water in it, luted to the retort merely by a fillet of brown paper. In about a quarter of an hour the receiver will appear filled with a yellow-coloured gas; it is then to be removed, and others applied successively till the operation be finished.

This gas is oxy-muriatic acid, first discovered by Scheele, while he was making experiments on manganese, and called by him *dephlogisticated muriatic acid*, because he thought it muriatic acid deprived of phlogiston. The French chemists called it *oxygenated muriatic acid*, which Dr Pearson contracted into *oxy-muriatic acid*; and this last name we have adopted, because it is shorter and equally distinct.

431 Its composition.

The true theory of the formation and composition of this acid, which was first given by Berthollet, will appear from the following facts: The *black* oxyd of manganese is, during the process, converted into *white* oxyd, and must therefore have given out a quantity of oxygen. When oxy-muriatic acid dissolved in water is presented to the light in a vessel half empty, oxygen gas is disengaged and floats above, and the acid is converted

condensed muriatic acid gas, we have from the above equation $l = \frac{m + m' - l' D}{D} = \frac{5}{1,5} = 3,3$; and $d = \frac{m}{l} = \frac{10}{3,3} = 3,03$. *See Irish Transactions*, vol. iv.

This calculation, however, is formed upon the supposition that the water suffers no condensation at all—a supposition certainly contradicted by every analogy, and which, as Mr Keir has shewn, the experiments mentioned in Mr Kirwan's first paper are insufficient to prove.

Oxy-muriatic Acid.

verted into common muriatic acid: Consequently oxy-muriatic acid is composed of muriatic acid and oxygen. Black oxyd of manganese is composed of white oxyd and oxygen; muriatic acid has a stronger affinity for oxygen than the white oxyd; during the distillation the black oxyd is decomposed, the oxygen combines with muriatic acid, and the product is oxy-muriatic acid gas.

432
Its properties.

Oxy-muriatic acid gas is of a yellow colour. It supports flame, but cannot be breathed without proving noxious. The death of the ingenious and industrious Pelletier, to whom we have so often referred, was occasioned by his attempting to respire it. A consumption was the consequence of this attempt, which, in a short time, proved fatal.

It does not unite readily with water. Scheele found, that after standing 12 hours over water, 4/5ths of the gas were absorbed: the remainder was common air, which no doubt had been contained in the vessel before the operation. Berthollet surrounded several bottles containing it with ice: as soon as the water in these bottles was saturated, the gas became concrete, and sunk to the bottom of the vessels; but the smallest heat made it rise in bubbles, and endeavour to escape in the form of gas*. Westrum observed that it became solid when exposed in large vessels to the temperature of 40°; and that then it exhibited a kind of crystallization†. The specific gravity of water saturated with this gas at the temperature of 43°, is 1,003‡. Water impregnated with it has not an acid, but an austere taste§, unlike that of other acids.

* *Jour. de Phys.* 1785.
† *Jour. de Physique*, xxxvii. 382.
‡ *Berthollet, Jour. de Phys.* 1785.
§ *Scheele.*

It renders vegetable colours *white*, and not red, as other acids do; and the colour thus destroyed can neither be restored by acids nor alkalies. It has the same effects on yellow wax. If the quantity of vegetable colours to which it is applied be sufficiently great, it is found reduced to the state of common muriatic acid. Hence it is evident, that it destroys these colours by communicating oxygen. This property has rendered oxy-muriatic acid a very important article in bleaching.

Nitrous gas, hydrogen, sulphur, sulphurous acid, and phosphorus, decompose this acid, by depriving it of its oxygen, and leaving the muriatic acid in a separate state. Phosphorus, however, does not produce this effect so readily, except when assisted by heat*.

* *Morveau, Encycl. Method. Chimie* I. 251.

433
Nitro-muriatic acid.

When muriatic acid is mixed with nitric acid, the compound has precisely the smell and the qualities of oxy-muriatic. It can scarcely be doubted, therefore, that as far as it acts as an acid, different from the muriatic and the nitric, it is nothing else but oxy-muriatic acid.

This mixture of the two acids was formerly called *aqua regia;* but at present it is called by the French chemists *nitro-muriatic acid.* It is first mentioned by Isaac the Hollander, and seems to have been known before the muriatic acid itself. It was prepared by pouring nitric acid on common salt. The nitric acid decomposes the salt, and part of it unites with the muriatic acid thus set at liberty.

434
Its action on other bodies.

Oxy-muriatic acid oxydates all the metals (except, perhaps, titanium) without the assistance of heat.

It decomposes red sulphuret of mercury, or cinnabar, which neither sulphuric nor nitric acid is able to accomplish†.

† *Bergman.*

All the substances placed before muriatic acid in the table of the affinities of oxygen, are capable of decomposing this acid. Many of them, when plunged into it while in the state of gas, actually take fire. Westrum observed, for instance, that when pieces of wood were plunged into this gas, they took fire; that arsenic burned with a blue and green flame; bismuth, with a lively bluish flame; nickel, with a white flame, bordering on yellow; cobalt, with a white flame, approaching to blue; zinc, with a lively white flame; tin, with a feeble bluish flame; lead, with a sparkling white flame; copper and iron, with a red flame: that powdered charcoal took fire in it at the temperature of 90°, and that ammonia produced with it a loud detonation‡.

‡ *Jour. de Physique*, xxxvii. 385.

With alkalies, earths, and metallic oxyds, it is capable of combining and forming neutral salts, which have been called *oxy-muriats.*

435
Its affinities.

The affinities of this acid, according to Lavoisier, are as follows:

Alumina,
Jargonia*?
Ammonia,
Oxyd of antimony,
——— Silver,
——— Arsenic,
Barytes,
Strontites?
Oxyd of bismuth,
Lime,
Oxyd of cobalt,
——— Copper,
——— Tin,
——— Iron,
Magnesia (B),
Oxyd of manganese,
——— Mercury,
——— Molybdenum,
——— Nickel,
——— Gold,
——— Platinum,
——— Lead,
Potass,
Soda,
Oxyd of tungsten,
——— Zinc (C).

* *Vauquelin, Ann. de Chim.* xxii. 208.

436
Of the component parts of muriatic acid.

The component parts of muriatic acid are still imperfectly known. Dr Girtanner pretended, about the year 1790, that he had decomposed it; and that it consisted of hydrogen combined with a greater proportion of oxygen than enters into the composition of water. He passed electrical explosions through muriatic acid, and

(B) According to Tromsdorf, oxy-muriatic acid is incapable of combining with magnesia. *Ann. de Chim.* xxii. 218.

(C) This is the order of the affinities of nitro-muriatic acid. Many facts (some of which shall appear afterwards) concur to prove that the affinities of the oxy-muriatic acid are the same, and indeed that they are the same acids.

Oxy-muriatic Acid.

and obtained a quantity of oxygen and hydrogen gas. But a repetition of these experiments shewed, that the gases were owing, not to the decomposition of the acid, but to that of the water with which the acid was combined.

The experiments of Mr Lambe (D) have lately opened a new and unexpected path, which seems to lead directly to the discovery of the component parts of this acid. He found, that when iron was acted upon by sulphurated hydrogen gas, a substance was produced which possessed all the properties of oxy-muriat of iron (oxy-muriatic acid combined with iron). The sulphurated hydrogen gas which he used was obtained from sulphuret of iron, formed by fusing equal parts of iron and flowers of sulphur; and it was extricated by diluted sulphuric acid. In a solution of this gas in distilled water, he digested iron-filings, previously purified by repeated washings with distilled water. The bottle was filled with the solution, and corked. The iron was presently acted upon; numerous bubbles arose, which drove the cork out of the bottle; they were strongly inflammable, and probably, therefore, pure hydrogen gas. The liquor gradually left its odour of sulphurated hydrogen gas, and after some days smelled very much like stagnant rain water. As the bubbles ceased to be produced, it recovered its transparency. On evaporating a small quantity of this solution in a watch-glass to dryness, a bitter deliquescent salt was left behind. On this salt a little sulphuric acid was dropped, and paper moistened with ammonia was held over the glass; white vapours were immediately formed over the glass; and consequently some volatile acid was separated by the sulphuric acid. Mr Lambe evaporated about eight ounce-measures of the same liquor, and, as before, dropped a little sulphuric acid on the residuum; a strong effervescence was excited, very pungent acid fumes arose, which, from their smell, were readily known to be muriatic. The same truth was established beyond a doubt, by holding a bit of paper moistened with water, which made the vapours visible in the form of a grey smoke; a distinguishing characteristic, as Bergman has observed, of the muriatic acid.—When manganese and mercury were dissolved in sulphurated hydrogen gas, the salts formed gave the same unequivocal marks of the presence of muriatic acid†.

† *Lambe*, *ibid.*

Shall we conclude from these facts, that the basis of muriatic acid is sulphurated hydrogen; that muriatic acid is sulphurated hydrogen combined with oxygen; that this combination takes place during the solution of the iron; and that the escape of hydrogen is owing to the decomposition of the water? (23)

SECT. VII. *Phosphoric Acid.*

Phosphoric Acid.

437 Discovery of phosphorus.

PHOSPHORUS is capable of forming combinations with two different quantities of oxygen; with the larger it forms phosphoric; and with the smaller phosphorus acid.

Phosphoric acid was unknown till after the discovery of phosphorus. Boyle is perhaps the first person who mentions it: he discovered it by allowing phosphorus to burn slowly in common air. But Margraf was the first person who examined its properties, and discovered it to be a peculiar acid.

It may be procured by exposing phosphorus to a moderate heat: the phosphorus takes fire, combines with oxygen, and is converted into an acid.

438 Method of preparing it.

It may also be prepared by exposing phosphorus during some weeks to the ordinary temperature of the atmosphere, even in winter; when the phosphorus undergoes a slow combustion, and is gradually changed into a liquid acid. For this purpose, it is usual to put small pieces of phosphorus on the inclined side of a glass funnel, through which the liquor which is formed drops into the bottle placed to receive it. From one ounce of phosphorus about three ounces of acid liquor may be thus prepared, called *phosphoric acid by deliquescence*.

Scheele has contrived another mode of obtaining the phosphoric acid from phosphorus without combustion, by the mere action of the nitric acid on phosphorus‡. Mr Lavoisier has repeated and described this process§. He put two pounds of nitric acid, the specific gravity of which was 1,29895, into a retort, the contents of which were equal to six or seven French pints, and to which a balloon was fitted. Having placed this retort in a sand-bath, and brought the heat of the acid contained in it to $133\frac{1}{4}$ deg. he added successively small quantities of phosphorus, about ten or twelve grains at a time, until he had dissolved $2\frac{1}{4}$th oz. At first the effervescence was great, but at last he was obliged to apply heat to effect the solution. The operation lasted 17 or 18 hours. A good deal of nitrous acid had passed into the receiver. He then poured the contents of the retort into a smaller retort, and evaporated by means of a stronger heat, until the phosphoric acid began to distil in white vapours. The remaining acid was so thick, that he could not pour it out of the retort, and therefore could not ascertain its quantity; but he supposes it might be eight or nine ounces, in which he thinks there were about $2\frac{1}{4}$ ounces of phosphorus; the remaining $\frac{1}{4}$ ounce being supposed to have evaporated. The quantity of oxygen imbibed he reckons at $3\frac{1}{2}$ ounces, and the quantity of water at about 2 ounces.

‡ *On Fire*, § lxxvii.

§ *Mem. Acad.* 1780.

Lavoisier

(D) Analysis of the waters of two mineral springs at Leminton Priors. *Manchester Memoirs*, vol. V. part 1st.

(23) If these experiments be correct, and muriatic acid is really composed of sulphurated hydrogen and oxygen, it would enable us to explain many phænomena which have heretofore been inexplicable. The immense quantities of sulphurated hydrogen which we excrete would no longer be a mystery, as the muriatic acid we take in would be a sufficient source to derive it from. The action of sulphurets on most metals might be accounted for, and even the solution of *gold* in the sulphuret of potash or *hepar sulphuris* might at least receive a plausible explanation. These and various other phænomena in chemistry which are at present inexplicable might be accounted for upon this composition of muriatic acid; but it is waste of time to form explanations which must rest on a foundation so slightly laid. T. P. S.

Phosphoric Acid.

Lavoisier computes, that phosphoric acid contains 100 parts of phosphorus and 154 of oxygen.

439 Its properties.

The colour of this acid is white; it has no smell, has an acid taste, but is not corrosive(E.)

It is exceedingly fixed. When exposed to the fire in a matrass with a long neck, it loses at first the greater part of its water; then an odour of garlic is felt, owing to some phosphorus from which it is exceedingly difficult to clear it entirely; there is likewise a small quantity of the acid volatilized along with the water. The liquor then becomes thick and milky: small luminous decrepitations take place from time to time, and they continue for some time after the vessel is taken from the fire. If the matter be then put into a crucible and placed among burning coals, it first boils violently, and gives out a vapour which tinges flame green, and is at last converted to a white transparent glass, insoluble in water.

The specific gravity of this acid in a state of dryness is 2,687†, that of phosphoric acid by deliquescence 1.417*. It is capable of crystallizing; its crystals are quadrangular prisms terminated by quadrangular pyramids.

† *Bergman.* * *Morveau.*

Phosphoric acid obtained by deliquescence, when mixed with an equal quantity of distilled water, acquired so little *heat* as to raise the thermometer only one degree, as Mr Sage observed.

Mr Lavoisier raised Reaumur's thermometer from 8° to 14° or 15° by mixing phosphoric acid boiled to the consistence of a syrup, with an equal quantity of water; and from 8° to 32° or 33° when the acid was as thick as turpentine*.

* *Keir's Dictionary.*

440 Its action on other bodies.

Phosphoric acid is capable of oxydating iron, tin, lead, zinc, antimony, bismuth, manganese. When fused with several of these metals, as tin, lead, iron, and zinc, it is converted into phosphorus; a proof that they have a stronger affinity for oxygen.

It does not act upon gold, platinum, silver, copper, mercury, arsenic, cobalt, nickel. It appears, however, to have some action on gold in the *dry way*, as it is called; for when fused with gold-leaf, it assumes a purple colour; a proof that the gold has been oxydated.

It is capable of combining with alkalies, alkaline earths, alumina, and metallic oxyds; and of forming salts, known by the name of *phosphats*.

Phosphoric acid, by the assistance of heat, is capable of decomposing glass.

441 Its affinities.

Its affinities are as follows:

- Lime,
- Barytes,
- Strontites‡
- Magnesia,
- Potass,
- Soda,
- Ammonia,
- Alumina,
- Jargonia*,
- Metallic oxyds, as in sulphuric acid,
- Water.

‡ *Hope, Transf. Edin.* IV.

* *Vauquelin, Ann. de Chim.* xxii. 208.

442 Phosphorous acid.

The Phosphorous Acid is formed when phosphorus is exposed to a slow spontaneous combustion at the temperature of the atmosphere; but it gradually absorbs more oxygen, and is converted into phosphoric acid.

Concerning phosphorous acid, nothing of any consequence is at present known, except that it contains less oxygen than phosphoric acid.

Boracic Acid.

Sect. VIII. *Boracic Acid.*

443 Borax.

The word *borax* first occurs in the works of Geber, an Arabian chemist of the tenth century. It is a name given to a species of white salt much used by various artists. Its use in soldering metals appears to have been known to Agricola.

Borax is found mixed with other substances in Thibet. It seems to exist in some lands adjacent to lakes, from which it is extracted by water, and deposited in those lakes: whence in summer, when the water is shallow, it is extracted and carried off in large lumps. Sometimes the water in these lakes is admitted into reservoirs, at the bottom of which, when the water is exhaled by the summer's heat, this salt is found.—Hence it is carried to the East-Indies, where it is in some measure purified and crystallized: in this state it comes to Europe, and is called *tincal*. In other parts of Thibet, it seems, by accounts received from China, they dig it out of the ground at the depth of about two yards, where they find it in small crystalline masses, called by the Chinese *mi poun*, *hovi poun*, and *pin poun*; and the earth or ore is called *pounxa**.

* *Kirwan's Mineralogy*, ii. 37.

444 Discovery of boracic acid.

Though borax has been in common use for nearly three centuries, it was only in 1702 that Homberg, by distilling a mixture of borax and green vitriol, discovered the *boracic acid*. He called it *narcotic* or *sedative salt*, from a notion of his that it possessed the properties indicated by these names. In his opinion, it was merely a product of the vitriol which he had used; but Lemery the Younger soon after discovered, that it could likewise be obtained from borax by means of the nitric and muriatic acids. Geoffroi afterwards discovered, that borax contained soda; and at last Baron proved, by a number of experiments, that borax was composed of boracic acid and soda; that it might be reproduced by combining these two substances—and that therefore the boracic acid was not formed during the decomposition of borax as former chemists had imagined, but was a peculiar substance which pre-existed in that salt.

445 Attempts to prove that it does not exist in borax;

This conclusion has been called in question by Mr Cadet*; who affirmed, that it was composed of *soda*, *the vitrifiable earth of copper*, *another unknown metal*, and *muriatic acid*. But this assertion has never been confirmed by a single proof; Mr Cadet has only proved, that boracic acid sometimes contains copper; and Beaumé's experiments are sufficient to convince us, that this metal is merely accidentally present, and that it is probably derived from the vessels employed in crystallizing borax: That boracic acid generally contains a little of the acid employed to separate it from the soda, with which it is combined in borax: And that crude borax contains a quantity of earth imperfectly saturated with boracic acid:—All which may be very true; but they are altogether insufficient to prove that boracic

* *Journ. de Phys.* 1782.

(E) We have observed, however, that when very much concentrated it destroyed the texture of vegetable substances, paper, for instance, very completely.

Boracic Acid.

cic acid is not a peculiar fubftance, fince it difplays properties different from every other body.

446 And to prove that it is phofphoric acid.

Meffrs Exfchaquet and Struve have endeavoured, on the other hand, to prove, that the phofphoric and boracic acids are the fame. But their experiments merely fhew, that thefe acids refemble one another in feveral particulars; and though they add confiderably to our knowledge of the properties of the phofphoric acid, they are quite inadequate to eftablifh the principle which thefe chemifts had in view; fince it is not fufficient to prove the identity of the two acids, to fhew us a refemblance in a few particulars, while they differ in many others. Boracic acid muft therefore be confidered as a diftinct fubftance, the component parts of which are entirely unknown.

447 Method of procuring it.

The eafieft method of procuring boracic acid is the following one: Diffolve borax in hot water, and filter the folution; then add fulphuric acid, by little and little, till the liquor be rather more than faturated. Lay it afide to cool, and a great number of fmall, fhining, laminated cryftals will form. Thefe are the boracic acid. They are to be wafhed with cold water, and drained upon brown paper.

448 Its properties.

This acid has a fourifh tafte at firft, then makes a bitterifh cooling impreffion, and at laft leaves an agreeable fweetnefs. Its cryftals have fome refemblance to fpermaceti, and it has the fame kind of feel.

It changes vegetable blues to red; it has no fmell; but when fulphuric acid is poured on it, a tranfient odour of mufk is produced*. The air produces no change on it.

* *Reufs De Sale Sedat.* 1778.

According to Reufs, it is foluble in 20 parts of cold water, eight parts of warm water, and 2,5 of boiling water. According to Wenzel, 960 grains of boiling water, diffolve 434 of this acid. According to Morveau, one pound of boiling water diffolves only 183 grains.

It is exceedingly fixed when not combined with water. When expofed to a violent fire it is converted into a white tranfparent glafs; which, however, is foluble in water, and produces the acid again by evaporation.

Boracic acid is alfo foluble in alcohol; and alcohol containing it burns with a green flame.

Its fpecific gravity is 1,479†.

† *Kirwan's Miner.* ii. 4.

Paper dipped into a folution of boracic acid burns with a green flame.

Though mixed with fine powder of charcoal, it is neverthelefs capable of vitrification; and with foot it melts into a black bitumen-like mafs, which is, however, foluble in water, and cannot be eafily calcined to afhes, but fublimes in part†.

† *Keir's Dictionary.*

With the affiftance of a diftilling heat it diffolves in oils, efpecially in mineral oils, and with thefe it yields fluid and folid products, which give a green colour to fpirit of wine.

When boracic acid is rubbed with phofphorus, it does not prevent its inflammation, but an earthy yellow matter is left behind†.

† *Ibid.*

449 Its action on other bodies.

It is hardly capable of oxydating, or diffolving any of the metals except iron and zinc, and perhaps copper.

Boracic acid combines with alkalies, alkaline earths, and alumina, and moft of the metallic oxyds, and forms compounds which are called *borats*.

450 Its affinities.

Its affinities are as follows

Lime,
Barytes,
Strontites‡,
Magnefia,
Potafs,
Soda,
Ammonia,
Oxyd of zinc,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— mercury,
Alumina,
Jargonia§,
Water,
Alcohol.

‡ *Dr Hope, Transf. Edin.* IV.

§ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. IX. *Fluoric Acid.*

Fluoric Acid.

451 Difcovery of fluoric acid.

The mineral called *fluor* or *fufible fpar*, was not properly diftinguifhed from other fpars till Margraf publifhed a differtation on it in the Berlin Tranfactions for 1768. He firft proved, that it contained no fulphuric acid, as had been formerly fuppofed; he then attempted to decompofe it, by mixing together equal quantities of this mineral and fulphuric acid, and diftilling them. By this method he obtained a *white fublimate*, which he fuppofed to be the fluor itfelf volatilized by the acid. He obferved, with aftonifhment, that the glafs retort was corroded, and even pierced with holes. Nothing more was known concerning fluor till Scheele publifhed his experiments three years after; by which he proved, that it was compofed chiefly of lime and a particular acid which has been called *fluoric acid*.

452 Method of obtaining it.

To obtain it, put eight ounces of finely powdered fluor into a retort, and pour on it an equal quantity of fulphuric acid, and lute to the retort as exactly as poffible, a receiver containing eight ounces of water. Vapours immediately appear and darken the infide of the veffel: Thefe are the acid in the ftate of gas. The diftillation is to be conducted with a very moderate heat, not only to allow the gas to condenfe, but alfo to prevent the fluor itfelf from fubliming. After the procefs, a cruft of white earth is found in the receiver, which has all the properties of filica.

Scheele fuppofed, that the filica produced was formed of fluoric acid and water; and Bergman adopted the fame opinion. But Wiegleb and Buccholz fhewed, that the quantity of filica was exactly equal to what the retort loft in weight; and Meyer completed the proof that it was derived from the glafs, by the following experiment: He put into each of three equal cylindrical tin veffels a mixture of three oz. of fulphuric acid and one oz. of fluor, which had been pulverized in a mortar of metal. Into the firft he put one oz. of pounded glafs; into the fecond, the fame quantity of quartz in powder; and into the third, nothing. Above each of the veffels he hung a fponge moiftened with water; and having covered them, he expofed them to a moderate heat. The fponge in the firft cylinder was covered with the cruft in half an hour; the fponge in the fecond in two hours; but no cruft was formed in the third, though it was expofed feveral days. In confequence of this decifive experiment, Bergman gave up his opinion, and wrote an account of Meyer's

Fluoric Acid.

Meyer's experiment to Morveau, who was employed in tranflating his works, to enable him to correct the miftake in his notes.

453 Attempts to difprove its exiftence.

Soon after the difcovery of this acid, difficulties and doubts concerning its exiftence as a peculiar acid were ftarted by fome French chemifts, difguifed under the name of Boulanger, and afterwards by Mr Achard and Mr Monnet. To remove thefe objections, Mr Scheele inftituted and publifhed a new fet of experiments: which not only completely eftablifhed the peculiar nature of the fluoric acid, but once more difplayed the unrivalled abilities of the illuftrious difcoverer. Thefe important particulars we pafs over thus flightly, becaufe they have been partly treated of already in the article CHEMISTRY (*Encycl.*) One experiment, however, we cannot omit, becaufe it is fufficient of itfelf to deftroy almoft all the objections of his antagonifts, which confifted in attempting to prove, that the fluoric acid was merely a modification of the acid employed to extract it. We fhall give it in Mr Scheele's own words.

454 Refuted by Scheele,

"I melted together (fays he) in a crucible two ounces of finely pulverized fluor fpar with four ounces of potafs. As foon as they were melted, I poured out the mafs, rubbed it, when it was become cold, to a powder, and extracted the alkali from it again by lixiviation with water. I evaporated the lixivium to drynefs; and threw away the remaining undiffolved powder (which was only one of the component parts of the fluor, and which diffolved readily, and with effervefcence, in acids) from its folution, in which it may be precipitated by fulphuric acid in the form of felenite (fulphat of lime). Upon a little of the dried alkali, put into a fmall retort, I poured fome fulphuric acid, fitted to it a receiver containing fome water; and even before the retort was become hot, I obferved this water to be covered over with a pellicle of filiceous earth: a certain proof that the alkali had extracted the acid from the fluor during its expofure to the fire with it. Should Mr Achard, agreeably to the opinion which he has adopted, conclude from this experiment, that the alkali feparated the volatile earth from the fluor (F); ftill he muft certainly allow this earth of his to be of an acid nature, fince the alkali is capable of difengaging it from the calcareous earth.—The remaining portion of the dried alkali I diffolved again in water, and faturated the fuperfluous alkali with pure nitric acid. After expelling from this faturated folution, by means of heat, the carbonic acid gas, which in fuch cafes is always retained in the liquor, I dropped fome of it into lime-water; whereupon I obtained a white precipitate, which was a regenerated fluor. I now diffolved fome oxyd of lead in vinegar, and continued to add to the ley, which had been faturated with nitric acid, as much of this folution as was requifite, till all precipitation ceafed. Thus I transferred the fluor acid from the alkali to the oxyd of lead. After wafhing the precipitate in cold water, and drying it, I dropped upon a fmall quantity of it a few drops of fulphuric acid: a frothing up immediately enfued, accompanied with an extrication of fluor acid vapours. But perhaps, in this cafe, the volatile earth of fluor unites with the fulphuric acid, and converts this fixed, or almoft fixed acid into acid gas. I can eafily make allowance to Dr Prieftley for being inclined to draw fuch a conclufion, fince this celebrated philofopher does not pretend to be a chemift (G). Being defirous of feeing whether heat alone was capable of expelling this acid from the oxyd of lead, I put a little of this fluorated oxyd into a fmall retort, the receiver to which contained fome water. The oxyd was melted; but I could not perceive any acid. The bottom of the retort was moreover quite corroded and diffolved, fo that the whole ran into the fire. Thus the oxyd of lead retains this acid in the fire, and will not part with it, unlefs the oxyd is combined with fome other fubftance. I therefore rubbed the remainder of my fluorated oxyd of lead with an equal quantity of charcoal powder, and diftilled the mixture in an open fire in a fmall glafs retort, to which was adapted a receiver containing fome water. As foon as the reduction of the oxyd of lead took place, the neck of the retort became incrufted with a white fublimate, and a filiceous pellicle appeared upon the water. The fublimate had a four tafte, becaufe the filiceous earth of which it confifts is penetrated with fluoric acid; and the acid water in the receiver let fall, on the addition of volatile alkali, a filiceous earth†."

Sorry are we to add, that fince the death of this admirable man, to ufe the words of Mr Kirwan‡, a man as eminent in the chemical as Newton in the mathematical branch of natural philofophy, Mr Monnet § has thought proper to renew his attacks in a ftyle of haughtinefs and acrimony that infpires infinite difguft. The fallacy of his reafoning is fufficiently expofed by Mr Leonhardi, in the 6th volume of his late learned edition of Macquer's Dictionary.

† Crell's Journal, I. 222. English tranflation.

‡ Mineralogy, I. 126.

§ Journ. de Phyf. xxx. 253.

455 And Leonhardi.

Fluoric acid may be obtained in the form of gas, by applying a moderate heat to fulphuric acid and fluor fpar, and receiving the product over mercury.

456 Its properties.

This gas is the acid in a ftate of purity. It is invifible and elaftic like air; it does not maintain combuftion, nor can animals breathe it without death. It has a pungent fmell, not unlike that of muriatic acid.

It is heavier than common air. It corrodes the fkin almoft inftantly. It combines rapidly with water; and if it has been obtained by means of glafs veffels, it depofits at the fame time a quantity of filica.

Water impregnated with this gas does not freeze at a higher temperature than 23°*.

* Prieftley, ii. 362.

457 Its action on other bodies.

In the ftate of gas this acid does not act upon nitrous gas nor fulphur. Alcohol and ether abforb it, but it does not alter their qualities†.

It is capable of oxydating iron, zinc, copper, and arfenic.

† Ibid.

It does not act upon gold, platinum, filver, mercury, lead, tin, antimony, cobalt.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms compounds denominated *fluats*.

It is capable, as we have feen, of diffolving filica, which is infoluble in every other acid; accordingly it corrodes

(F) Mr Achard affirmed, that fluor was compofed of a peculiar volatile earth.

(G) Dr Prieftley at firft advanced this hypothefis; but he afterwards gave it up.

Carbonic Acid.

corrodes glafs. This property has induced feveral ingenious men to attempt, by means of it, to engrave, or rather etch, upon glafs.

458 Its affinities.

The affinities of fluoric acid are as follows:

Lime,
Barytes,
Strontites*,
Magnefia,
Potafs,
Soda,
Ammonia,
Oxyd of zinc,
——— manganefe †,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arfenic,
——— bifmuth,
——— mercury,
——— filver,
——— gold,
——— platinum,
Alumina,
Jargonia ‡ ?
Water,
Silica,
Alcohol.

* Dr Hope.

† Lavoifier.

‡ Vauquelin, Ann. de Chim. xxii. 208.

SECT. X. *Of Carbonic Acid.*

CARBONIC acid is compofed of carbon and oxygen. According to Lavoifier's experiments, the proportions are 28 parts of carbon and 72 of oxygen. Mr Prouft informs us, that there is alfo a *carbonous acid* (H); but with this acid we are not at prefent acquainted, and cannot therefore defcribe it.

459 Difcovery of carbonic acid.

Paracelfus and Van Helmont were acquainted with the fact, that air is extricated from folid bodies during certain proceffes, and the latter gave to air thus produced the name of *gas*. Boyle called thefe kinds of air *artificial airs*, and fufpected that they might be different from the air of the atmofphere. Hales afcertained the quantity of air that could be extricated from a great variety of bodies, and fhewed that it formed an effential part of their compofition. Dr Black proved, that the fubftances then called *lime*, *magnefia*, and *alkalies*, are compounds, confifting of a *peculiar fpecies of air*, and pure lime, magnefia, and alkali. To this fpecies of air he gave the name of *fixed air*, becaufe it exifted in thefe bodies in a fixed ftate. This air or gas was afterwards inveftigated by Dr Prieftley, and a great number of its properties afcertained. From thefe properties Mr Keir† firft concluded that it was an acid; and this opinion was foon confirmed by the experiments of Bergman, Fontana, &c. Dr Prieftley at firft fufpected that this acid entered as an element into the compofition of atmofpherical air; and Bergman adopting the fame opinion, gave it the name of *aerial acid*. Mr Bewdly called it *mephitic acid*, becaufe it could not be refpired without occafioning death; and this name was alfo adopted by Morveau. Mr Keir called it *calcareous acid*; and at laft Mr Lavoifier, after difcovering its compofition, gave it the name of *carbonic acid gas*.

† Keir's Macquer, art. *Air*.

460 Theories about its compofition.

The opinions of chemifts concerning the *compofition* of carbonic acid have undergone as many revolutions as its name. Dr Prieftley and Bergman feem at firft to have confidered it as an element; and feveral celebrated chemifts maintained that it was the acidifying principle. Afterwards it was difcovered that it was a compound, and that oxygen gas was one of its component parts. Upon this difcovery the prevalent opinion of chemifts was, that it confifted of oxygen and phlogifton; and when hydrogen and phlogifton came (according to Mr Kirwan's theory) to fignify the fame thing, it was of courfe maintained that carbonic acid was compofed of oxygen and hydrogen: and though Mr Lavoifier demonftrated, that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; becaufe carbon was itfelf confidered as a compound, into which a very great quantity of hydrogen entered. But after Mr Lavoifier had demonftrated, that the weight of the carbonic acid produced was precifely equal to the carbon and oxygen employed; after Mr Cavendifh had difcovered that oxygen and hydrogen when combined did not form carbonic acid, but water—it was no longer poffible to hefitate that this acid was compofed of carbon and oxygen. Accordingly all farther difpute about it feems now at an end. At any rate, as we have already examined the objections that have been made to this conclufion, it would be improper to enter upon them here.

461 Its analyfis.

If any thing was ftill wanting to put this conclufion beyond the reach of doubt, it was to *decompound* carbonic acid, and thus to exhibit its component parts by analyfis as well as fynthefis. This has been actually done by the ingenious Mr Tennant. Into a tube of glafs he introduced a bit of phofphorus and fome carbonat of lime. He then fealed the tube hermetically, and applied heat. Phofphat of lime was formed, and a quantity of carbon depofited. Now phofphat of lime is compofed of phofphoric acid and lime; and phofphoric acid is compofed of phofphorus and oxygen. The fubftances introduced into the tube were phofphorus, lime and carbonic acid; and the fubftances found in it were phofphorus, lime, oxygen, and carbon. The carbonic acid, therefore, muft have been decompofed, and it muft have confifted of oxygen and carbon. This experiment was repeated by Dr Pearfon, who afcertained that the weight of the oxygen and carbon were together equal to that of the carbonic acid which had been introduced; and in order to fhew that it was the carbonic acid which had been decompofed, he introduced pure lime and phofphorus; and inftead of obtaining phofphat of lime and carbon, he got nothing but

(H) When there are two acids having the fame bafe, but containing different quantities of oxygen, they are diftinguifhed by their termination. The name of that which contains moft oxygen ends in *ic*, the other in *ous*. Thus fulphuric and fulphurous acids, nitric and nitrous, phofphoric and phofphorous, carbonic and carbonous.

Carbonic Acid.

but phosphuret of lime. These experiments were also confirmed by Messrs Fourcroy, Vauquelin, Sylvestre, and Brogniart(I)†.

† Ann. de Chim. xiii. 312.

Carbonic acid may be obtained by pouring sulphuric acid upon chalk, and receiving the product in a pneumatic apparatus.

462 Its properties,

It is invisible and elastic like common air. It extinguishes a candle, and is unfit for respiration. It has no smell.

‡ Bergman, i. 9.

Its specific gravity is 0.0018‡; but this varies according to its dryness or moisture.

It reddens the tincture of turnsoil, but no other vegetable colour*.

* Ibid.

Atmospheric air contains about $\frac{1}{100}$ part of this gas(K).

Water absorbs it by agitation, or by allowing it to remain long in contact with it. At the temperature of 41° water absorbs its own bulk of this gas. The specific gravity of water saturated with it is 1,0015. This water at the temperature of 35°, has little taste; but if it be left a few hours in the temperature of 88°, it assumes an agreeable acidity, and a sparkling appearance†.

† Ibid.

Ice absorbs no carbonic acid; and if water containing it be frozen, the whole separates in the act of freezing‡.

‡ Priestley, i. 120.

This gas also separates from water at the boiling temperature||.

|| Ibid.

Alcohol and oil of turpentine absorb double their weight of this gas; olive oil its own bulk. Ether mixes with it in the state of gas§.

§ Bergman, ibid.

Phosphorus suffers no change in this gas except it contains a mixture of oxygen gas¶. It has an affinity for common air. Bergman left a bottle of it uncorked, and found that in a few days it contained nothing but common air. Common air, indeed, has so strong an affinity for this gas, that it attracts it from water, as Mr Welter has observed*.

¶ Brugnatelli, Nicholson's Journal, i. 446.

* Ann. de Chim. iii. 91.

It is absorbed by red hot charcoal, as Morozzo and La Metherie have shewn.

463 Compounds,

It is capable of combining with alkalies, alkaline earths, and alumina, and several metallic oxyds, and of forming compounds known by the name of *carbonats*. It has no affinity for jargonia, according to Klaproth*; but according to Vauquelin, it has†.

* Journ. de Phys. xxxvi. 186.

† Ann. de Chim. xxii. 204.

464 And affinities.

Its affinities, as arranged by Bergman, are as follows:

Barytes,
Lime,
Strontites‡,
Potass,
Soda,
Magnesia,
Alumina,
Metallic oxyds, as in *sulphuric acid*,
Oxygen gas||,
Water,
Alcohol.

‡ Dr Hope.

|| Mr Welter.

Sect. XI. *Of Acetous Acid.*

Acetous Acid.

Acetous acid or vinegar was known many ages before the discovery of any other acid, those only excepted which exist ready formed in vegetables. It is mentioned by Moses, and indeed seems to have been in common use among the Israelites and other eastern nations at a very early period.

The methods of procuring, purifying and concentrating this acid have been already given in the articles Chemistry, Fermentation, and Vinegar *(Encycl.)* and cannot therefore be repeated in this place.

It has been ascertained beyond a doubt, that this acid is composed of carbon, hydrogen, and oxygen; but neither the manner in which these substances are combined, nor their proportions, have been accurately ascertained.

Acetous acid, as commonly prepared, is very fluid, has a pleasant smell and an acid taste. It reddens vegetable colours. In this state it is mixed with a great proportion of water; but Mr Lowitz of Petersburg has discovered that it may be obtained in a solid crystallized form. Of this curious and instructive process we shall transcribe his own account*.

465 Lowitz's method of obtaining pure acetous acid.

* Crell's Journal, i. 242. Eng. transl.

"I have long been accustomed (says he) to prepare concentrated vinegar by congelation in the following manner: I freeze a whole barrel of vinegar as much as possible, then distil the remaining unfrozen vinegar in a water-bath; by which means I at first especially collect the spirituous etherial part; the vinegar, which next comes over, I freeze again as much as possible, and afterwards purify it by distilling it again with three or four pounds of charcoal powder. Thus I never fail to get a very pure sweet-smelling, highly concentrated vinegar; the agreeable odour of which, however, may be still further improved by the addition of a proper quantity of the etherial liquor collected at the beginning of the first distillation, but which must be previously dephlegmated by two or three rectifications.

"After the distillation in the water-bath was over, that no vinegar might be lost, I used to move the retort, with the charcoal powder which remained in it, to a sand-bath; and thus I obtained by means of a strong fire, a few ounces more of a remarkably concentrated vinegar, which was of a yellow colour.

"Having collected about ten ounces of this concentrated vinegar, I exposed it last winter in the month of December to a cold equal to —22°; in which situation it shot into crystals from every part. I let what remained fluid drop away from the crystals into a bason placed underneath, first in the cold air, and afterwards at the window within doors. There remained in the bottle snow-white finely foliated crystals, closely accumulated one upon the other, and which I at first took to be nothing but ice. On placing them upon the warm stove, they dissolved into a fluid which was perfectly as limpid

(I) Count Mouffin-Pouschin having boiled a solution of carbonat of potass on purified phosphorus, obtained carbon. This he considered as an instance of the decomposition of carbonic acid, and as a confirmation of the experiments related in the text. See *Ann. de Chim.* xxv. 105.

(K) At least near the surface of the earth. Lamanon, Monges, and the other unfortunate philosophers who accompanied La Peyrouse in his last voyage, have rendered it not improbable that at great heights the quantity of this gas is much smaller. They could detect none in the atmosphere at the summit of the Peak of Teneriffe See *Lamanon's Memoir at the end of La Perouse's Voyage.*

limpid as water, had an uncommonly ftrong, highly pungent, and almoft fuffocating acetous fmell, and in the temperature of —37° immediately congealed into a folid white cryftallized mafs, refembling camphor.

"After I had obferved that vinegar in this ftate is of fuch an extraordinary ftrength and purity as to be in its higheft degree of perfection, I took all poffible pains to find out a method of obtaining all the acetous acid in the ftate of glacial vinegar.

"To avoid circumlocution, I fhall denote the ftrength of each fort of vinegar which it was neceffary for me to know in my experiments, by degrees, which I afcertain in the following manner: *viz.* to one drachm of vinegar I add, drop by drop, a clear folution of equal parts of carbonat of potafs and water, till all at once a cloudinefs or precipitation appears. Although, on the appearance of this fign, the acid is already fuperfaturated with the alkali, yet it feems to me to be a more accurate teft for afcertaining its ftrength than the ceffation of effervefcence; for as the point of faturation approaches, the effervefcence becomes fo imperceptible, that it is almoft impoffible to determine with precifion when it is really at an end. Now, every five drops of the alkaline folution, which I find it neceffary to add to the vinegar till the precipitation takes place, I reckon as one degree. Thus, for example, if a determinate quantity of vinegar requires 25 drops for that effect, I denote its ftrength by five degrees. This is about the ftrength of good diftilled vinegar.

"I call that vinegar which, in confequence of its concentration, is capable of cryftallizing in a great degree of cold, *cryftallizable vinegar;* the cryftals of vinegar, feparated after the cryftallization is completed from the remaining fluid portion, I call *glacial vinegar;* and, laftly, to the fluid refiduum I give the name of *mother-ley of vinegar.*

"From a great number of experiments, I have found that vinegar muft have at leaft 24 degrees of concentration before it can be brought to cryftallize by expofure to the moft intenfe cold. Vinegar muft be of the ftrength of 42 degrees at leaft in order to become glacial vinegar; *viz.* in this ftate of concentration it has the property of cryftallizing in a degree of cold not exceeding that in which water begins to freeze.

I have found that charcoal, on being diftilled with vinegar in a water bath, poffeffes the fingular and hitherto unknown property of imbibing a certain quantity of the acetous acid in a very concentrated ftate, and of retaining it fo ftrongly, that the acid cannot be feparated from it again, but by the application of a confiderably greater degree of heat than that of boiling water. Upon this circumftance is founded the new method which I have difcovered of concentrating vinegar, fo as to obtain all its acid in the pureft ftate, *viz.* that of a glacial vinegar.

"Let a barrel of vinegar be concentrated by freezing in the manner above defcribed, and let the concentrated vinegar thus obtained, free from all inflammable or fpirituous parts, be put into two retorts: Add to each of them five pounds of good charcoal reduced to a fine powder, and fubject them to diftillation in a water bath. When no more drops of vinegar come over, put the diftilled liquor into two frefh retorts; and after adding five pounds of charcoal powder to each, proceed as before to the diftillation in a water bath. In the mean while, the two firft retorts are to be placed in a fand-bath, that by means of a brifk fire, the cryftallizable vinegar, which is retained in the apparently dry charcoal powder, may be expelled from it. The heat muft be ftrong enough to make the drops follow one another every two feconds; and when, in this degree of heat, 20 feconds intervene between each drop, the vinegar which has been collected muft be removed; for what follows, is hardly any thing elfe but mere water. In this manner about fix ounces and a half of cryftallizable vinegar, which is generally of the ftrength of between 36 and 40 degrees, may be collected from each retort. As foon as the diftillation by the water bath in the two retorts is over, the diftilled liquor is to be poured back again into the firft retorts upon the charcoal powder, which remains in them, and which has been already ufed; and from each of thefe retorts the remaining cryftallizable vinegar (which generally amounts to as much as the firft quantity) is to be abftracted by diftillation in a fand bath. Thefe operations may be alternately repeated till all the acid of the vinegar which had been concentrated by freezing is converted into cryftallizable vinegar; or until the diftilled liquor, conftantly becoming weaker and weaker at every repetition of the diftillation, comes over at length in the ftate of mere water, which, with the above mentioned quantity of charcoal powder, generally happens at the fourth or fifth diftillation. Now, in order to obtain the greateft part of the pure acid contained in the cryftallizable vinegar in the form of glacial vinegar, it muft be fet to cryftallize in a great degree of cold; and the mother-ley muft be afterwards thoroughly drained from the glacial vinegar, by letting it drop from the cryftals, firft in the cold, and then in the room before the window. The mother-ley may be rendered further cryftallizable, by diftilling it with a little charcoal powder; the weaker part, which comes over firft, being put afide. But if a perfon wifhes to keep the cryftallizable vinegar for other purpofes, and without feparating any glacial vinegar from it, he muft diftil the whole of it again with charcoal powder in a fand-bath.

"I have found by accurate experiments, that, by means of this curious procefs, ten pounds of vinegar concentrated by freezing to the 90th degree, may be made to yield 38 ounces of cryftallizable vinegar, from which 20 ounces of glacial vinegar may be obtained.

"What conftitutes the excellence of this method is, that the concentration and purification are effected by one and the fame medium, *viz.* the charcoal powder; in confequence of which, both intentions are fulfilled at the fame time.

"Laft year, after much reflection, I was fo happy as to find out another very effectual method of feparating the acetous acid from the other fubftances combined with it, fo as to obtain it at once in the ftate of a glacial vinegar of the greateft poffible ftrength. The feparating medium which I thought of is fulphat of potafs fuperfaturated with fulphuric acid; a falt in which, conformably to my purpofe, the fulphuric acid exifts in a perfectly dry and dephlegmated ftate.

"By means of this falt a highly concentrated glacial vinegar may be obtained in the following manner:

"Let three parts of acetated foda, prepared with vinegar diftilled over charcoal, and evaporated to perfect drynefs, be melted in a ftrong heat; then pour it out, and

Acetous Acid.

and rub it to a very fine powder. Mix this powder very accurately with eight parts of ſuperſaturated ſulphat of potaſs that has been previouſly well dried, and in like manner reduced to a fine powder; put the whole into a retort, and diſtil with a gentle heat, in ſuch manner, that along with the drops ſome vapours alſo may be perceived to come out of the neck of the retort; but by no means ſo that the receiver ſhall be filled with theſe vapours. Notwithſtanding the moderate heat, the vinegar comes over very faſt, and the quantity of glacial vinegar, of the ſtrength of 54 degrees, which is thus obtained, amounts to nearly two parts."

466 Action of acetous acid on other bodies.

Acetous acid is capable of oxydating iron, zinc, lead, nickel, tin, copper.

It does not act upon gold, ſilver, platinum, mercury, biſmuth, cobalt, antimony, arſenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms compounds known by the name of *acetites*.

467 Its affinities.

Its affinities are as follows:

Barytes,
Potaſs,
Soda,
Strontites?
Lime,
Magneſia,
Ammonia,
Oxyd of zinc,
—— manganeſe,
—— iron,
—— lead,
—— tin,
—— cobalt,
—— copper,
—— nickel,
—— arſenic,
—— biſmuth,
—— mercury,
—— antimony,
—— ſilver,
—— gold,
—— platinum,
Alumina †,
Jargonia?*
Water,
Alcohol.

† *Lavoiſier.*
* *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XII. *Of Acetic Acid.*

If acetite of copper be diſtilled, an acid comes over of a more pungent ſmell than acetous acid, capable of cryſtallizing, and having a ſtronger affinity for other bodies than acetous acid. It is called *acetic acid*, and is ſuppoſed to contain a larger proportion of oxygen than acetous acid. This additional doſe it is ſuppoſed to receive from the oxyd of copper, which during the proceſs is reduced to the metallic ſtate. It can hardly be doubted that the glacial vinegar of Lowitz, deſcribed in the preceding ſection, is really acetic acid, though it would perhaps be difficult to explain its formation. Its affinities are the ſame with thoſe of the acetous acid.

Sect. XIII. *Of Oxalic Acid.*

Oxalic Acid.

Sugar, a well-known ſubſtance extracted from the ſugar-cane, appears to have been uſed in the Eaſt at a very early period; but it made its way weſtward very ſlowly. As a medicine, it is mentioned by Dioſcorides; but it was not in common uſe in Europe till after the 14th century.

468 Compoſition of ſugar.

It has been proved that ſugar is compoſed of oxygen, carbon, and hydrogen. Lavoiſier concluded, from a long ſeries of delicate experiments, that it conſiſts of 8 parts of hydrogen, 64 of oxygen, and 28 of carbon.

469 Diſcovery of oxalic acid.

From ſugar, by a particular proceſs, an acid has been obtained called *oxalic acid*, becauſe it exiſts ready formed, as Scheele has proved, in the *oxalis acetoſella*, or wood ſorrel. At firſt, however, it was called the *acid of ſugar*, or the *ſaccharine acid*.

As the earlieſt and beſt account of the oxalic acid was publiſhed by Bergman, he was for a long time reckoned the diſcoverer of it; but Mr Ehrhart, one of Scheele's intimate friends, informs us, that the world is indebted for its knowledge of this acid to that illuſtrious chemiſt,* and Hermſtadt and Weſtrum aſſign the diſcovery to the ſame author †. The aſſertions of theſe gentlemen, who had the beſt opportunity of obtaining accurate information, are certainly ſufficient to eſtabliſh the fact, that Scheele was the real diſcoverer of oxalic acid.

* *Ehrert's Magazine for Apothecaries*, 1785, Part i. p. 54.
† *Keir's Dictionary.*

470 Method of procuring it.

Bergman gives us the following proceſs for obtaining this acid. "Put one ounce of white ſugar powdered into a tubulated retort, with three ounces of ſtrong nitric acid, the ſpecific gravity of which is to that of water as 1,567. When the ſolution is over, during which many fumes of the nitrous acid eſcape, let a receiver be fitted, and the liquor made to boil, by which abundance of nitrous gas is expelled. When the liquor in the retort acquires a reddiſh brown colour, add three ounces more of nitric acid, and continue the boiling till the fumes ceaſe, and the colour of the liquor vaniſhes. Then let the contents of the retort be emptied into a wide veſſel; and, upon cooling, a cryſtallization will take place of ſlender, quadrilateral priſms, which are often affixed to each other at an angle of 45°. Theſe cryſtals, collected and dried on blotting paper, will be found to weigh 1 $\frac{1}{2}$ dr. 19 gr. By boiling the remaining lixivium with two ounces of nitric acid in the retort, till the red fumes almoſt diſappear, and by repeating the cryſtallization as before, $\frac{1}{2}$ dr. 13 gr. of ſolid acid will be obtained. If the proceſs be repeated once more upon the reſiduum, which has now a glutinous conſiſtence, with the ſucceſſive additions of ſmall quantities of nitric acid, amounting in all to two ounces, a ſaline brown deliqueſcent maſs will be formed, weighing half a dram, of which about a half will be loſt by a farther purification. The cryſtals obtained thus at different times may be purified by ſolution and cryſtallization, and by digeſting the laſt lixivium with ſome nitric acid, and evaporation with the heat of the ſun."

By the ſame proceſs Bergman obtained it from gum arabic, alcohol, and honey; Scheele, Hermſtadt, Weſtrum, Hoffman, &c. from a great variety of other vegetable productions; and Berthollet from a great number of animal ſubſtances.

It is of great conſequence not to uſe too much nitric acid, otherwiſe the quantity of oxalic acid will be diminiſhed; and if a very great quantity of nitric acid be uſed, no oxalic acid will be obtained at all.* On the contrary, if too ſmall a quantity of nitric acid be uſed, the

* *Bergman.*

Oxalic Acid.

the acid obtained will not be the oxalic, but the tartarous †. We think we have observed, that a considerably larger proportion of oxalic acid may be obtained by pouring nitric acid on sugar, and allowing these substances to act upon each other while cold. When the process is conducted in that manner, hardly any thing separates but nitrous gas.

† Hermstadt.

471 Its properties.

Oxalic acid is capable of crystallization, or rather it is generally obtained in that state. Its crystals are quadrilateral prisms, the ends of which often terminate in ridges ‡.

‡ Bergman, i. 255.

They are soluble in their own weight of boiling water: water at the temperature of 65,7° dissolves half its weight of them. The specific gravity of the solution is 1,0593 ||. One hundred parts of boiling alcohol dissolves 56 parts of these crystals; but at a mean temperature only 40 parts §. They are not easily soluble in ether. Fixed and volatile oils dissolve them, and they may be again obtained by gentle evaporation. Too violent a heat would sublime the acid itself.

|| Ibid.

§ Ibid.

Oxalic acid has a very acrid taste when it is concentrated, but a very agreeable acid taste when sufficiently diluted with water ¶.

¶ Ibid.

It changes all vegetable blues except indigo to a red. One grain of crystallized acid, dissolved in 1920 grains of water, reddens the blue paper with which sugar loaves are wrapt: one grain of it, dissolved in 3600 gr. of water, reddens paper stained with turnsole.* According to Morveau, one part of the crystallized acid is sufficient to communicate a sensible acidity to 2633 parts of water †.

* Ibid.

† Encycl. Method. art. Acide Saccharin.

Its fixity is such, that none of it is sublimed when water containing it in solution is raised to the boiling temperature.

When this crystallized acid is exposed to heat in an open vessel, there arises a smoke from it, which affects disagreeably the nose and lungs. The residuum is a powder of a much whiter colour than the acid had been. By this process it loses $\frac{3}{10}$ths of its weight; but soon recovers them again on exposure to the air. When distilled, it first loses its water of crystallization, then liquifies and becomes brown; a little phlegm passes over, a white saline crust sublimes, some part of which passes into the receiver; but the greatest part of the acid is destroyed, leaving in the retort a mass $\frac{1}{50}$th of the whole, which has an empyreumatic smell, blackens sulphuric acid, renders nitric acid yellow, and dissolves in muriatic acid without alteration. That part of the acid which sublimes is unaltered. When this acid is distilled a second time, it gives out a white smoke, which, condensing in the receiver, produces a colourless uncrystallizable acid, and a dark coloured matter remains behind.* During all this distillation a vast quantity of elastic vapour makes its escape. From 279 grains of oxalic acid, Bergman obtained 109 cubic inches of gas, half of which was carbonic acid and half hydrogen. Fontana from an ounce of it obtained 430 cubic inches of gas, one-third of which was carbonic acid, the rest hydrogen. From these facts, it is evident that oxalic acid is composed of oxygen, hydrogen, and carbon; but the proportions are still unknown.

* Bergman.

When nitric acid is frequently distilled off oxalic acid, acetous acid is produced.* The sulphuric acid, when concentrated, seems to produce the same effect. Muriatic and acetous acids dissolve oxalic acid, but without altering it †.

* Westrum.

† Bergman.

472 Its action on other bodies.

Oxalic acid is capable of oxydating lead, copper, iron, tin, bismuth, nickel, cobalt, zinc, manganese.

It does not act upon gold, silver, platinum, mercury, arsenic?

Oxalic acid combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms salts known by the name of *oxalats*.

473 Its affinities.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Strontites ‡,
Magnesia,
Potass,
Soda,
Ammonia,
Alumina,
Jargonia || ?
Metallic oxyds as in *sulphuric acid*,
Water,
Alcohol.

‡ Dr Hope, Transf. Edin. iv.

|| Vauquelin, Ann. de Chim. xxii. 208.

Sect. XIV. *Of Tartarous Acid.*

Tartarous Acid.

474 Discovery of tartarous acid.

Tartar, or *cream of tartar* as it is commonly called when pure, has occupied the attention of chemists for several centuries. Duhamel and Grosse, and after them Margraf and Rouelle the Younger, proved, that it was composed of an acid united to potass; but Scheele was the first who obtained this acid in a separate state. He communicated his process for obtaining it to Retzius, who published it in the Stockholm Transactions for 1770. It consisted in boiling tartar with lime, and in decomposing the tartrite of lime thus formed by means of sulphuric acid.

475 Its properties.

This acid, by a gentle evaporation, yields crystals so irregular in their figure, that every chemist who has treated of this subject has given a different description of them. According to Bergman, they generally consist of divaricating lamellæ;* according to Van Packen, they assume oftenest the form of long pointed prisms †; Spielman and Corvinus ‡ obtained them in groupes, some of them lance-shaped, others needle formed, others pyramidal. Morveau obtained them needleform §. They do not experience any change in the air; heat decomposes them. In the open fire they burn without leaving any other residuum than a coal, which generally contains a little lime||. In close vessels, the product is carbonic acid and hydrogen gas¶. If the proper quantity of nitric acid be distilled off the crystals, they are converted into oxalic acid, and the nitric acid, as usual, passes into the nitrous acid.* Hence it is evident that tartarous acid also, like the four former, is composed of oxygen, hydrogen, and carbon; but the proportions are equally unascertained.

* Bergman, iii. 368.

† De Sale Essent. acidi Tartari.

‡ Analecta de Tartaro.

§ Encycl. Method. Chim. i. 323.

|| Bergman, ibid. and ii. 465.

¶ Spielman and Corvinus, ibid.

* Hermstadt and Westrum.

This acid, when in crystals, dissolves readily in water. Bergman obtained a solution, the specific gravity of which was 1,230†. Morveau observed, however, that crystals formed spontaneously in a solution, the specific gravity of which was 1,084.

† Bergman, i. 250.

476 Its action on other bodies.

It has a very sharp acid taste, and reddens vegetable blues.

Tartarous

Citric Acid.

Tartarous acid does not oxydat gold, filver, platinum, lead, bifmuth, nor tin, and hardly antimony and nickel.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms falts known by the name of *tartrites*.

477 Its affinities. The order of its affinities is the fame as that given for oxalic acids; except that, according to Lavoifier, the oxyd of filver comes before that of mercury.

Sect. XV. *Of Citric Acid.*

478 Method of obtaining citric acid. Chemists have always confidered the juice of oranges and lemons as a peculiar acid. This juice contains a quantity of mucilage and water, which render the acid impure, and fubject to fpontaneous decompofition. Mr Georgius took the following method to feparate the mucilage. He filled a bottle entirely with lemon-juice, corked it, and placed it in a cellar: in four years the liquid was become as limpid as water, a quantity of mucilage had fallen to the bottom in the form of flakes, and a thick cruft had formed under the cork. He expofed this acid to a cold of 23°, which froze a great part of the water, and left behind a ftrong and pretty pure acid*. It was Scheele, however, that firft pointed out a method of obtaining this acid perfectly pure. He faturated lemon-juice with lime, edulcorated the precipitate, which confifted of citric acid and lime, feparated the lime from it by diluted fulphuric acid, cleared it from the fulphat of lime by repeated filtrations and evaporation; then evaporated it to the confiftence of a fyrup, and fet it by in a cool place: a quantity of cryftals formed, which were pure citric acid†. It exifts ready formed alfo in the juices of the following berries: *Vaccinium occicoccos, vaccinium vitis idæa, prunus padus, folanum dulcamara, rofa canina*‡, *cherries*§.

* Stockholm Tranf. 1774.

† Scheele's Effays.

‡ Scheele, Crell's Annals, 1788.

§ Weftrum.

Scheele advifes the ufe of an excefs of fulphuric acid, in order to infure the feparation of all the lime; but, according to Dizé, this excefs is neceffary for another purpofe‖. A quantity of mucilage ftill adheres to the citric acid in its combination with lime, and fulphuric acid is neceffary to decompofe this mucilage, which, as Fourcroy and Vauquelin have proved, it is capable of doing. His proof of the prefence of mucilage is, that when the folution of citric acid in water, which he had obtained, was fufficiently concentrated by evaporation, it affumed a brown colour, and even became black towards the end of the evaporation. The cryftals alfo were black. By repeated folutions and evaporations, this black matter was feparated, and found to be carbon. Hence he concluded that mucilage had been prefent; for mucilage is compofed of carbon, hydrogen, and oxygen; fulphuric acid caufes the hydrogen and oxygen to combine and form water, and the carbon remains behind. It is not certain, however, as Mr Nicholfon remarks very juftly†, that the fulphuric acid may not act upon the citric acid itfelf, and that the carbon may not proceed from the decompofition of it; at leaft the experiments of Mr Dizé are infufficient to prove the contrary. In that cafe, the fmaller the excefs of fulphuric acid ufed the better.

‖ Nicholfon's Journal, ii. 43.

† Nicholfon, ibid.

479 Its properties. The cryftals of citric acid are rhomboidal prifms, the fides of which are inclined to each other in angles of about 120 and 60 degrees, terminated at each end by four trapezoidal faces, which include the folid angles‡. They are not altered by expofure to the air.

‡ Dizé, ibid.

An ounce of diftilled water, at the temperature of the atmofphere, diffolves one ounce and two drams of cryftallized citric acid; and during the folution the temperature is lowered 29,75°. Boiling water diffolves twice its weight of this acid§.

§ Id. ibid.

Citric acid has a very acid tafte; it turns vegetable blues to a red.

480 Its action on other bodies. It is capable of oxydating iron, zinc, tin. It does not act upon gold, filver, platinum, mercury, bifmuth, antimony, arfenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms falts known by the name of *citrats*.

Fire decompofes this acid, converting it into an acidulous phlegm, carbonic acid gas, and carbonated hydrogen gas. Its folution in water is alfo gradually decompofed, if accefs of air be permitted. It is evident, therefore, that this acid is alfo compofed of oxygen, hydrogen, and carbon.

Scheele faid that he could not convert it into oxalic acid by means of nitric acid, as he had done feveral other acids; but Weftrum affirms, that this converfion may be effected; and thinks that Scheele had probably failed from having ufed too large a quantity of nitric acid, by which he had proceeded beyond the converfion into oxalic acid, and had changed the citric acid into vinegar; and in fupport of his opinion, he quotes his own experiments: from which it appeared that, by treating fixty grains of citron acid with different quantities of nitric acid, his products were very different. Thus with 200 grains of nitric acid he got 30 grains of oxalic acid; with 300 grains of nitric acid he obtained only 15 grains of the oxalic acid; and with 600 grains of nitric acid no veftige appeared of the oxalic acid. On diftilling the products of thefe experiments, efpecially of the laft, he obtained vinegar mixed with nitric acid.

481 Its affinities. The affinities of this acid are as follows*:

Lime (L),
Barytes,
Strontites†,
Magnefia,
Potafs,
Soda,
Ammonia,
Oxyd of zinc,
——— manganefe‡,
——— iron,
——— lead,
——— cobalt,
——— copper,
——— arfenic,
——— mercury,
——— antimony‖,
——— filver,
——— gold,
——— platinum,
Alumina§,
Jargonia¶?
Water,

* See Bergman and Lavoifier.

† Dr Hope, Tranf. Edin. iv.

‡ Lavoifier.

‖ Id.

§ Id.

¶ Vauquelin, Ann. de Chim. xxii. 2c8.

(L) Mr De Breffey places barytes before lime.

Malic Acid.

Water,
Alcohol.

Sect. XVI. *Of Malic Acid.*

482 Diſcovery of malic acid.

Scheele diſcovered a peculiar acid in the juices of ſeveral fruits, which, becauſe it is found moſt abundantly in apples, has been called *malic acid.*

483 Method of obtaining it.

He obtained it by the following proceſs. Saturate the juice of apples with potaſs, and add to the ſolution acetite of lead till no more precipitation enſues. Waſh the precipitate carefully with a ſufficient quantity of water; then pour upon it diluted ſulphuric acid till the mixture has a perfectly acid taſte, without any of that ſweetneſs which is perceptible as long as any lead remains diſſolved in it; then ſeparate the ſulphat of lead, which has precipitated, by filtration, and there remains behind pure malic acid*.

This acid is contained in the berries of the *barberis vulgaris*, the *ſambucus nigra*, the *prunus ſpinoſa*, the *ſorbus aucuparia*, and the *prunus domeſtica*†.

If nitric acid be diſtilled with an equal quantity of ſugar, till the mixture aſſumes a brown colour (which is a ſign that all the nitric acid has been abſtracted from it), this ſubſtance will be found of an acid taſte; and after all the oxalic acid which may have been formed is ſeparated by lime-water, there remains another acid, which may be obtained by the following proceſs: Saturate it with lime, and filter the ſolution; then pour upon it a quantity of alcohol, and coagulation takes place. This coagulum is the acid combined with lime. Separate it by filtration, and edulcorate it with freſh alcohol; then diſſolve it in diſtilled water, and pour in acetite of lead till no more precipitation enſues. The precipitate is the acid combined with lead, from which it may be ſeparated by diluted ſulphuric acid. It poſſeſſes all the properties of malic acid‡. This acid, therefore, may be obtained from ſugar; and it may be converted into oxalic acid, by diſtilling off it the proper quantity of nitric acid§.

* *Swediſh Tranſ.* and *Crell's Annals for* 1785.
† *Ibid.*
‡ *Ibid.*
§ *Hermſtadt, Phyſ. Chem.*

This acid bears a ſtrong reſemblance to the citric, but differs from it in the following particulars:

484 Its properties.

1. The citric acid ſhoots into fine cryſtals, but this acid does not cryſtallize.

2. The ſalt formed from the citric acid with lime is almoſt inſoluble in boiling water; whereas the ſalt made with malic acid and the ſame baſis is readily ſoluble by boiling water.

3. Malic acid precipitates mercury, lead, and ſilver, from the nitrous acid, and alſo the ſolution of gold when diluted with water; whereas citric acid does not alter any of theſe ſolutions.

4. Malic acid ſeems to have a leſs affinity than citric acid for lime; for when a ſolution of lime in the former acid is boiled one minute with a ſalt formed from volatile alkali and citric acid, a decompoſition takes place, and the latter acid combines with the lime and is precipitated.

485 Its combinations.

The malic acid combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms ſalts known by the name of *malats.*

Its affinities have not yet been aſcertained.

Sect. XVII. *Of Lactic Acid.*

Lactic Acid.

If milk be kept for ſome time it becomes ſour. The acid which then appears in it was firſt examined by Scheele, and found by him to have peculiar properties. It is called *lactic* acid. In the whey of milk this acid is mixed with a little curd, ſome phoſphat of lime, ſugar of milk, and mucilage. All theſe muſt be ſeparated before the acid can be examined. Scheele accompliſhed this by the following proceſs:

486 Method of obtaining lactic acid.

Evaporate a quantity of ſour whey to an eighth part, and then filtrate it: this ſeparates the cheeſy part. Saturate the liquid with lime-water, and the phoſphat of lime precipitates. Filtrate again, and dilute the liquid with three times its own bulk of water; then let fall into it oxalic acid, drop by drop, to precipitate the lime which it has diſſolved from the lime-water: then add a very ſmall quantity of lime water, to ſee whether too much oxalic acid has been added. If there has, oxalat of lime immediately precipitates. Evaporate the ſolution to the conſiſtence of honey, pour in a ſufficient quantity of alcohol, and filtrate again; the acid paſſes through diſſolved in the alcohol, but the ſugar of milk and every other ſubſtance remains behind. Add to the ſolution a ſmall quantity of water, and diſtil with a ſmall heat, the alcohol paſſes over, and leaves behind the lactic acid diſſolved in water*.

This acid is incapable of cryſtallizing: when evaporated to dryneſs, it deliqueſces again in the air†.

487 Its properties,

When diſtilled, water comes over firſt, then a weak acid reſembling the tartarous, then an empyreumatic oil mixed with more of the ſame acid, and laſtly carbonic acid and hydrogen gas—there remains behind a ſmall quantity of coal‡.

488 Combinations,

The combinations which this acid forms with alkalies, earths, and metallic oxyds, are called *lactats.*

489 And affinities.

Its affinities, according to Bergman, are as follows:

Barytes,
Potaſs,
Soda,
Ammonia,
Lime,
Magneſia,
Alumina,
Jargonia§?
Metallic oxyds as in *ſulphuric acid.*
Water,
Alcohol.

* *Scheele, Stockholm Tranſ.* 1780.
† *Ibid.*
‡ *Ibid.*
§ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XVIII. *Of Saccholactic Acid.*

490 Sugar of milk.

If a quantity of freſh whey of milk be filtrated, and then evaporated by a gentle fire till it is of the conſiſtence of honey, and afterwards allowed to cool, a ſolid maſs is obtained. If this be diſſolved in water, clarified with the white of eggs, filtrated and evaporated, to the conſiſtence of a ſyrup, it depoſits on cooling a number of brilliant white cubic cryſtals which have a ſweet taſte, and for that reaſon have been called *ſugar of milk.* Fabricius Bartholet, an Italian, was the firſt European who mentioned this ſugar. He deſcribed it in his *Encyclopædia Hermetico dogmatica*, publiſhed at Boulognia in 1619; but it ſeems to have been known in India long before that period.

491 Method of obtaining saccholactic acid.

After Mr Scheele had obtained oxalic acid from ſugar, he wiſhed to examine whether the ſugar of milk would furniſh the ſame product. Upon four ounces of pure ſugar of milk, finely powdered, he poured 12 ounces

Saccholactic Acid.

ounces of diluted nitric acid, and put the mixture in a large glafs retort, which he placed in a fand bath. A violent effervefcence enfuing, he was obliged to remove the retort from the fand bath till the commotion ceafed. He then continued the diftillation till the mixture became yellow. As no cryftals appeared in the liquor remaining in the retort, after ftanding two days he repeated the diftillation as before, with the addition of eight ounces of nitric acid, and continued the operation till the yellow colour, which had difappeared on addition of the nitrous acid, returned. The liquor in the retort contained a white powder, and when cold was obferved to be thick. Eight ounces of water were added to dilute this liquor, which was then filtrated, by which the white powder was feparated; which being edulcorated and dried weighed $7\frac{1}{2}$ dr. The filtrated folution was evaporated to the confiftence of a fyrup, and again fubjected to diftillation, with four ounces of nitric acid as before; after which, the liquor, when cold, was obferved to contain many fmall, oblong, four cryftals, together with fome white powder. This powder being feparated, the liquor was again diftilled with more nitric acid as before; by which means the liquor was rendered capable of yielding cryftals again, and by one diftillation more with more nitrous acid, the whole of the liquor was converted into cryftals. Thefe cryftals, added together, weighed five drams; and were found, upon trial, to have the properties of the oxalic acid.

Mr Scheele next examined the properties of the white powder, and found it to be an acid of a peculiar nature; he therefore called it the *acid of fugar of milk*. It is now called the *faccholactic acid*.

492 Its properties.

According to Scheele it is foluble in 60 parts of its weight of boiling water; but Meffrs Hermftadt* and Morveau† found, that boiling water only diffolved $\frac{1}{80}$th part. It depofited about $\frac{1}{4}$th part on cooling in the form of cryftals‡.

The folution has an acid tafte, and reddens the infufion of turnfole§. Its fpecific gravity at the temperature of 53,7°, is 1,0015‖.

When diftilled, it melts very readily, becomes black, and frothes; a brown falt fublimes into the neck of the retort, which has the odour of a mixture of amber and benzoin, having an acid tafte, eafily foluble in alcohol, with greater difficulty in water, and burning in the fire with a flame. There paffes into the receiver a brown liquid having fome of this falt diffolved in it: There remains behind a coal¶, which Hermftadt found to contain a fmall quantity of lime. Concentrated fulphuric acid diftilled on this falt becomes black, frothes and decompofes it*.

* *Phyf. Chem.*
† *Encycl. Method.* i. 290.
‡ *Scheele.*
§ *Id.*
‖ *Morveau, ibid.*
¶ *Scheele, ibid.*
* *Id. ibid.*

493 Hermftadt attempts to difprove its exiftence.

Mr Hermftadt of Berlin had made fimilar experiments on fugar of milk at the fame time with Scheele, and with fimilar refults; but he concluded, that the white powder which he obtained was nothing elfe than oxalat of lime with excefs of acid, as indeed Scheele himfelf did at firft. After he became acquainted with Scheele's conclufions, he publifhed a paper in defence of his own opinion; but his proofs are very far from eftablifhing it, or even rendering its truth probable. He acknowledges himfelf, that he has not been able to decompofe this fuppofed falt: he allows that it poffeffes properties diftinct from the oxalic acid, but he afcribes this difference to the lime which it contains; yet all the lime which he could difcover in 240 grains of this falt was only 20 grains; and if the alkali which he employed was a carbonat (as it probably was), thefe 20 muft be reduced to 11. Now Morveau has fhewn, that oxalic acid, containing the fame quantity of lime, exhibits very different properties. Befides, this acid, whatever it is when united with lime, is feparated by the oxalic, and muft therefore be different from it, as it would be abfurd to fuppofe that an acid could difplace itfelf*. The faccholactic acid muft therefore be confidered as a diftinct acid, as it poffeffes peculiar properties.

* *Morveau, Encycl. Method.* i. p. 291.

494 Its compounds and affinities.

Its compounds with alkalies, earths, and metallic oxyds, are denominated *faccholats*.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Magnefia,
Potafs,
Soda,
Ammonia,
Alumina,
Jargonia†?
Metallic oxyds as in *fulphuric acid*,
Water,
Alcohol.

† *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XIX. *Of Gallic Acid.*

Gallic Acid.

495 Nut galls.

There is an excrefcence known by the name of *nut gall*, which grows on fome fpecies of oaks. This fubftance contains a peculiar acid, called from that circumftance *gallic acid*, the properties of which were firft examined with attention by the commiffioners of the academy of Dijon; and the refult of their experiments was publifhed in 1777, in the third volume of their Elements of Chemiftry. In thefe experiments, however, they employed the infufion of galls, in which the acid is combined with the tanning principle(m). It was referved for Scheele to obtain it in a ftate of purity.

496 Difcovery of gallic acid.

He obferved, in an infufion of galls made with cold water, a fediment which proved on examination to have a cryftalline form, and an acid tafte. By letting an infufion of galls remain a long time expofed to the air, and removing now and then the mouldy fkin which formed on its furface, a large quantity of this fediment was obtained, which being edulcorated with cold water, rediffolved in hot water, filtrated and evaporated very flowly, yielded an acid falt in cryftals as fine as fand*.

* *Stockholm Tranf.* 1786.

There is a fhorter method of obtaining this acid in a ftill purer ftate than Scheele obtained it.

497 Method of obtaining it.

Pour

(m) A fubftance lately difcovered by French chemifts, which exifts alfo in oak-bark, and every other body which may be fubftituted for that bark in the operation of tanning. It refembles the refins in many properties; but its diftinguifhing property is that of forming with glue a compound infoluble in water. When a little of the decoction of glue is dropped into an infufion of nut-galls, a white curdy precipitate is inftantly feen: This is the tanning principle combined with glue. The name *tanning principle* has been applied to it, becaufe *tanning* confifts in combining this principle with *fkins*, by which they are converted into leather.

Gallic Acid.

Pour fulphuric ether on a quantity of powdered galls, and allow it to remain a few hours; by which time it becomes coloured. Put this tincture into a retort, and diftil off the ether with a fmall heat. The refiduum poffeffes the colour and brittlenefs of a refin, and has all the characters of Rouell's refiduous-extract; it does not attract moifture from the atmofphere. Diffolve it in its own weight of water, and add fulphuric acid, drop by drop, till the liquor has become of a manifeftly acid tafte. It caufes a white precipitate, which becomes coloured, and is immediately rediffolved. At the end of fome hours a refinous matter will have precipitated. Decant off the fluid, dilute it with half its weight of water, filtrate and evaporate it to $\frac{4}{5}$ths in a moderate heat; add pure barytes, till the liquor is no longer capable of decompofing muriat of barytes; then filtrate it again: and on evaporation in a moderate heat fmall white prifmatic cryftals of gallic acid are formed on the fides of the veffel†.

† *Mr J. J. Dizé, Jour. de Phyf.* Dec. 1791.

It appears from the experiments of Deyeux, that the fubftance extracted from nut-galls by ether does not differ much from the extract by water‡. Probably, then, the only reafon for employing ether is the fmall heat neceffary for evaporating it.

‡ *Ann. de Chim.* xvii. 8.

There is ftill another method of obtaining this acid. Diftil nut-galls in a ftrong heat, a white fubftance fublimes, which cryftallizes in the form of needles: This is gallic acid. If the cryftals are impure, they may be purified by a fecond fublimation: but the heat muft not be too violent, otherwife the cryftals will melt into a brown mafs*. This procefs was difcovered by Scheele.

* *Ibid.*

498 Prouft's method.

But the moft elegant method of obtaining gallic acid is that of Mr Prouft. When a folution of muriat of tin is poured into an infufion of nut-galls, a copious yellow precipitate is inftantly formed, confifting of the tanning principle, combined with the oxyd of tin. After diluting the liquid with a fufficient quantity of water to feparate any portion of this precipitate which the acids might hold in folution, the precipitate is to be feparated by filtration. The liquid contains gallic acid, muriatic acid, and muriat of tin. To feparate the tin, a quantity of fulphurated hydrogen gas is to be mixed with the liquid. Sulphuret of oxyd of tin is precipitated under the form of a brown powder. The liquid is then to be expofed for fome days to the light, covered with paper, till the fuperfluous fulphurated hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and put by to cool. Cryftals of gallic acid are depofited. Thefe are to be feparated by filtration, and wafhed with a little cold water. The evaporation of the reft of the liquid is to be repeated till all the gallic acid is obtained from it†.

† *Ibid.* xxv. 225.

499 Its properties.

The gallic acid thus obtained has a very acid tafte, and reddens vegetable colours. It is foluble in $1\frac{1}{2}$ parts of boiling water, and in 12 parts of water at the temperature of the atmofphere. Alcohol diffolves one-fourth of its weight of this acid at the temperature of the atmofphere. When boiling hot it diffolves a quantity equal to its own weight.

When placed upon burning coals, gallic acid takes fire, and at the fame time diffufes a very ftrong odour, which has fomething aromatic in it. When ftrongly heated, it melts, boils, becomes black, is diffipated, and leaves a quantity of charcoal behind it. When diftilled, a quantity of oxygen gas is difengaged, an acid liquor is found in the receiver, with fome gallic acid, not decompofed, and there remains in the retort a quantity of carbon. If what has paffed into the receiver be again diftilled, more oxygen gas is obtained, fome gallic acid ftill fublimes, and a quantity of carbon remains in the retort. By repeated diftillations, the whole of the acid may be decompofed. This decompofition may be more eafily accomplifhed by diftilling repeatedly a folution of gallic acid in water. The products are oxygen gas, charcoal, and an acid liquor.

500 Its compofition.

From thefe experiments, Mr Deyeux, who performed them, has concluded, that gallic acid is compofed of oxygen, and a much larger proportion of carbon than enters into the compofition of carbonic acid. But this conclufion is not warranted by the analyfis; for Mr Deyeux did not find that the quantity of oxygen gas and carbon obtained was equal to that of the gallic acid decompofed: and in the acid liquor which came over, there evidently exifted a quantity of water, which doubtlefs was formed during the diftillation. Scheele, by treating gallic acid with nitric acid in the ufual manner, converted it into oxalic acid. Now it is certain, that oxalic acid contains hydrogen as well as carbon. It cannot be doubted, then, that gallic acid is compofed of oxygen, hydrogen, and carbon, in proportions not yet afcertained. But Mr Deyeux has proved, that the quantity of carbon is very great, compared with that of the hydrogen.

Gallic acid combines with alkalies, earths, and metallic oxyds, and forms compounds, known by the name of *gallats*.

Its affinities have not yet been determined; but oxyd of iron feems to have a ftronger affinity for it than for any other fubftance; for gallic acid is capable of taking it from every other acid. In confequence of this property, the infufion of galls is employed to detect the prefence of iron in any liquid. As foon as it is poured in, if iron be prefent, a black or purple colour is produced.

SECT. XX. *Of Benzoic Acid.*

Benzoic Acid.

501 Benzoin.

BENZOIN or *benjamin* (as it is fometimes called) is a kind of refin brought from the Eaft Indies; obtained, according to Dr Dryander, from the ftyrax benzoe, a tree which grows in the ifland of Sumatra. This fubftance confifts partly of a peculiar acid, defcribed as long ago as 1608 by Blaife de Vigenere, in his Treatife on Fire and Salt, under the name of *flowers of benzoin*, becaufe it was obtained by fublimation. This acid, which is now called *the benzoic acid*, may be fublimed from benzoin by heat; or it may be obtained by Scheele's procefs, which has been defcribed in the article CHEMISTRY *(Encycl.)*

502 Properties of benzoic acid.

Benzoic acid has little or none of the peculiar odour which diftinguifhes benzoin. Its tafte is not acid, but fweetifh and very pungent*. It hardly affects the infufion of violets; but it reddens that of turnfole, efpecially if that infufion be hot†. Heat volatilizes this acid, and makes it give out a ftrong odour, which excites coughing. When expofed to the heat of the blow-pipe in a filver fpoon, it melts, becomes as fluid as water, and evaporates without taking fire. It only burns when in contact with flame, and then it leaves no

* *Morveau, Encycl. Method. Chimie*, i. 44.

† *Lichtenftein.*

Succinic Acid.

no residuum behind. When thrown upon burning coals, it rises in a white smoke. When allowed to cool after being melted, it hardens, and a radiated crust forms on its surface‡.

‡ *Idem.*

It suffers no other alteration in the air than losing the little of the odour of benzoin which remained to it*.

* *Morveau, ibid.*

Cold water dissolves no sensible quantity of it; but it is soluble enough in hot water: 480 grains of boiling water dissolve 20 grains of it; 19 of these are deposited, when the water cools, in long, slender, flat, feather like crystals†.

† *Lichtenstein.*

Concentrated sulphuric acid dissolves it without heat or any other change, except becoming somewhat brown: when water is poured into the solution, the benzoic acid separates and coagulates on the surface without any alteration‡. Nitric acid presents precisely the same phenomena, and also the sulphurous and nitrous acids. Neither the muriatic, the oxy-muriatic, nor the phosphoric acids dissolve it. The acetous, formic, and sebacic acids, when hot, dissolve it precisely as water does; but it crystallizes again when these acids cool ||.

‡ *Id.*

|| *Id.*

Alcohol dissolves it copiously, and lets it fall on the addition of water*.

* *Id.*

503 Its combinations and affinities.

Little is known respecting its base.

It combines with alkalies, earths, and metallic oxyds, and forms salts, known by the name of *benzoats*.

Its affinities, from the experiments of Trommsdorf, appear to be as follows:

White oxyd of arsenic,
Potass,
Soda,
Ammonia,
Barytes,
Lime,
Magnesia,
Alumina,
Jargonia ‡?
Water,
Alcohol.

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXI. *Of Succinic Acid.*

504 Amber.

Amber is a well-known brown, transparent, inflammable body, pretty hard, and susceptible of polish, found at some depth in the earth, and on the sea-coast of several countries. It was in high estimation among the ancients both as an ornament and a medicine.—When this substance is distilled, a volatile salt is obtained, which is mentioned by Agricola under the name of *salt of amber*; but its nature was long unknown. Boyle was the first who discovered that it was an acid*. From *succinum*, the Latin name of amber, this acid has received the appellation of *succinic acid*.

* *Boyle abridged by Shaw*, iii. 369.

505 Method of obtaining succinic acid.

It is obtained by the following process: Fill a retort half way with powdered amber, and cover the powder with a quantity of dry sand; lute on a receiver, and distil in a sand-bath without employing too much heat. There passes over first an insipid phlegm; then a weak acid, which, according to Scheele, is the acetous†; then the succinic acid attaches itself to the neck of the retort; and if the distillation be continued, there comes over at last a thick brown oil, which has an acid taste.

† *Bergman's Notes on Scheffer.*

The succinic acid is at first mixed with a quantity of oil. Perhaps the best method of purifying it is that recommended by Pott, to dissolve it in hot water, and to put upon the filter a little cotton, previously moistened with oil of amber; this substance retains most of the oil, and allows the solution to pass clear. The acid is then to be crystallized by a gentle evaporation. And this process is to be repeated till the acid be quite pure. The crystals are white, shining, and of a foliated triangular prismatic form: they have an acid taste, but are not corrosive: they redden tincture of turnsole; but have little effect on that of violets.

506 Its properties,

They sublime when exposed to a considerable heat, but not at the heat of a water-bath. In a sand-bath they melt, and then sublime and condense in the upper part of the vessel; but the coal which remains shews that they are partly decomposed*.

* *Pott.*

One part of this acid dissolves in 96 parts of water at the temperature of 50°, according to Spielman‡, in 24 parts at the temperature of 52°, and in 2 parts of water at the temperature of 212°, according to Stockar de Neuforn †; but the greatest part crystallizes as the water cools. According to Roux, however, it still retains more of the acid than cold water is capable of dissolving‡.

‡ *Inst. Chem.* § xii.

† *De Succino.*

‡ *Morveau, ibid*, p. 72.

240 grains of boiling alcohol dissolve 177 of this acid; but crystals again shoot as the solution cools*.

* *Wenzel.*

507 Combinations and affinities.

The combinations of this acid are called *succinats*.

Its component parts are still unknown.

Its affinities, according to Morveau, are as follows:

Barytes,
Lime,
Potass,
Soda,
Ammonia,
Magnesia,
Alumina,
Jargonia †?
Metalic oxyds, as in *sulphuric acid*,
Water,
Alcohol.

† *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXII. *Of Camphoric Acid.*

508 Camphor.

Camphor is a well-known white crystalline substance, of a strong taste and smell, obtained from a species of laurel in the East Indies; and Mr Proust has shown that several volatile oils contain a considerable quantity of it*. It is so volatile, that it cannot be melted in open vessels, and so inflammable, that it burns even on the surface of water.

* *Ann. de Chim.* iv. 179.

When camphor is set on fire in contact with oxygen gas, it burns with a very brilliant flame; much caloric is disengaged, water is formed, the inner surface of the vessel is covered with a black matter, which is undoubtedly carbon, and a quantity of carbonic acid gas is also produced.† Hence it follows, that it is composed of hydrogen and carbon, at least principally.

† *La Grange, Ann. de Chim.* xxiii. 153.

If one part of camphor and six parts of pulverised clay be mixed together, by means of alcohol, in a mortar, the mixture made up into balls, and when dry put into a retort, and distilled by a moderate heat—a quantity of oil comes over, and there remains in the retort a black substance, which consists of the clay intimately mixed with a quantity of carbon. If the fire be not cautiously managed, a quantity of camphor also sublimes.

Camphoric Acid.

limes. By this process, camphor is decompounded, and separated into oil and carbon.

122,248 parts of camphor
produced 45,856 parts of oil
and 30,571 of carbon.

Total 76,427
Loss 45,821

Carbonated hydrogen gas and carbonic acid were also formed‡.

‡ Ibid.

509 Oil of camphor.

The oil obtained has the following properties:

It has a sharp caustic taste, and leaves upon the tongue a sense of coldness. It has an aromatic odour, approaching to that of thyme or rosemary. Its colour is a golden yellow.

When exposed to the air, it partly evaporates, and there remains a thick brown matter with a sharp bitterish taste, which at last also evaporates.

With alkalies, it forms a soap, which possesses all the characters of soaps made with volatile oils.

Alcohol dissolves it entirely; and when water is added to the solution it becomes milky, but no precipitate is produced‡.

‡ Ann. de Chim. xxiii. 159.

These properties show that this is a volatile oil, and consequently it is probable that camphor is composed of volatile oil and carbon.

510 Camphoric acid.

Mr Kosegarten, by distilling nitric acid off camphor eight times successively, obtained an acid in crystals*, to which the name of *camphoric acid* has been given.

* Kosegarten, de Camphora, &c. 1785.

His experiments have been repeated by Mr Bouillon La Grange. He mixed together 122,284 parts of camphor with 489,136 parts of nitric acid of the specific gravity 1,33, and distilled them. Much nitrous and carbonic acid gas were disengaged, and part of the camphor was sublimed; but part was converted into an acid. He returned the sublimed camphor into the retort, poured on it the same quantity of nitric acid as at first, and distilled again. This process he repeated till the whole camphor was acidified†. The quantity of camphoric acid obtained amounted to 53,498. The quantity of nitric acid was 2114,538.

† Ann. de Chim. ibid.

511 Its properties.

Camphoric acid thus obtained is in snow-white crystals, of the form of parallelopipedons*.

* Kosegarten.

These crystals effloresce in the air ‡.

‡ La Grange.

Camphoric acid has a slightly acid bitter taste, and a smell like that of saffron.

It reddens vegetable colours.

It is soluble in 200 parts of cold water, according to Kosegarten; in 96 parts of water at the temperature of 60°, according to La Grange. Boiling water dissolves $\frac{1}{12}$th of its weight§.

§ Kosegarten.

According to Kosegarten, it is insoluble in alcohol; according to La Grange, alcohol dissolves it, and when the solution is left in contact with the air of the atmosphere, the acid crystallizes. It is not precipitated from its solution in alcohol by the addition of water*.

* Bouillon La Grange, Ann. de Chim. xxvii. 40.

When this acid is placed on ignited coals, it emits a dense aromatic fume, and is entirely dissipated. By a gentler heat, it melts, and is sublimed. If it be put into a heated porcelain tube, and oxygen gas be passed through it, the acid does not undergo any change, but is sublimed.

By mere distillation, it first melts and then sublimes; by which process its properties are in some respect changed. It no longer reddens the tincture of turnsol, but acquires a brisk aromatic smell; its taste becomes less penetrating, and it is no longer soluble either in water or the sulphuric and muriatic acids. Heated nitric acid turns it yellow and dissolves it. Alcohol likewise dissolves it; and if this solution be left in contact with the air of the atmosphere, it crystallizes.

Camphoric acid does not produce any change in sulphur; alcohol and the mineral acids totally dissolve it; and so likewise do the volatile and the fat oils.

Camphoric acid does not precipitate lime from lime-water. It produces no change on the solution of indigo in sulphuric acid.

512 Its combinations and affinities.

It forms combinations with the alkalies, earths, and metallic oxyds, which are called *camphorats*.

Its affinities, as far as ascertained by La Grange, are as follows*.

* Ann. de Chim. xxvii. 21.

Lime,
Potass,
Soda,
Barytes,
Ammonia,
Alumina,
Magnesia.

Suberic Acid.

Sect. XXIII. *Of Suberic Acid.*

513 Discovery of suberic acid.

Cork, a substance too well known to require any description, is the bark of a tree which bears the same name. By means of nitric acid, Brugnatelli converted it into an acid†, which has been called the *suberic acid*, from *Suber*, the Latin name of the cork tree. Several chemists affirmed that this acid was the oxalic, because it possessed several properties in common with it. These assertions induced Buillon La Grange to undertake a set of experiments on suberic acid. These experiments, which have been published in the 23d volume of the *Annales de Chimie*, completely establish the peculiar nature of suberic acid, by shewing that it possesses properties different from those of every other acid.

† Crell's Annals, 1787.

514 Method of preparing it.

To prepare it, a quantity of sound cork grated down small is to be put into a retort, six times its weight of nitric acid of the specific gravity 1,261 poured upon it, and the mixture distilled by means of a gentle heat. Red vapours are immediately discharged; the cork swells up and becomes yellow, and as the distillation advances, it sinks to the bottom, and its surface remains frothy. If that froth does not form properly, it is a proof that some part of the cork has escaped the action of the acid. In that case, after the distillation is pretty far advanced, the acid which has passed into the receiver is to be poured back into the retort, and the distillation continued till no more red vapours can be perceived; and then the retort is to be immediately taken out of the sand-bath, otherwise its contents would become black and adhere to it. While the matter contained in the retort is hot, it is to be poured into a glass vessel, placed upon a sand-bath over a gentle fire, and constantly stirred with a glass rod. By this means it becomes gradually thick. As soon as white vapours, exciting a tickling in the throat, begin to disengage themselves, the vessel is removed from the bath, and the mass continually stirred till it is almost cold.

By this means an orange coloured mass is obtained of the consistence of honey, of a strong and sharp odour while hot, but having a peculiar aromatic smell when cold.

On

On this mafs twice its weight of boiling water is to be poured, and heat applied till it becomes liquid; and then that part of it which is infoluble in water is to be feparated by filtration (N). The filtred liquor becomes muddy; on cooling it depofits a powdery fediment, and a thin pellicle forms on its furface. The fediment is to be feparated by filtration, and the liquor reduced to a dry mafs by evaporating in a gentle heat. This mafs is *fuberic acid*. It is ftill a little coloured, owing to fome accidental mixture, from which it may be purified either by faturating it with potafs and precipitating it by means of an acid, or by boiling it along with charcoal powder.

515 Its properties.

Suberic acid thus obtained is not cryftallizable, but when precipitated from potafs by an acid it affumes the form of a powder; when obtained by evaporation it forms thin irregnlar pellicles.

Its tafte is acid and flightly bitter; and when diffolved in a fmall quantity of boiling water it acts upon the throat, and excites coughing.

It reddens vegetable blues; and when dropped into a folution of indigo in fulphuric acid (*liquid blue*, as it is called in this country), it changes the colour of the folution, and renders it green.

Water at the temperature of 60° or even 70° diffolves only $\frac{1}{57,6}$ part of its weight of fuberic acid, and if the acid be very pure, only $\frac{1}{144}$th part: boiling water, on the contrary, diffolves half its weight of it.

When expofed to the air, it attracts moifture, efpecially if it be impure.

When expofed to the light of day, it becomes at laft brown; and this effect is produced much fooner by the direct rays of the fun.

When heated in a matrafs, the acid fublimes, and the infide of the glafs is furrounded with zones of different colours. If the fublimation be ftopped at the proper time, the acid is obtained on the fides of the veffel in fmall points formed of concentric circles. When expofed to the heat of the blow-pipe on a fpoon of platinum, it firft melts, then becomes pulverulent, and at laft fublimes entirely with a fmell refembling that of febacic acid (O).

It is not altered by oxygen gas:—the other acids do not diffolve it completely. Alcohol developes an aromatic odour, and an ether may be obtained by means of this acid.

It converts the blue colour of nitrat of copper to a green; the fulphat of copper alfo to a green; green fulphat of iron to a deep yellow; and fulphat of zinc to a golden yellow (P).

516 Its action on other bodies.

It has no action either on platinum, gold, or nickel; but it oxydates filver, mercury, copper, lead, tin, iron, bifmuth, arfenic, cobalt, zinc, antimony, manganefe, and molybdenum.

With alkalies, earths, and metallic oxyds, it forms compounds known by the name of *fuberats*.

517 Its affinities.

Its affinities are as follows (Q):

Barytes,

(N) When this fubftance is put into a matrafs, water poured on it, and heat applied, it melts; and when the veffel is taken from the fire and allowed to cool, one part of it, which is of the confiftence of wax, fwims on the furface of the water, and another part precipitates to the bottom of the veffel, and affumes the appearance of a whitifh magma. When this magma is feparated by filtration, and wafhed and dried, a white taftelefs powder is obtained, mixed with ligneous threads, foluble in acids and alkalies.

(O) An acid which fhall be afterwards defcribed.

(P) Owing perhaps to the prefence of a little iron in the fulphat.

(Q) The place which the fuberic acid occupies in the affinities of the alkalies, earths, and metallic oxyds, as far as this fubject has been inveftigated by Bouillon La Grange, will appear by the following tables:

Potass.	Soda.	Barytes.	Lime.
Sulphuric acid,	Sulphuric acid,	Sulphuric acid.	Oxalic acid,
Nitric,	Nitric,	Oxalic,	Sulphuric,
Muriatic,	Muriatic,	* * *	* * *
Suberic,	Suberic.	Muriatic,	Muriatic,
		Suberic.	Suberic.
			Magnesia as lime.

Alumina.	Oxyd of Tin.	Oxyd of Silver.	Oxyd of Molybdenum.
Sulphuric acid.	* * *	Muriatic,	Suberic acid.
* * *	Muriatic,	* * *	
Oxalic,	Suberic.	Sulphuric,	
Suberic,		Suberic.	

Oxyd of Mercury.	Oxyd of Lead.	Oxyd of Copper.	Oxyd of Antimony.
Sebacic acid,	* * *	* * *	* * *
* * *	Muriatic,	Sulphuric,	Muriatic,
Nitric,	Suberic.	Suberic.	Suberic,
Suberic.			Manganese the fame.

Oxyd of Iron.	Oxyd of Bismuth.	Oxyd of Arsenic.
* * *	* * *	* * *
Sulphuric,	Muriatic,	Nitric acid,
Suberic.	Suberic.	Suberic,

Cobalt and Zinc the fame with arfenic.

Laccic Acid.

Barytes,
Potafs,
Soda,
Lime,
Ammonia,
Magnefia,
Alumina.*

* Ann. de Chim. xxiii. 42.

518 Its compofition.

Mr Buillon La Grange, to whom we are indebted for all the facts relative to this acid, fuppofes that it is compofed of oxygen, hydrogen, and carbon: but Mr Jamefon, in confequence of the refult of a feries of experiments which he made on charcoal, has been led to fufpect that it confifts entirely of carbon and oxygen. He found that, by the action of nitric acid upon charcoal, a brown, bitter, deliquefcent mafs was formed, foluble in water, alcohol, and alkalies, and which emitted, particularly when heated, a very fragrant odour. This matter was more or lefs foluble in water according to the time that it had been expofed to the action of the acid. When the nitric acid ufed was concentrated, and confiderable in quantity, part of the charcoal was converted into an acid, which poffeffed the characters of the fuberic †.

† Jamefon's Mineralogy of Shetland and Arran, p. 167.

Thefe facts are curious, and may extend our knowledge of the nature of vegetable acids, but they are infufficient to prove the abfence of hydrogen in fuberic acid, becaufe charcoal cannot eafily be procured perfectly free from hydrogen, and becaufe feveral of the properties of fuberic acid indicate the prefence of hydrogen in it, its becoming brown, for inftance, when expofed to the light. Mr Jamefon has obferved, that the acid which exifts ready formed in peat poffeffes the properties of fuberic acid.

Sect. XXIV. *Of Laccic Acid.*

519 Difcovery of white lac.

About the year 1786, Dr Anderfon of Madras mentioned in a letter to the governor and council of that place, that nefts of infects, refembling fmall cowry fhells, had been brought to him from the woods by the natives, who eat them with avidity. Thefe fuppofed nefts he foon afterwards difcovered to be the coverings of the females of an undefcribed fpecies of coccus, which he fhortly found means to propagate with great facility on feveral of the trees and fhrubs growing in his neighbourhood (R).

On examining this fubftance, which he called *white lac*, he obferved in it a very confiderable refemblance to bees wax; he noticed alfo, that the animal which fecretes it provides itfelf by fome means or other with a fmall quantity of honey, refembling that produced by our bees; and in one of his letters he complains, that the children whom he employed to gather it were tempted by its fweetnefs to eat fo much of it as materially to reduce the produce of his crop. Small quantities of this matter were fent into Europe in 1789, both in its natural ftate and melted into cakes; and in 1793 Dr Pearfon, at the requeft of Sir Jofeph Banks, undertook a chemical examination of its qualities, and his experiments were publifhed in the Philofophical Tranfactions for 1794.

520 Its analyfis.

A piece of white lac, from 3 to 15 grains in weight, is probably produced by each infect. Thefe pieces are of a grey colour, opaque, rough, and roundifh. When white lac was purified by being ftrained through muflin, it was of a brown colour, brittle, hard, and had a bitterifh tafte. It melted in alcohol, and in water of the temperature of 145°. In many of its properties it refembles bees wax, though it differs in others; and Dr Pearfon fuppofes that both fubftances are compofed of the fame ingredients, but in different proportions.

Two thoufand grains of white lac were expofed in fuch a degree of heat as was juft fufficient to melt them. As they grew foft and fluid, there oozed out 550 grains of a reddifh watery liquid, which fmelled like newly baken bread (S). To this liquid, Dr Pearfon has given the name of *laccic acid* †.

† Pearfon's Tranf. of the Chemical Nomenclature.

521 Properties of laccic acid.

It poffeffes the following properties:

It turns paper ftained with turnfole to a red colour.

After being filtered, it has a flightly faltifh tafte with bitternefs, but is not at all four.

When heated, it fmells precifely like newly baken hot bread.

On ftanding, it grows fomewhat turbid, and depofits a fmall quantity of fediment.

Its fpecific gravity at the temperature of 60° is 1,025.

A little of it having been evaporated till it grew very turbid, afforded on ftanding fmall needle fhaped cryftals in mucilaginous matter.

Two hundred and fifty grains of it were poured into a very fmall retort and diftilled. As the liquor grew warm, mucilage like clouds appeared; but as the heat increafed they difappeared again. At the temperature of 200°, the liquor diftilled over very faft: A fmall quantity of extractive matter remained behind. The diftilled liquor while hot fmelled like newly baken bread, and was perfectly tranfparent and yellowifh. A fhred of paper ftained with turnfole, which had been put into the receiver, was not reddened; nor did another which had been immerfed in a folution of fulphat of iron, and alfo placed in the receiver, turn to a blue colour upon being moiftened with the folution of potafs (T).

About one hundred grains of this diftilled liquid being evaporated till it grew turbid, after being fet by for a night, afforded acicular cryftals, which under a lens appeared in a group not unlike the umbel of parfley. The whole of them did not amount to the quarter of a grain. They tafted only bitterifh.

Another 100 grains being evaporated to drynefs in a very low temperature, a blackifh matter was left behind, which did not entirely difappear on heating the fpoon-

(R) The Chinefe collect a kind of wax, which they call *pe-la*, from a coccus, depofited for the purpofe of breeding on feveral fhrubs, and manage it exactly as the Mexicans manage the cochineal infect. It was the knowledge of this that induced Dr Anderfon to attempt to propagate his infect.

(S) The fame liquid appears on preffing the crude lac between the fingers; and we are told, that when newly gathered it is replete with juice.

(T) A proof that the acid was not the pruffic.

Laccic Acid. ſpoon containing it very hot in the naked fire; but on heating oxalic acid to a much leſs degree, it evaporated and left not a trace behind.

Carbonat of lime diſſolved in this diſtilled liquor with effervеſcence. The ſolution taſted bitteriſh, did not turn paper ſtained with turnſole red, and on adding to it carbonat of potaſs a copious precipitation enſued. A little of this ſolution of lime and of alkali being evaporated to dryneſs, and the reſiduum made red hot, nothing remained but carbonat of lime and carbonat of potaſs.

This liquid did not render nitrat of lime turbid, but it produced turbidneſs in nitrat and muriat of barytes.

To five hundred grains of the reddiſh-coloured liquor obtained by melting white lac, carbonat of ſoda was added till the effervеſcence ceaſed, and the mixture was neutraliſed; for which purpoſe three grains of the carbonat were neceſſary. During this combination a quantity of mucilaginous matter, with a little carbonat of lime, was precipitated. The ſaturated ſolution being filtrated and evaporated to the due degree, afforded on ſtanding deliqueſcent cryſtals, which on expoſure to fire left only a reſiduum of carbonat of ſoda.

Lime-water being added to this reddiſh-coloured liquor produced a light purple turbid appearance; and on ſtanding there were clouds juſt perceptible.

Sulphuret of lime occaſioned a white precipitation, but no ſulphurated hydrogen gas was perceptible by the ſmell.

Tincture of galls produced a green precipitation.

Sulphat of iron produced a purpliſh colour, but no precipitation; nor was any precipitate formed by the addition firſt of a little vinegar, and then of a little potaſs, to the mixture.

Acetite of lead occaſioned a reddiſh precipitation, which rediſſolved on adding a little nitric acid.

Nitrat of mercury produced a whitiſh turbid liquor.

Oxalic acid produced immediately the precipitation of white acicular cryſtals, owing probably to the preſence of a little lime in the liquid.

Tartrite of potaſs produced a precipitation not unlike what takes place on adding tartarous acid to tartrite of potaſs (u); but it did not diſſolve again on adding potaſs.

Such were the properties of this acid diſcovered by Dr Pearſon. Its deſtructibility by fire, and its affording carbon, diſtinguiſh it from all the acids deſcribed in this article before the acetous; and its peculiar ſmell when heated, its precipitating tartrite of potaſs without forming tartar, its bitteriſh taſte, and its being converted into vapour at the temperature of 200°, diſtinguiſh it from all the acids hitherto examined*.

* *Phil. Tran.* 1794. p. 383.

Sect. XXV. *Of Pyromucous Acid.*

522 Method of obtaining pyromucous acid.

Pyromucous (v) acid is procured by diſtilling ſugar or any of the ſweet juices. As they foam very much, the retort ſhould be large, and ſeven-eighths of it empty. A prodigious quantity of carbonic acid and carbonated hydrogen gas is diſengaged: A very thin light coal remains behind in the retort. Morveau found the glaſs of the retort attacked. The quantity of ſugar diſtilled was 2304 grains; the coal weighed 982 grains. There were 428 grains of a brown liquor in the receiver, conſiſting moſtly of an acid phlegm. This rediſtilled gave 313 grains of a liquor almoſt limpid, the ſpecific gravity of which was 1,0115 at the temperature of 77°. It reddened blue paper. This acid may be concentrated by freezing, or by combining it with ſome baſe, potaſs for inſtance, and decompoſing the compound by a ſtronger acid, as, for example, the ſulphuric. 523

Its properties.

It has a very ſharp taſte. When expoſed to heat in open veſſels it evaporates, leaving a brown ſpot. Diſtilled in cloſe veſſels, it leaves charcoal behind it.

It does not diſſolve gold as Schrickel and Lemery and ſeveral other chemiſts affirmed.

It does not attack ſilver nor mercury, nor even their oxyds†. It corrodes lead, and forms ſtyptic and long cryſtals. Copper forms with it a green ſolution: With iron it forms green cryſtals; with antimony and zinc greeniſh ſolutions. 524

† *Schrickel.*

Combinations and affinities.

The compounds which it forms are called *pyromucites*. Its affinities, according to Morveau, are as follows:

Potaſs,
Soda,
Barytes,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia†,
Metallic oxyds as in ſulph. acid,
Water,
Alcohol.

† *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXVI. *Of Pyro-lignous Acid.*

525 Method of obtaining pyro-lignous acid.

It is well known that the ſmoke of burning wood is exceedingly offenſive to the eyes: And chemiſts have long ago obſerved, that an acid might be obtained by diſtilling wood.

It is to Mr Goettling, however, and to the Dijon academicians, who repeated his experiment, that we are indebted for what knowledge we poſſeſs of the peculiar properties of this acid, which, becauſe it is obtained from wood by means of fire, has been called *the pyro-lignous acid* (w). It appears to be the ſame from whatever kind of wood it is obtained.

Mr Goettling filled an iron retort with pieces of birch tree bark, and obtained by diſtillation a thick, brown, very empyreumatic acid liquor. This liquor he allowed to remain at reſt for three months, and then ſeparated from it a quantity of oil which had riſen to the top. By diſtilling this liquor again, and then ſaturating it with potaſs, and evaporating it to dryneſs, he obtained a brown ſaline maſs; which, by being rediſſolved in water, and evaporated, yielded greyiſh white cryſtals: Theſe cryſtals were compoſed of pyro-lignous acid

(u) On this addition, tartar, or acidulated tartrite of potaſs, is formed, which precipitates, becauſe it is very little ſoluble in water. The addition of potaſs diſſolves it again.

(v) Morveau called this acid *ſyrupous* acid.

(w) Goettling called it *ligneous acid.*

acid and potaſs. He poured upon them, by little and little, a quantity of ſulphuric acid; and by applying a gentle heat, the pyro-lignous acid came over in conſiderable purity†.

† *Crell's Journal*, 1779.

The Dijon academicians obtained this acid from beech wood: by diſtilling 55 ounces, they procured 17 ounces of acid; which, when rectified by a ſecond diſtillation, was of the ſpecific gravity 1,02083.

526 Its properties, combinations, and affinities.

It reddens vegetable colours: when expoſed to a ſtrong heat, it takes fire and is deſtroyed. It unites very well with alcohol.

Its compounds are called *pyro-lignites*.

Its affinities, as fixed by Mr Eloy Bourſier de Clervaux and Mr de Morveau, are as follows:

Lime,
Barytes,
Potaſs,
Soda,
Magneſia,
Ammonia,
Oxyd of zinc,
——— manganeſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,
——— gold,
——— platinum,
Alumina,
Jargonia‡?

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXVII. *Of Pyro-tartarous Acid.*

An acid may alſo be obtained by diſtilling tartar; it is called *pyro-tartarous acid.*

527 Properties of pyro-tartarous acid.

It has an empyreumatic taſte and odour, reddens the tincture of turnſole; but has no effect on that of violets.

Little is known concerning this acid, except that many of its properties are the ſame with thoſe of the pyro-lignous; and Morveau conjectures, that, if properly purified, it would probably be diſcovered to be the ſame with it.

The compounds which it forms are called *pyro-tartrites*.

Its affinities are unknown. Morveau ſuppoſes that they are the ſame with thoſe of the pyro-lignous acid.

528 Vegetable acids,

The 18 preceding acids are all (except the lactic and ſaccholactic) denominated *vegetable acids*, becauſe they are obtained from vegetable ſubſtances. We have placed the lactic and ſaccholactic acids in the ſame claſs; becauſe they bear a ſtrong reſemblance to vegetable acids, and becauſe they are evidently compoſed of the ſame ingredients with them.

529 Deſtroyed by fire.

Vegetable acids are diſtinguiſhed from all the acids deſcribed in the beginning of this chapter, by their deſtructibility by fire.

530 Convertible into each other.

There is no circumſtance in chemiſtry which has attracted greater attention than the poſſibility of converting the various vegetable acids into each other by means of different proceſſes. To explain what paſſes during theſe proceſſes, it would be neceſſary to know exactly the component parts of every vegetable acid, the manner in which theſe acids are combined, and the affinities which exiſt between each of their ingredients. This, however, is very far from being the caſe at preſent. Though a vaſt number of experiments have been made on purpoſe to throw light on this very point, the difficulties which were to be encountered have been ſo great, that no accurate reſults have yet been obtained.

531 Enquiry into the proportions of their ingredients.

It follows from theſe experiments that all the vegetable acids are compoſed chiefly, at leaſt, of oxygen, hydrogen, and carbon; but that the proportions differ in every individual acid. We ſay chiefly, becauſe it has been ſuſpected from ſome phenomena, that one or two of theſe acids contain beſides a little azot. Let us take a view of what is at preſent known of the compoſition of theſe acids in their order.

1. As to carbonic acid, its compoſition has been aſcertained with tolerable accuracy; it conſiſts of about 28 parts of carbon, and 72 of oxygen.

2. By diſtilling 7680 grains of acetite of potaſs, Dr Higgens obtained the following products*:

* *Higgins on Acetous Acid*, p. 26.

Potaſs, - - -	3862,994 grains.
Carbonic acid gas, -	1473,564
Carbonated hydrogen gas, -	1047,6018
Reſiduum, conſiſting of carbon,	78,0000
Oil, - - -	180,0000
Water, - - -	340,0000
Deficiency(x), - -	726,9402

This deficiency Dr Higgens found to be owing to a quantity of water and oil which is carried off by the elaſtic fluids, and afterwards depoſited by them. He calculated it, in the preſent caſe, at 700 grains of water and 26,9402 grains of oil. Now, ſince acetite of potaſs is compoſed of acetous acid and potaſs, and ſince the whole of the potaſs remained unaltered, it follows that the acetous acid was converted into carbonic acid gas, carbonated hydrogen gas, carbon, oil and water; all of which are compoſed of oxygen, hydrogen and carbon.

Now 1473,564 gr. of carbonic acid gas are compoſed of 1060,966 gr. of oxygen, and 415,598 gr. of carbon.

1047,6018 grains of carbonated hydrogen gas, from a compariſon of the experiments of Dr Higgens and Lavoiſier, may be ſuppoſed to conſiſt of about 714,6008 grains of carbon, and 333,0010 of hydrogen.

200 9402 grains of oil contain 163,4828 grains of carbon, and 43,4574 grains of hydrogen.

1040 grains of water contain 884 grains of oxygen and 156 grains of hydrogen.

Therefore 3817,006 grains of acetous acid are compoſed of 1944,966 — 29,1 = 1915,866 grains of oxygen, 532.4584 grains of hydrogen, and 1368,6816 grains of carbon. Conſequently 100 parts of acetous acid are compoſed of

50,19

(x) For 29,1 grains of oxygen gas had alſo diſappeared from the air of the veſſels.

50,19 oxygen
13,94 hydrogen,
35,87 carbon.

100,00

Theſe numbers can only be conſidered as approximations to the truth; for the object of Dr Higgins was not to aſcertain the proportions of the ingredients which compoſe acetous acid; and therefore his experiments were not conducted with that rigid accuracy which would have been neceſſary for that purpoſe.

It is extremely probable, that during the acetous fermentation, or the converſion of alcohol into acetous acid, a quantity of water is formed*; and it is certain that oxygen is abſorbed. It follows from this, that acetous acid contains more carbon and leſs hydrogen than alcohol. Now we have reaſon, from Lavoiſier's experiments, to believe, that alcohol is formed of

51,72 oxygen,
18,40 hydrogen,
29,88 carbon.

Lavoiſier ſuppoſes that this acid contains alſo azot.

3. Acetic acid is ſuppoſed to conſiſt of the ſame baſe with acetous acid, combined with a larger proportion of oxygen; we would rather ſay, that it is acetous acid combined with oxygen.

4. When oxalic acid is diſtilled with ſix times its weight of ſulphuric acid, the products are acetous acid, ſulphurous acid, carbonic acid gas, and ſulphuric acid remains in the retort†. Hence it follows, that oxalic acid contains more carbon than acetous acid; but that it is compoſed of the ſame ingredients. It has been ſuppoſed, that oxalic acid is compoſed of ſugar and oxygen. Now ſugar, according to Lavoiſier, is compoſed of

Hydrogen, - - - - -	8
Oxygen, - - - - -	64
Carbon, - - - - -	28

Theſe proportions are rather unfavourable to that notion; at leaſt if any dependence can be put in the compoſition of acetous acid as deduced from the experiments of Dr Higgins.

5. Hermſtadt diſſolved four ounces of tartarous acid in 16 ounces of water, and kept the ſolution in a veſſel covered with paper in a warm place. In three months the taſte of the ſolution was changed, and the air in the upper part of the veſſel was found to be carbonic acid. In ſix months the ſolution was converted into acetous acid. It follows from this experiment, that tartarous acid contains more carbon than acetous acid, and that their ingredients are the ſame. If any doubts ſhould remain, the following experiment is ſufficient to remove them. Weſtrum mixed ſtrong ſulphuric acid with tartarous acid, and added mangaueſe; acetous acid was produced, and a great quantity of carbonic acid gas was diſengaged. When nitric acid is diſtilled off tartarous acid, it is converted into oxalic acid, as Scheele firſt proved. Hence it has been ſuppoſed by ſome, that oxalic acid differs from tartarous merely in containing more oxygen: but this is very far indeed from being proved. According to Haſſenfratz, tartarous acid contains a conſiderable quantity of azot.

6. When citrat of lime is allowed to remain in a bottle ſlightly corked along with a little alcohol, the citric acid is gradually converted into acetous acid‡.

* Hermſtadt, Crell's Annals, 1786.

† Crell, Jour. de Phyſ. 1785.

‡ Stahl.

Weſtrum converted it into oxalic acid by means of nitric acid.

7. Malic acid was converted into oxalic by means of nitric acid by Scheele. It has been ſuppoſed to contain more oxygen than oxalic acid. Some of it is always formed during the common proceſs of converting ſugar into oxalic acid. Were we to judge from an experiment, which, however, was not performed with ſufficient accuracy, we would conclude that the baſe of malic acid is gum; for by diſtilling two parts of weak nitric acid off one part of gum in a very ſmall heat, we obtained a quantity of acid more in weight than the gum, which exhibited ſeveral of the diſtinguiſhing properties of malic acid. It was exceedingly light, white, and ſpongy, and attracted water very quickly from the atmoſphere, and could not afterwards be brought by evaporation to its former ſtate.

8. Scheele converted lactic acid into acetous by mere expoſure to the atmoſphere, and found that a quantity of carbonic acid was diſengaged. Hence this acid is merely the acetous with a ſmaller proportion of carbon.

9. The gallic acid, we have ſeen, contains more carbon than any of the others.

10. Nothing is known concerning the compoſition of the benzoic and ſuccinic acids. Hermſtadt ſays he converted benzoic acid to oxalia by means of nitric acid: but Morveau did not obſerve that any change was produced.

11. The baſe of camphoric is probably camphor.

Though theſe eighteen are the only acids which have hitherto been examined with attention, it cannot be doubted that the number of vegetable acids, either exiſting naturally, or at leaſt capable of being formed by art, is conſiderably greater. Morveau has lately aſcertained, that the red colours of flowers are owing to acids: This had already been conjectured by Linnæus.

Sect. XXVIII. *Of Pruſſic Acid.*

532 Diſcovery of Pruſſian blue.

About the beginning of the preſent century, Dieſbach, a chemiſt of Berlin, wiſhing to precipitate a ſolution of cochineal mixed with a little alum and ſulphat of iron, borrowed from Dippel ſome potaſs, from which that chemiſt had *diſtilled* ſeveral times his *animal oil*. On pouring in the potaſs, Dieſbach was ſurprized to ſee, inſtead of the red precipitate which he had expected, a beautiful blue powder falling to the bottom of the veſſel. By reflecting on the materials which he had employed, he eaſily diſcovered the method of procuring the blue powder at pleaſure*. This powder was called *Pruſſian blue*, from the place where it was diſcovered. It was announced in the Berlin Memoirs for 1710; but the proceſs was concealed, becauſe it had become a lucrative article of commerce. A method of preparing it, however, was publiſhed by Woodward in the Philoſophical Tranſactions for 1724, which he ſaid he had got from one of his friends in Germany. This method was as follows: Detonate together 4 ounces of nitre and as much tartar, in order to procure an extemporaneous alkali; then add 4 ounces of dried bullock's blood, mix the ingredients well together, and put them into a crucible covered with a lid, in which there is a ſmall hole; calcine with a moderate fire till the blood emits no more ſmoke or flame capable of blackening any white body expoſed

533 Method of preparing it.

* Stahl's 300 Experiments.

Prussic Acid.

exposed to it: increase the fire towards the end, so that the whole matter contained in the crucible shall be moderately but sensibly red. In this state throw it into two pints of water, and boil it for half an hour. Decant off this water, and continue to pour on more till it come off insipid. Add all these liquids together, and boil them down to two pints. Dissolve two ounces of sulphat of iron and eight ounces of alum in two pints of boiling water; mix this with the former liquor while both are hot. An effervescence takes place, and a powder is precipitated of a green colour mixed with blue. Separate this precipitate by filtration, and pour muriatic acid upon it till it becomes of a beautiful blue; then wash it with water and dry it.

Different explanations were given of the nature of this precipitate by different chemists. All of them acknowledged that it contained iron, but to account for the colour was the difficult point. Brown and Geoffroy, and Neumann, discovered in succession, that a great many other animal substances besides blood communicated to alkalies the property of forming Prussian blue. Macquer undertook an examination of this substance, and published the result of his experiments in the Memoirs of the French Academy for 1752.

534 Its composition discovered by Macquer.

He observed, that when alkali is added to a solution of iron in any acid, the iron is precipitated of a yellow colour, and soluble in acids; but if iron be precipitated from an acid by an alkali prepared as above described, by calcination with blood (which has been called a *Prussian alkali*), it is of a green colour. Acids dissolve only a part of this precipitate, and leave behind an insoluble powder which is of an intense blue colour. The green precipitate therefore is composed of two different substances, one of which is Prussian blue; the other, as he ascertained by experiment, is the brown or yellow oxyd of iron; and the green colour is owing to the mixture of the blue and yellow substances. When heat is applied to the insoluble precipitate, its blue colour is destroyed, and it becomes exactly similar to common oxyd of iron. It is composed therefore of iron and some other substance, which heat has the property of driving off. If this insoluble precipitate be boiled with a very pure alkali, it loses its blue colour also, and at the same time the alkali acquires the property of precipitating of a blue colour solutions of iron in acids, or it has become precisely the same with the Prussian alkali. Prussian blue, therefore, is composed of iron and something which a pure alkali can separate from it, something which has a greater affinity for alkali than for iron. By boiling a quantity of alkali with Prussian blue, it may be completely saturated with this something, which we shall call *colouring matter*, and then it has lost all its alkaline properties. No acid can separate this colouring matter from iron after it is once united with it. When iron dissolved in an acid is mixed with an alkali saturated with the colouring matter, a double decomposition takes place, the acid unites with the alkali, and the colouring matter with the iron, and forms Prussian blue. The reason that, in the common method of preparing Prussian blue, a quantity of yellow oxyd is precipitated, is, that there is not a sufficient quantity of colouring matter (for the alkali is never saturated with it) to saturate all the iron displaced by the alkali; a part of it therefore is mixed with Prussian blue. Muriatic acid dissolves this oxyd, carries it off, and leaves the blue in a state of purity. Such were the conclusions which Macquer drew from his experiments; experiments which not only discovered the composition of Prussian blue, but threw a ray of light on the nature of affinities, which has contributed much towards the advancement of that important branch of chemistry.

The nature of the colouring matter, however, was still unknown. Macquer himself supposed, that it was pure phlogiston; but the opinion was untenable. He had shewn that it possessed the property of forming neutral salts, and therefore Bergman and Morveau suspected that it was an acid.

Scheele undertook the task of examining its nature, and published the result of his experiments in the Stockholm Transactions for 1782.

He observed, that the Prussian alkali, after being exposed for some time to the air, lost the property of forming Prussian blue; the colouring matter must therefore have left it.

535 Decomposed by Scheele.

He put a small quantity of it into a large glass globe, corked it up, and kept it some time; but no change was produced either in the air or the Prussian alkali. Something must therefore displace the colouring matter when the alkali is exposed to the open air, which is not present in a glass vessel. Was it carbonic acid gas? To ascertain this, he put a quantity of Prussian alkali into a glass globe filled with that gas, and in 24 hours the alkali was incapable of producing Prussian blue. It is therefore carbonic acid gas which displaces the colouring matter. He repeated this experiment with this difference, that he hung in the globe a bit of paper which had been previously dipped into a solution of sulphat of iron, and on which he had let fall two drops of an alkaline lixivium, in order to precipitate the iron. This paper was taken out in two hours, and became covered with a fine blue on adding a little muriatic acid. Carbonic acid, then, has the property of separating the colouring matter from alkali without decomposing it.

536 The colouring matter separated.

He found also that other acids produced the same effect. The colouring matter then may be obtained perhaps in a separate state. He accordingly made a number of attempts to procure it, and at last discovered the following process: He boiled together for some minutes two ounces of Prussian blue in powder, one ounce of the red oxyd of mercury, and six ounces of water; then passed the whole through a filter, and washed the residuum with two ounces of boiling water. The oxyd of mercury has a greater affinity for the colouring matter than the oxyd of iron; it therefore unites with it, and forms with it a salt soluble in water. The iron remains behind upon the filter, and the liquid is a solution of the colouring matter combined with mercury. He poured this solution upon half an ounce of pure iron-filings, and added at the same time three grains of sulphuric acid. The iron separates the oxygen from the mercury, in order to combine with the sulphuric acid; the mercury is precipitated in its metallic state, and leaves behind it a quantity of sulphat of iron and of colouring matter dissolved in water, but not combined, as the colouring matter is unable to separate the iron from the acid*.

He then distilled in a gentle heat; the colouring matter came over by the time that one fourth of the liquor had passed into the receiver. It was mixed, however, with a small quantity of sulphuric acid; from which he separated

* *Berthollet, Ann. de Chimie*, i. 30.

Pruffic Acid.

feparated it by diftilling a fecond time over a quantity of carbonat of lime. The fulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, becaufe carbonic acid has a ftronger affinity for lime than it has. Thus he obtained the
537 colouring matter in a ftate of purity.

Its component parts.

It remained now to difcover its component parts. He formed a very pure Pruffian blue, which he diftilled, and increafed the fire till the veffel became red. The fmall quantity of water which he had put into the receiver contained a portion of the blue colouring matter and of ammonia; and the air of the receiver confifted of azot, carbonic acid gas, and the colouring matter. He concluded from this experiment, that the colouring matter was compofed of ammonia and carbon. He mixed together equal quantities of pounded charcoal and potafs, put the mixture into a crucible, and kept it red hot for a quarter of an hour: he then added a quantity of fal ammoniac in fmall pieces, which he pufhed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceafed to give out vapours of ammonia, and then threw it into a quantity of water. The folution poffeffed all the properties of the Pruffian alkali. Thus Mr Scheele fucceeded in forming the colouring matter; and it was confidered as proved that it was compofed of ammonia and carbon.

But after the publication of Scheele's experiments, it was difcovered that ammonia itfelf is compofed of azot and hydrogen. It became therefore a queftion, whether ammonia entered into the compofition of this fubftance, or merely its ingredients? whether it was compofed of ammonia and carbon, or of azot, hydrogen, and carbon combined in a different manner? This point has been decided by the following experiments. Mr Clouet made a quantity of ammoniacal gas pafs through a red hot porcelain tube filled with charcoal, and by this procefs formed a quantity of the colouring matter.* Here the temperature was fo high, that the ammonia muft have been decompofed; and the colouring matter cannot be formed by combining ammonia and charcoal except at a temperature equally high. There is reafon therefore to fuppofe that the ammonia is decompofed. When oxy-muriatic acid is mixed with the colouring matter, it communicates to it a quantity of oxygen, and caufes it in confequence to affume very different properties. When a fixed alkali or lime is added to it in this ftate, it is immediately decompofed, and converted into ammonia and carbonic acid gas. The colouring matter in this ftate contains all the ingredients neceffary to form thefe two fubftances, namely, azot, hydrogen, carbon, oxygen; but in order to induce the ingredients to form thefe two compounds, the affiftance of an alkali or lime to combine with the carbonic acid is neceffary; juft as fulphur combines more eafily with oxygen when united with an alkali or with iron than when feparate.*

* Ann. de Chim. xi.

* Berthollet, Ann. de Chim. i.

The colouring matter, then, which we fhall henceforth call the *Pruffic acid*, is compofed of azot, hydrogen, and carbon; but the proportions of thefe ingredients have not yet been determined. It is confidered as an acid, though the prefence of oxygen has not been proved, becaufe it has the property of forming neutral falts with the fame bafes as other acids. 538

Properties of Pruffic acid.

The Pruffic acid is exceedingly volatile, and evidently capable of exifting in a gafeous ftate. It has a peculiar odour, not difagreeable, and which has been compared to the flowers of the peach. It has a fweetifh and fomewhat hot tafte, and excites cough †.

It has no affinity for alumina nor for alcohol ‡.

† Scheele.

‡ Morveau.

This fubftance differs exceedingly in its action from all other acids. 539

Its action on other bodies.

It is capable of combining, like them, with earths, alkalies, and metallic oxyds, and of forming compounds which have been denominated *Pruffiats*. But it enters much more readily into triple compounds with alkalies or earths, and metallic oxyds, than into combinations with earths or alkalies feparately; and though its affinity appears to be greater for alkalies and earths than for metallic oxyds, yet when in a free or gafeous ftate it does not enter into combinations with earths or alkalies without difficulty, and it is feparated from them much more eafily than from metallic oxyds. Mere expofure to the light of the fun, or to a heat of 110°, is fufficient for that purpofe. 540

Its affinities.

Its affinities are fuppofed to be as follows;

Potafs,
Soda,
Ammonia,
Lime,
Barytes,
Magnefia,
Oxyd of zinc,
——— iron,
——— manganefe,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— bifmuth,
——— antimony,
——— arfenic,
——— filver,
——— mercury,
——— gold,
——— platinum (Y).

Sect. XXIX. *Of Formic Acid.*

541

Difcovery of formic acid.

In the 15th century feveral botanifts obferved with aftonifhment, that the flower of fuccory, when thrown into an ant-hill, became as red as blood: But it was Mr S. Fifher who firft difcovered that ants poffeffed a peculiar acid, which he obtained by diftilling thefe animals. His experiments were publifhed in the Philofophical Tranfactions for 1670. Though Hoffman afterwards repeated his procefs, little was known concerning the nature of this acid till Margraf undertook its examination,

(Y) We fufpect that this is not the real order of the affinities of this acid; the metallic oxyds ought probably to be placed before the alkalies and earths, and the metallic Pruffiats ought to occupy the place which is at prefent filled by the metallic oxyds. The reafons for this conjecture will appear afterwards. See Part III. chap. ii. fect. 23. of this article.

Formic Acid.

mination, and publifhed his experiments in the Berlin Memoirs for 1749.

The fpecies of ants from which the formic acid is obtained is the *formica rufa*, which refide moft commonly in woods, or at leaft in elevated and dry places. They have been found to contain the greateft quantity of acid in the months of June and July. If at that feafon one of thefe animals be preffed upon paper tinged with turnfole, it changes the colour of it to a moft lively red; they even fometimes ftain it merely by crawling over it.

542 Method of obtaining it.

There are two methods of obtaining the formic acid, diftillation and lixiviation.

When the firft method is to be employed, the ants are to be wafhed clean, dried with a gentle heat, put into a retort, and diftilled with a moderate heat, gradually increafed till all the acid has come over. It is mixed with an empyreumatic oil, from which it is feparated by paffing it through a ftrainer previoufly moiftened with water. By this procefs Meffrs Ardviffon and Oehrn obtained from a pound of ants 7½ ounces of acid, the fpecific gravity of which, at the temperature of 60°, was 1,0075.* Morveau obtained from 49 ounces of ants 23 ounces of pretty ftrong acid †. Margraf added a quantity of water, but it is evident that this ferves merely to weaken the acid.

* *Differt. on the Acid of Ants*, 1777, in *Baldinger's New Magazine for Arts.*

† *Encycl. Method.* i. 61.

When the other method is preferred, the ants are to be wafhed in cold water, put upon a clean linen cloth, and boiling water poured on them repeatedly till it can extract no more acid. The linen is then to be fqueezed, and the feveral liquors mixed and filtrated. This method was firft ufed by Ardviffon and Oehrn: they obtained from a pound of ants an acid liquor which had more fpecific gravity than common vinegar. It is to be purified from the oil which adheres to it by repeated diftillations. After four diftillations the empyreumatic oil ftill manifefts its prefence by its fmell, but this fmell vanifhes if the acid be expofed for fome time to the air; a quantity of effential oil, however, ftill remains, which cannot be feparated. The fpecific gravity of the acid thus rectified is 1,0011 ‡.

‡ *Ardviffon and Oehrn, ibid.*

Hermftadt employed a third method. He expreffed the juice of dry ants, and by this means obtained from 2 lbs. of thefe animals 21 oz. 2 dr. of juice, which on diftillation yielded a clear pure acid, equal in ftrength to very concentrated vinegar.*

* *Crell's Annals*, 1784.

543 Its properties.

This acid feems to be capable of affuming a gafeous form; at leaft Hermftadt obferved, that when he put fome of it into a bottle with a glafs ftopper, the ftopper was frequently raifed by an elaftic fluid making its efcape, and that after fome days it had loft its fmell †. When this acid is boiled with nitric acid, a gas is extricated, which renders lime water turbid, and has a very pungent odour †.

† *Ibid.*

† *Ardviffon, ibid.*

This acid has a ftrong but not unpleafant fmell, a cauftic tafte, and when much diluted a pleafant acidity. When moft concentrated, its fpecific gravity is 1,0453 ‡.

‡ *Ibid.*

One part of this acid, mixed with 75 parts of water, gives a faint red to fyrup of violets; mixed with 430 parts of water, it reddens paper coloured with turnfole; mixed with 1300 parts of water, it produces no effect on the infufion of turnfole ‡. It mixes readily with alcohol.

‡ *Morveau*, p. 62.

It unites readily with the other acids. When boiled with fulphuric acid, it becomes black. White acrid vapours rife when the mixture becomes hot; and when it boils, a gas rifes which unites with difficulty to water and lime-water; the formic acid is again obtained, but its quantity is diminifhed §.

§ *Ibid.*

Nitric acid decompofes it altogether, and is itfelf converted into nitrous acid. Muriatic acid does not alter it. Oxy-muriatic acts like nitric acid.*

* *Ibid.*

Its compounds are called *formiats*. 544 Its compounds and affinities.

Its affinities are the fame with thofe given above for the Pruffic acid.

Sebacic Acid.

Sect. XXX. *Of Sebacic Acid.*

545 Difcovery of febacic acid,

Chemists had long fufpected that an acid could be obtained from tallow, on account of the acrid nature of the fumes which it emitted at a high temperature; but it was M. Grutzmacher who firft demonftrated this acid in a differtation *De Offium Medulla*, publifhed in 1748 ‡. M. Rhodes mentioned it in 1753, and Segner publifhed a differtation on it in 1754, and Crell examined its properties very fully in two differtations publifhed in the Phil. Tranf. for 1780 and 1782. It was called at firft *acid of fat*, and afterwards *febacic acid*.

‡ *Leonhardi.*

It may be procured by heating together a mixture of fuet and lime. Sebat of lime is formed, which may be purified by folution in water. It is then to be put into a retort, and fulphuric acid poured on it. Sebacic acid paffes over on the application of heat.

546 Its properties,

Sebacic acid has an acid, fharp, bitterifh tafte, and a very pungent fmell. It reddens tincture of litmus.

Heat caufes it to affume a yellow colour.

It oxydates filver, mercury, copper, iron, lead, tin, zinc, antimony, manganefe.

It does not act upon bifmuth, cobalt, nickel. When mixed with nitric acid it diffolves gold.

Its compounds are called *febats*. 547 Compounds, and affinities.

Its affinities, according to Morveau, are as follows:

Barytes,
Potafs,
Soda,
Lime,
Magnefia,
Ammonia,
Alumina,
Jargonia †,
Oxyd of zinc,
——— manganefe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arfenic,
——— bifmuth,
——— mercury,
——— antimony,
——— filver,

† *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXX. *Of Bombyc Acid.*

548 Difcovery of bombyc acid.

Mr Boissier de Sauvages obferved, that the juice of the filkworm, in the difeafe called in France *mufcadine*, was acid; and Chauffier remarked, that the filkworm, after being converted into a butterfly, gives out a

Zoonic Acid.

a liquor which turns vegetable blues to a red. He found, that during the time that the animal was forming its cocon, the acid was depofited in a refervoir near the anus. By means of a pair of fciffars he collected fome which reddened blue paper, united with alkalies with effervefcence, and even attacked the fciffars. He afterwards collected it by infufing the chryfalids in alcohol, which diffolved the acid, but left the impurities untouched.

This acid has never been examined with attention; fo that almoft all its properties are unknown.

Sect. XXXI. *Of Zoonic Acid.*

549 Method of obtaining zoonic acid.

Mr Berthollet has obtained a peculiar acid by diftilling vegetable and animal fubftances, to which he has given the name of the *zoonic acid*†. He procured it by diftilling the gluten of wheat, the yeft of beer, bones, and woollen rags; and concludes, therefore, that it may be produced by the diftillation of all animal fubftances.

† *Ann. de Chim.* xxvi. 86.

To obtain this acid pure, he mixed lime with the diftilled liquid, after having feparated the oil, which it always contains (for the product of the diftillation of animal fubftances is chiefly oil and carbonat of ammonia). He boiled this mixture till the carbonat of ammonia was exhaled: he then filtered it, added a little more lime, and boiled it again till the fmell of the ammonia had gone off entirely. The liquor, which now contained only zoonat of lime, he filtered again, and then added a little water impregnated with carbonic acid, in order to precipitate any lime which might happen to be diffolved in the liquid without being combined with the zoonic acid.

After concentrating the zoonat of lime, he mixed it with phofphoric acid, and diftilled it in a retort. At a heat nearly equal to that of boiling water, the zoonic acid paffes over in a ftate of purity.

550 Its properties.

The zoonic acid has an odour like that of meat when frying, and it is actually formed during that procefs. It has an auftere tafte.

It gives a red colour to paper tinged with turnfole.

With alkalies and earths it produces falts, which do not appear capable of cryftallizing.

It forms a white precipitate in the folutions of acetite of lead and nitrat of mercury.

Part of the zoonic acid feems to be deftroyed by the action of heat during the diftillation of the zoonat of lime with phofphoric acid: for the liquor, which is in ebullition, becomes brown, and grows black at the end of the operation; hence Mr Berthollet concludes that the zoonic acid contains carbon. The zoonat of filver, when kept, becomes gradually brown; hence he concludes that the acid contains hydrogen. Thefe conclufions he draws from a very ingenious theory of his, which has been already defcribed in the article Bleaching in this *Supplement**.

* *Berthollet, Ann. de Chim.* xxvi.

551 Animal acids.

The five preceding acids have obtained the name of *animal acids*, becaufe they are all obtained from the animal kingdom. It can fcarcely be doubted that a more accurate examination of animal fubftances will add confiderably to the number of thefe acids.

Sect. XXXII. *Of Arfenic Acid.*

Arsenic acid, which was firft difcovered by Scheele, may be produced by fimply mixing the white oxyd

Arfenic Acid.

of arfenic with oxy-muriatic acid, and applying a heat fufficient to fublime the muriatic acid. The theory of this operation is evident: the white oxyd has a greater affinity for oxygen than muriatic acid has; of courfe it combines with it, and is thus converted into arfenic acid, and the muriatic acid is eafily fublimed by applying heat. 552 Method of obtaining arfenic acid.

Landriani has informed us, that this acid may be alfo formed by fubliming feveral times fucceffively the white oxyd of arfenic, and taking care every time to renew the air. This procefs is equally fimple; the oxyd combines at a high temperature with the oxygen of the atmofphere.

553 Its properties.

This acid is exceedingly fixed. When expofed to the air it attracts humidity, and at laft becomes liquid. At the temperature of 60° it diffolves in two-thirds of its weight of water. Its folution may be evaporated to drynefs, and even converted into a glafs, which attracts moifture from the air, and acts powerfully on the crucible.

It is poifonous as well as the white oxyd of arfenic*.

* *Scheele.*

When expofed to a red heat, it is partly decompofed and converted into white oxyd of arfenic†.

† *Id.*

It does not act upon gold, platinum, filver, mercury.

It oxydates copper, iron, lead, tin, zinc, bifmuth, antimony, cobalt, nickel, manganefe, and arfenic, and in a very ftrong heat mercury and filver.

According to Berthollet's experiments, arfenic acid is compofed of eight parts of white oxyd of arfenic, and one part of oxygen.

554 Its compounds and affinities.

Its compounds are called *arfeniats.*

Its affinities are as follows:

Lime,
Barytes,
Magnefia,
Potafs,
Soda,
Ammonia,
Oxyd of zinc,
——— manganefe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— bifmuth,
——— mercury,
——— antimony,
——— filver,
——— gold,
——— platinum,
Alumina,
Jargonia †?
Water.

† *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. XXXIII. *Of Tungftic Acid.*

555 Properties of tungftic acid.

Tungstic acid, or oxyd of tungften, was firft difcovered by Scheele; but the acid which he examined was not pure, being compofed, as Mr Luyart has fhewn, of nitric acid, ammonia, and tungftic acid. The real acid is infoluble in water, taftelefs, and incapable of turning vegetable blues red till it has been firft rendered foluble

Molybdic Acid. ſoluble by being partly combined with ammonia. It is of a beautiful yellow colour, which becomes blue when expoſed to the light, or heated violently in cloſe veſſels. It does not recover its yellow colour, except by calcination in the open air, and then increaſes in weight. When put into muriatic acid along with tin, zinc, or iron, the liquor becomes blue*. Treated with acetous acid, it becomes blue. When reduced to a glaſs with phoſphat of ſoda, the blue colour appears and diſappears, according as the blue or yellow part of the flame is directed to it, as happens to manganeſe. Probably this blue ſubſtance is an oxyd of tungſten with a ſmaller quantity of oxygen.

* Renman.

556
Its compounds and affinities.

Its compounds are called *tungſtats*.

Its affinities are as follows*:

Lime,
Barytes,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia†?

* Luyorts.

† Vauquelin, Ann. de Chim. xxii. 208.

Sect. XXXIV. *Of Molybdic Acid.*

557
Properties of molybdic acid.

Concrete molybdic acid, firſt diſcovered by Scheele, is white, and has an acid but metallic taſte. Its ſpecific gravity is 3,75*. It is not altered in the air. When heated in a crucible till it is beginning to melt, it experiences no alteration. It remains fixed even in a great fire as long as the crucible is covered; but the moment it is uncovered, the acid riſes unaltered in a white ſmoke. It diſſolves in 570 parts of water. The ſolution reddens turnſole; nitric acid does not affect it, but ſulphuric and muriatic acids diſſolve it by the aſſiſtance of heat.

* Bergman.

It may be prepared by treating the ore of molybdenum with nitric acid, and waſhing the acid when formed in water.

When combined with potaſs, it forms a colourleſs ſalt.

Mixed with filings of tin and muriatic acid, it immediately becomes blue, and precipitates flakes of the ſame colour, which diſappear after ſome time, if an exceſs of muriatic acid has been added, and the liquor aſſumes a browniſh colour.

With the ſolution of nitrat of lead it forms a white precipitate, ſoluble in nitric acid.

When mixed with a little alcohol and nitric acid, it does not change its colour.

With a ſolution of nitrat of mercury, or of nitrat of ſilver, it gives a white flaky precipitate.

With the nitrat of copper it forms a greeniſh precipitate.

With ſolutions of ſulphat of zinc, muriat of biſmuth, muriat of antimony, nitrat of nickel, muriats of gold and platinum, it produces white precipitates when theſe ſolutions do not contain an exceſs of acid.

When melted with borax, it gives it a bluiſh colour.

Paper dipt in this acid becomes in the ſun of a beautiful blue colour*.

Sulphur is capable of partly decompoſing it by heat.

Its compounds are called *molybdats*.

Its affinities are unknown.

* Vauquelin, Philoſophical Magazine, i. 282.

Sect. XXXV. *Of Chromic Acid.*

Chromic Acid.

558
Analyſis of the red lead of Siberia,

In the year 1770, Mr Pallas diſcovered, in the gold mine of Bereſof, near Ekaterimbourg in Siberia. a mineral of a red colour, with a ſhade of yellow cryſtallized in ſmall acute angled quadrangular priſms, ſometimes ſmooth, ſometimes longitudinally ſtreaked, and often hollow. Mr Macquart, profeſſor of medicine at Paris, who in 1783 had been ſent to the north by the French government in order to collect mineralogical information, brought with him a quantity of this mineral, which has been diſtinguiſhed by the name of *red lead ore of Siberia*, and in 1789 analyſed four ounces of it along with Mr Vauquelin. They found it to contain,

Lead	$36\frac{1}{9}$
Oxygen	$37\frac{5}{9}$
Iron	$24\frac{8}{9}$
Alumina	2
	$100\frac{5}{9}$

and a little ſilver*.

* Ann. de Chim. i. 301.

Mr Bindheim of Moſcow analyſed it ſoon after, and found it to contain,

Lead	60
Molybdic acid	11,66
Nickel	5,66
Oxyd of iron,	1
Air and water,	6
Silica	4,5
	87,82

and a little copper and cobalt†.

† Berl. Beob. iv. 2911.

Vauquelin examined it again in 1797, and found that all the former analyſes were inaccurate.

A hundred parts of this mineral reduced to a fine powder were mixed with 300 parts of the ſaturated carbonat of potaſs, and about 4000 parts of water; and this mixture was expoſed for an hour to a boiling heat. He obſerved, 1ſt, that when theſe matters began to act upon each other there was produced a ſtrong efferveſcence, which continued a long time; 2d, that the orange colour of the lead became a brick red; 3d, that at a certain period the whole matter ſeemed to diſſolve; 4th, that in proportion as the efferveſcence advanced the matter reappeared under the form of a granulated powder of a dirty yellow colour; 5th, that the liquor aſſumed a beautiful golden yellow colour. When the efferveſcence had entirely ſubſided, and appeared to have no longer any action on the ſubſtances, the liquor was filtered, and the metallic duſt collected on the paper. After being waſhed and dried it weighed no more than 78 parts: the potaſs, therefore, had taken from it 22 parts.

He poured upon the 78 parts juſt mentioned ſome of the nitric acid, diluted in 12 parts of water, which produced a briſk efferveſcence. The greater part of the matter was diſſolved: the liquor aſſumed no colour, and there remained only a ſmall quantity of powder of an orange-yellow colour. The liquor of the reſiduum was ſeparated by the help of a ſyphon, the matter waſhed ſeveral times, and the waſhings united with the firſt liquor. This reſiduum dried, weighed no more than 14 parts: from which it follows, that the nitric acid had diſſolved 64.

He again mixed theſe 14 parts with 42 parts of the carbonat of potaſs and the neceſſary quantity of water, and

Chromic Acid.

and then treated them as before, and the phenomena were the fame. The liquor, after being filtered, was united to the former; and the refiduum, wafhed and dried, weighed no more than two parts, which were ftill red lead, and therefore thrown away.

The two nitric folutions, united and evaporated, produced 92 parts of nitrat of lead, cryftallized in octahedra, perfectly white and tranfparent. Thefe 92 parts of nitrat of lead, diffolved in water, were precipitated by a folution of the fulphat of foda. This produced 81 parts of the fulphat of lead, which were equivalent to 56,68 of metallic lead.

559 And difcovery of chromic acid.

The alkaline liquors were found to contain a falt compofed of potafs combined with a peculiar acid, which Mr Vauquelin afterwards called *chromic acid*.

Thefe liquors, fubjected to evaporation until a faline pellicle was formed on their furface, produced, on cooling, yellow cryftals; among which there was carbonat of potafs, not decompofed. Thefe cryftals diffolved in water, and the folution united with the mother water, the whole was mixed with weak nitric acid until the carbonat of potafs was faturated. The liquor then had a very dark orange-red colour. Being united with a folution of the muriat of tin, newly made, it firft affumed a brown colour, which afterwards became greenifh. Mixed with a folution of the nitrat of lead, it immediately produced the red lead. Laftly, evaporated fpontaneoufly, it produced ruby-red cryftals, mixed with cryftals of the nitrat of potafs. Ninety-eight parts of this mineral, decompofed as above mentioned, having produced 81 parts of the fulphat of lead, 100 parts would have given 82,65, which are equivalent to 57,1 of metallic lead. "But admitting, as experiment proves (fays Mr Vauquelin), that 100 parts of lead abforb, in combining with acids, 12 parts of oxygen, the 57,1 of metallic lead ought to contain in the red lead 6,86, of this principle, and we ought to have for the mineralizing acid 36,4.

560 Its properties.

Chromic acid cryftallizes in the form of elongated prifms of a ruby colour.

When mixed with filings of tin and the muriatic acid, it becomes at firft yellowifh brown, and afterwards affumes a beautiful green colour.

When mixed with a little alcohol and nitric acid, it immediately affumes a bluifh green colour, which preferves the fame fhade even after deficcation. Ether alone gives it the fame colour.

With a folution of nitrat of mercury, it gives a precipitate of a dark cinnabar colour.

With a folution of nitrat of filver, it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by expofure to the light. This combination, expofed to the heat of the blow-pipe, melts before the charcoal is inflamed. It affumes a blackifh and metallic appearance. If it be then pulverifed, the powder is ftill purple; but after the blue flame of the lamp is brought in contact with this matter, it affumes a green colour, and the filver appears in globules difleminated throughout its fubftance.

With nitrat of copper, it gives a chefnut red precipitate.

With the folutions of fulphat of zinc, muriat of bifmuth, muriat of antimony, nitrat of nickel, and muriat of platinum, it produces yellowifh precipitates when thefe folutions do not contain excefs of acid. With muriat of gold, it produces a greenifh precipitate.

When melted with borax or glafs, it communicates to them a beautiful emerald green colour.

Paper impregnated with chromic acid affumes in the light a greenifh colour.

When mixed with muriatic acid, the mixture was capable of diffolving gold like aqua regia; when this mixture of the two acids is diftilled, oxy-muriatic acid is difengaged, and the liquor affumes a very beautiful green colour.

Sulphuric acid, while cold, produces no effect upon it; but when warmed, it makes it affume a bluifh green colour, probably by favouring the difengagement of oxygen.

When this acid is heated along with charcoal, it is reduced to the metal called *chromum*. It is therefore compofed of this metal and oxygen. From Vauquelin's experiments, it appears to contain one part of chromum and two parts of oxygen.

Such are the properties of this acid, as far as they have hitherto been difcovered. Vauquelin is the only chemift who has examined it; and from his memoir the above account has been taken*.

* *Ann. de Chim.* xxv. 194. and *Philofophical Magazine*, i. 279.

361. 561 Metallic acids.

The four laft defcribed acids are called *metallic acids*, becaufe they are compofed of metals and oxygen.

It is believed, that moft of the metals, we would rather fay of the metallic oxyds, are capable of being converted into acids by being combined with oxygen. It is certain that this is the cafe with platinum; and Hermftadt, by diftilling nitric acid off tin, converted it into a white mafs, foluble in three parts of water, which has been called *ftannic acid*†. Several more of the metallic oxyds act the part of acids: But no complete fet of experiments on this important fubject has yet appeared.

† *Ann. de Chim.* iv. 162.

Chap. VI. *Of* Affinity.

562 Importance of affinity.

The meaning of the word *affinity* has been already explained; and it muft appear evident, from the ufe which has been made of it in this article, that the confideration of the nature of affinity is the moft important part of chemiftry. While its laws are unknown, chemiftry is not a fcience, but a wildernefs of facts without beauty or regularity: every thing is equally perplexing and incomprehenfible. The chemift, inftead of being able to trace the operations of Nature, is loft in an endlefs maze of uncertainty, without a guide to conduct him, or a ray of light to illuminate his fteps. It is the knowledge of affinity which difpels the darknefs, removes the confufion, fhews us the order which fubfifts in all the phenomena of nature, points out their dependence on one another, and enables us to direct them as we think proper, to make them fubfervient to the improvement of the arts, and thus to render them the minifters of our comforts and enjoyments.

563 It unites bodies particle to particle.

1. When two bodies are united together by affinity, how fmall a portion foever of the compound we examine, we fhall always find it to contain both of the ingredients. From this it is evident, that affinity combines bodies, particle with particle.

By *particles* we do not mean what philofophers have called *atoms*, or the fmalleft parts into which it is poffible to divide matter; but the fmalleft parts which

Affinity.

make an integrant of any ſubſtance. Water, for inſtance, conſiſts of oxygen and hydrogen; but when we ſpeak of a particle of water, we do not mean the oxygen or the hydrogen ſeparately, but the ſmalleſt poſſible quantity of theſe combined in ſuch a manner as to form water. It is the *integrant particles* of bodies which are united by affinity. Thus ſulphuric acid is compoſed of ſulphur and oxygen combined together; and ammonia, of hydrogen and azot combined in the ſame manner. Now when ſulphuric acid and ammonia combine, it is not their elements, ſulphur, oxygen, azot, and hydrogen, which unite together, particle with particle, but the particles of the acid and the alkali as integrants. This is evident; becauſe if theſe ſubſtances be ſeparated from each other by means of a ſtronger affinity, they are found preciſely in the ſame ſtate as before they entered into combination.—When the ſubſtances which combine are *ſimple*, the ultimate and integrant particles are the ſame: But we are not certain that any of the bodies with which we are acquainted is ſimple, in the ſtrict and proper ſenſe of the word.

564 Opinions of the older chemiſts about affinity.

2. What is this *affinity* which unites bodies together? The older chemiſts thought that all ſolvents, or ſubſtances capable of diſſolving others, were compoſed of particles which had the form of wedges or hooks; that ſolution conſiſted in the inſinuation of theſe wedges or hooks between the particles of the bodies to be diſſolved; and that chemical combination was merely the linking of the different particles together by means of holes in one ſet of particles, into which the hooks or the wedges of the other ſet were thruſt. Such explanations, abſurd as they may appear, were faſhionable among chemical philoſophers till the days of Sir Iſaac Newton, who firſt aſcribed the chemical union of bodies to an *attraction* between the particles themſelves. This explanation, after a violent ſtruggle on the part of the chemiſts, has been at laſt unanimouſly adopted.

565 It is an attraction between the particles of bodies.

Affinity, then, is an *attraction* between the particles of different bodies, by which they are *drawn* towards one another, and kept united. This we take for granted, and conſider as a *fact*, without pretending to explain *how* they come to be poſſeſſed of this power, or *how* they exert it; both of which are evidently beyond the reach of the human underſtanding.

But though we cannot diſcover the manner in which affinity acts, we can ſee, at leaſt, that it follows certain laws, and that they are invariable; for ſimilar phenomena always occur when the circumſtances are the ſame.

566 Whether the ſame with gravitation.

Now what are the laws which affinity follows? There is a ſpecies of attraction which matter poſſeſſes, called *gravitation*, the laws of which were inveſtigated by Sir Iſaac Newton. Is affinity the *ſame* with gravitation, or does it follow different laws?

Upon a ſlight view of theſe two attractions, their phenomena appear very differnt. Gravitation acts at very great diſtances; affinity not until the bodies are mixed together: Gravitation acts on the whole maſs; affinity only on the particles: Bodies gravitate to one another directly as their maſſes, and inverſely as the ſquares of their diſtances. But how can affinity follow theſe laws, when it does not act till the bodies are apparently in contact? or ſuppoſing that it does act, how can they account for the phenomena of affinity? If barytes be preſented to a compound of ſulphuric acid and potaſs, the acid immediately leaves the alkali and combines with the earth: But had gravitation been the only power acting, ought not the barytes to have united with the ſulphat of potaſs without producing any decompoſition?

Theſe ſtriking differences have convinced many philoſophers, as they ſeem to have done Newton himſelf, that gravitation and affinity are different ſpecies of attraction. Let us not, however, embrace this concluſion vaguely, or without affixing a preciſe meaning to our words.

567 No poſitive proof that it is different.

Gravitation and chemical affinity are ſaid to be different ſpecies of attraction. But what is attraction? It is merely a general *fact*, or that tendency which is *obſerved* among all the portions of matter towards each other, but which exhibits very different appearances under different circumſtances. The tendency of matter towards matter at *ſenſible* diſtances is called *gravitation*, and its laws have been completely inveſtigated; but neither that tendency, nor theſe laws, have been, or can be, ſhewn to be *eſſential* to the exiſtence of matter. Chemical affinity is the tendency of particles towards each other at *inſenſible* diſtances, or when theſe particles are mixed together; and this tendency appears to be regulated by laws different from thoſe of gravitation. Like gravitation, it is merely an *obſerved fact;* and however different theſe facts may appear to be, they are probably both brought about by the ſame forces. It is indeed true, that gravitation is directly as the maſſes of matter, and inverſely as the ſquares of the diſtances of theſe maſſes; while the attraction, which is called *chemical affinity*, ſeems to obſerve very different rules. But we have ſhewn elſewhere (ſee OPTICS, n° 62—68, *Encycl.*; and BOSCOVICH in this *Suppl.*), that the ſame forces repel at one diſtance and attract at another; and that they may produce all the various phenomena of chemical affinity.

The difficulties to be accounted for in chemical affinities are their intenſity, their different degrees of ſtrength, and their being elective, or, which is the ſame thing, the capacity which one body has of diſplacing another.

How come affinities, it may be aſked, to differ in intenſity? Perhaps we might with propriety refer this queriſt to the ſtudy of Boſcovich's curve; but as our modern chemiſts are not generally verſant in ſuch ſtudies, we beg leave to obſerve, in this place, that we have no proof whatever of abſolute contact between bodies. On the contrary, it is highly probable, we had almoſt ſaid demonſtrable, that particles are in every inſtance at ſome diſtance from one another. For, on the ſuppoſition that two bodies were in actual contact, their attraction for each other would not only be as great as poſſible, but as great as the attraction of any other body for either of them *could poſſibly* be: Conſequently, it neceſſarily follows, that, ſince bodies chemically combined *can* be ſeparated, they are not in actual contact (A); but if they are not in contact, their diſtance from one another

Plate XVIII.

(A) Perhaps the following demonſtration, which we borrow from the ingenious Mr Brougham, will render this more evident. In fig. 7. let the body A have for P an attraction which at the diſtance of AP is proportional

Affinity. another *may* vary in different cases, and the force of affinity will vary with the distance. Here then is a reason why the affinity of different bodies varies in strength. Sulphuric acid, for instance, has a stronger affinity for barytes than for lime; because when the combinations are formed, the distance between the acid and barytes is not so great as that between the acid and lime.

But why do the distances differ? If affinity be the same with gravitation it must tend to bring the particles nearer one another: and what then prevents the lime from approaching as near the acid as the barytes does? We reply, *the figure of its particles*. This answer was first given to the question by Buffon, and it is fully adequate to solve the difficulty. The particles of bodies, indeed, are a great deal too minute for us to discover their figure by actual inspection; but the phenomena of crystallization show us that this difference actually exists.

The crystals of every body assume a peculiar figure. Now as these crystals are all formed in the same manner, and by the same law, it is impossible to conceive any other reason for their variety, but the difference in the form of the particles which compose them.

But why does one body displace another? When a particle of barytes is brought within a certain distance of a particle of sulphuric acid and lime combined together, affinity acts, and draws them nearer to one another; and the barytes, from its figure, approaches nearer the acid than the lime could, and forms with it a compound, the figure of which is such, relatively to that of the lime, that they cannot approach within a small enough distance of each other to counteract the attraction of the earth. Accordingly, no compound is formed; for all that is meant by two particles having formed a compound is, that their attraction for each other is greater than the attraction of the surrounding bodies for either.

568 Consequently it ought to be considered as the *same*.

Having thus seen that none of the phenomena of *affinity* are inconsistent with their resulting from the forces which bring about the phenomena of gravitation, we have a right to conclude that it is at least highly probable, that all the motions of the corporeal world are produced by the same power which, though not essential to matter, was impressed upon every atom of it by the Great Creator when he formed this universe; and that as the effects of this power are modified according to the situation of the bodies on which it acts, they are known by the different names of *gravity*, *adhesion*, *cohesion*, and *affinity*.

Gravity is the attraction between bodies so distant, that the masses alone influence the result, and that the power may be considered as placed in the centre of the attracting bodies. Affinity.

Adhesion supposes a distance too small for our senses. It has been demonstrated to be proportional to the number of touching points, which depends upon the figure of the particles that form the bodies.

Cohesion takes place only between particles of the same nature. These, instead of touching only in one superficies, as in adhesion, touch in every point where their figure will allow contact: consequently the force of cohesion also must depend upon the figure of the particles.

Affinity unites bodies of a different nature, not merely by one superficies, as *adhesion* does, but particle to particle, like *cohesion*; and the most perfect contact is formed that the figure of the particles will admit. Therefore, in this case also, the intensity depends upon the figure of the particles. 569

3. If we make the attempt, we shall find that water will not dissolve any quantity of common salt that we please. Water which refuses to take up any more is said to be *saturated* with salt. Neither can we combine *any* quantity of potass with a given portion of sulphuric acid: we may add as much of it as we please, indeed; but if we evaporate the liquid, in order to obtain the salt in crystals, we shall find that only *part* of the potass has united with the acid, and that the rest has crystallized separately. From these examples, it must appear evident, that bodies combine with one another by affinity, only in certain proportions; or, which is the same thing, that a determined number of particles of each of the ingredients goes to the formation of an integrant particle of the compound, and that into this integrant *no additional particles* of either ingredient *can* be admitted. Let us suppose, for instance, that the particles of sulphuric acid are tetrahedrons, and that the particles of potass are of such a form, that one of them can attach itself to each of the sides of the acid particle: In that case, an integrant particle of sulphat of potass would be composed of five particles, one of acid and four of alkali; for it is evident, that just four particles of potass would combine with every particle of acid, and that the acid would then be saturated, or, which is the same thing, would be incapable of receiving any more alkaline particles into combination with it. Let us suppose, now, that there is just as much potass as saturates the acid; if more acid be poured in, it cannot enter into combination with the potass, because all the potass is already combined with acid.

Saturation explained.

Thus it appears evident, from the nature of affinity, that the ingredients in every combination must mutually *saturate* each other, and that no more of either can be

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tional to PM; then let P move towards A, so as to come to the situation P′, and let the attraction here be P′M′; as it is continual during the motion of P to P′, M′M′ is a curve line. Now in the case of the attraction of bodies for one another, PM is less than P′M′; and consequently MM′ does not ever return into itself, and therefore it must go *ad infinitum*, having its arc between AB and AC, to which it approaches as asymptotes, the abscissa always representing the distance, and the ordinate the attraction at that distance. Let P′ now continue its motion to P″ and M′ will move M″; and if P″ meets A, or the bodies come into perfect contact, P″M′ will be infinite; so that the attraction being changed into cohesion will be infinite, and the bodies inseparable, contrary to universal experience; so that P can never come nearer to A than a given distance. *Nicholson's Journal*, I. 555.

Affinity.

be admitted into the compound than what is neceffary to produce this faturation. It follows equally, that there can be *no union* without faturation, except there be a deficiency in fome one of the ingredients: for fuppofing that there is a fufficient number of particles of potafs, and that every particle of fulphuric acid requires four of them, as before, for faturation, the very fame caufe that produces the union of one, two or three particles of potafs with a particle of acid, muft produce the union of all the four.

Even when there is a deficiency of one of the ingredients, faturation muft equally take place; for thofe particles of acid that happen to be neareft the alkali muft ftill be faturated; becaufe the affinity of all the acid particles for alkali was originally equal, and the difference of the diftance muft give the fuperiority to thofe that are neareft; and thofe particles of acid that are once faturated with potafs cannot be deprived of it by any of the other particles, otherwife the affinity of fome particles of fulphuric acid for potafs would be greater than that of others, which is abfurd.

It will no doubt be objected to all this, that there are innumerable inftances of additional portions of fome one of the ingredients being received into a compound after faturation, and that fome fubftances feem to be equally well faturated with different dofes of another. Oxygen, for inftance, combines with azot in three different proportions, and forms nitrous gas, nitrous acid, and nitric acid. The metals, too, form in the fame manner, different oxyds, and a great many inftances of the fame kind occur among the neutral falts.

But it ought to be remembered, that the conclufions againft which thefe objections are urged, are confequences deduced, we think fairly, from a propofition which we confider as demonftrated, that *affinity is a fpecies of attraction* (B). Thefe phenomena cannot therefore be admitted as valid objections, except it can be fhewn that they are really *incompatible* with thefe conclufions. Now that this is not the cafe, has been fhewn, in the moft fatisfactory manner by Morveau†. Thefe apparent exceptions are owing to an affinity which exifts between the compound as an integrant and one of its ingredients, and are not inftances of various degrees of faturation, but of the formation of new compounds. According to this very ingenious idea, which we believe firft originated with Bergman, and was firft feen in its full extent by Morveau, we have formerly explained in what manner the various metallic oxyds are formed: the firft oxyd is a compound of the metal and oxygen; the fecond, of the firft oxyd and oxygen: the third, of the fecond oxyd and oxygen; and fo on. In the fame manner we have explained the various combinations of azot and oxygen; and the explanation may eafily be extended to every other cafe. Thefe apparent objections, then, are not incompatible with the above conclufions, but perfectly confiftent with them, and confequently they cannot be admitted as of any force.

† *Encycl. Method.* i. 560.

There is one phenomenon, indeed, which proves, independent of thefe conclufions, that thefe combinations are actually formed in the manner we have fuppofed, and which therefore merits particular attention. The phenomenon is, that the affinity between the two fimple fubftances is *almoft always greater* than that between the compound and any of its ingredients. The affinity, for inftance, between azot and oxygen is greater than that between nitrous gas and oxygen; and the affinity between nitrous gas and oxygen greater than that between nitrous acid and oxygen: For if nitrous gas be mixed with nitric acid, the whole is converted into nitrous acid; but no change whatever is produced, when nitric and nitrous acids, or nitrous gas and nitrous acid, are mixed: and every fubftance which is capable of decompofing nitrous gas, is capable alfo of decompofing nitrous and nitric acids; but many fubftances are capable of decompofing nitrous and nitric acids which have no effect upon nitrous gas; in the fame manner, the affinity between fulphur and oxygen is greater than that between fulphurous acid and oxygen; for when fulphur is mixed with fulphuric acid, the whole is converted into fulphurous acid; but no change takes place when fulphur and fulphurous acid, or fulphurous and fulphuric acids are mixed together. A great many inftances of the fame kind might eafily be produced, if thefe were not fufficient to eftablifh the point. This curious fact affords a very ftrong proof that the bafes, as well as the quantity of oxygen, is different in almoft all the vegetable acids. Did the tartarous, oxalic, and acetous acids, for inftance, confift of the fame bafe with various dofes of oxygen; were the tartarous compofed of the bafe and oxygen; the oxalic of tartarous acid and oxygen; the acetous of oxalic acid and oxygen—in that cafe, a mixture of acetous and tartarous acids ought to form oxalic acid: but that this does not happen, any one may convince himfelf by actual experiment.

We do not mean to affirm that this fact, though it is certainly very often true, holds in all cafes; in fome perhaps, the reverfe may be true, though we do not recollect at prefent any inftance of that kind.

570 Of the ftrength of affinity.

4. Since the affinity of almoft every two bodies for each other differs *in ftrength* from that between every other two, it becomes an important problem *to determine the ftrength of every affinity in numbers*. The folution of this problem would give a clearnefs and precifion to chemiftry equal to that of any other branch of natural philofophy whatever, and enable it to advance with a degree of rapidity hitherto thought unattainable. No wonder, then, that this problem has occupied the attention of fome of the moft eminent philofophers who have dedicated their time to chemiftry.

571 Attempts to afcertain it.

If the obfervations formerly made, in order to fhew that

(B) Were any farther proof of this propofition required, we would obferve, that *cohefion* acts as an antagonift to affinity, and may be often rendered fo ftrong as to prevent affinity from acting with efficacy. Thus alumina and jargonia, when fufficiently heated, become infoluble in acids without undergoing any other alteration than that of an increafe of cohefion by their particles being brought nearer each other; for deftroy this cohefion, and they become as foluble as ever. Now it follows from this, that if cohefion be *attraction*, fo muft *affinity*. The experiments of Morveau, to be afterwards mentioned, demonftrate, that *adhefion* and *affinity* are produced by the fame caufe: Confequently, if adhefion be attraction, fo muft affinity.

Affinity.

that the difference in the ſtrength of affinities depends upon the different forms of the particles which have an affinity for each other, be concluſive, it is evident, that the certain method of learning the ſtrength of affinities would be to diſcover the forms of the particles of all bodies. But no method has hitherto been diſcovered by which it is poſſible of becoming acquainted with the figure of the particles of bodies. The experiments indeed of the Abbé Hauy (afterwards to be deſcribed) point out a method by which the primary figure of cryſtals may be inveſtigated with a good deal of plauſibility; but this leaves the knowledge of the figure of the particles which compoſe theſe cryſtals ſtill uncertain.

As nobody, therefore, has attempted to take this road, in order to calculate the ſtrength of affinities, let us at preſent conſider the different methods which have been propoſed for that purpoſe, that we may ſee whether any of them will anſwer the end intended.

572 By Wenzel,

Wenzel ſuppoſed, that the time taken by one body to diſſolve another is a meaſure of the affinity which ſubſiſts between them. But the hypotheſis of that ingenious philoſopher will not bear the teſt of examination; for the *time* of ſolution evidently depends upon circumſtances unconnected with affinity. The coheſion of the body to be diſſolved, and the nature of the compound formed, muſt occaſion very great differences in the time of ſolution of different bodies, even on the ſuppoſition that their affinities were all the ſame.

573 Fourcroy,

Fourcroy propoſed to meaſure the affinity of bodies by the difficulty of ſeparating them after they are combined: but we have no method for meaſuring this difficulty. Lavoiſier and De la Place, indeed, propoſed *caloric* for this purpoſe; but there are many compounds which caloric cannot ſeparate, and it never produces a ſeparation except by means of its affinity for one or other of the ingredients of the compound. Before caloric, therefore, could be employed as a meaſure, it would be neceſſary to know exactly the ſtrength of its own affinity for every other ſubſtance; which is juſt a caſe of the problem to be reſolved.

574 Macquer,

Macquer ſuppoſed, that the affinity of bodies for one another was in the compound ratio of the facility of their union, and the difficulty of their ſeparation: But as we are in poſſeſſion of no method of aſcertaining either of theſe, it is evident that this theory, even allowing it to be juſt (which it certainly is not), could be of no uſe for aſſiſting us to calculate the force of affinities.

575 Morveau,

Another method has been propoſed by the diſtinguiſhed philoſophical chemiſt Mr de Morveau (c).

In 1713, Dr Brook Taylor made ſome experiments on the adheſion of ſurfaces; and concluded from them, that the force of adheſion might be determined by the weight neceſſary to produce a ſeparation. But in 1772, Meſſrs La Grange and Cigna, obſerving that the ſurfaces of water and oil adhere together, and taking it for granted that theſe two liquids *repel* each other, concluded, in conſequence, that their adheſion was not owing to *attraction*; and hence inferred, that *adheſion*, in general, is always owing to the preſſure of the atmoſphere. This concluſion induced Morveau to examine the ſubject: he found, that adheſion was *not affected* by the preſſure of the atmoſphere; for it required the ſame weight to ſeparate a diſk of glaſs (30 lines in diameter) from the ſurface of mercury in the open air, and under an exhauſted receiver. He obſerved, that the ſame diſk adhered to water with a force of 258 grains, and to the ſolution of potaſs, though denſer, only with a force of 210. This reſult not only proved that adheſion was owing to attraction, but made him conceive the poſſibility of applying this method to the calculation of affinities; For the force of adheſion being neceſſarily proportional to the points of contact, and this being the caſe alſo with affinity, it is evident, that the adheſion and the affinity between the ſame ſubſtances are proportional, and that therefore the knowledge of the one would furniſh us with the ratio of the other.

Struck with this idea, he conſtructed cylinders of different metals, perfectly round, an inch in diameter and the ſame in thickneſs, and having a ſmall ring in their upper ſurface, by which they might be hung exactly in equilibrium. He ſuſpended theſe cylinders, one after another, to the beam of a balance; and after counterpoiſing them exactly, applied them to a quantity of mercury placed about two lines below them, making them ſlide along its ſurface, to prevent any air from lodging between them and the mercury. He then marked exactly the weight neceſſary to overcome their adheſion, taking care to change the mercury after every experiment. The table of the reſults is as follows:

Gold adheres to mercury with a force of	446 gr.
Silver, - - - - - - -	429
Tin, - - - - - - -	418
Lead, - - - - - - -	397
Biſmuth, - - - - - -	372
Platinum, - - - - - -	282*
Zinc, - - - - - - -	204
Copper, - - - - - -	142
Antimony, - - - - - -	126
Iron, - - - - - - -	115
Cobalt, - - - - - -	8

* *Morveau, Ann. de Chim.* xxv. 10.

The differences of theſe reſults cannot be owing to the preſſure of the air, which was the ſame in all; nor do they correſpond to the denſities of the metals; nor can they be owing to accidental differences in the poliſh of the cylinders, for a plate of rough iron adheres more ſtrongly to mercury than one of the ſame diameter exquiſitely poliſhed;—but they follow preciſely the order of affinity, and therefore may be conſidered as the meaſure of the ſtrength of the affinity between theſe different metals and mercury. They furniſh us alſo with a convincing proof, that *affinity* is *attraction*, and the ſame ſpecies of attraction with *adheſion*; and that therefore, if the one be reducible to *gravitation*, ſo muſt the other.

Mr Achard, convinced of the importance of Mr Morveau's obſervations, made a great many experiments on *adheſion*, and publiſhed the reſult of them in 1780. He proved,

(c) Now Mr Guyton: we have uſed the old name all along in the text to avoid ambiguity.

Affinity.

proved, that the force of adhesion was not affected by alterations in the height of the barometer, but that its force became weaker as the heat of the fluid increased (D); and that the temperature remaining the same, the force of adhesion increased in the same ratio with the surfaces of the adhering bodies. He made about 600 experiments on the adhesion of different solids and fluids, proved that the force of adhesion did not depend on the densities of the adhering bodies, nor on the different cohesive force of the fluids; and, after a laborious calculation, concluded, that it depended on the figure of the particles of the adhering fluid and solid.

These experiments and calculations of Mr Achard are certainly of importance; and we would have given them here, had not the objects of them been substances which can furnish but few data for calculating the force of affinities.

This method of measuring the force of affinities seems to be an accurate one, and if it could be applied to every case of affinity, would, in all probability, enable us to solve the problem which we are now considering: But unfortunately, its application is very limited, being confined to those cases alone in which one of the bodies can be presented in a fluid, and the other in a solid state. Nor can it be applied indiscriminately to all those cases; for whenever the cohesion of any liquid is much inferior to the force of its adhesion to any solid, the separation takes place in the particles of the liquid itself, and consequently we do not obtain the measure of its adhesion to the solid, but of its own cohesion, and that, too, imperfectly. Thus, for instance, Mr Achard found, that sealing-wax adhered to water with a force of 92 grains, and to alcohol only with a force of $53\frac{1}{4}$ths; yet we know that sealing-wax has a greater affinity for alcohol than for water; because alcohol dissolves it, which water is incapable of doing. The difference in the result in this instance was evidently owing to the smaller cohesion of alcohol. Mr Morveau's method must therefore be confined to those cases in which the cohesion of the liquid is stronger than its adhesion to the solid, which may be known by the surface of the solid not being moistened; and to those in which the cohesion is not much inferior to the adhesion; for then, it is evident, that the force of cohesion will be increased as the force of adhesion. Let us suppose, for instance, that two solids, A and B, are made to adhere to the surface of a liquid, and that A can only form an adhesion with 50 particles of the liquid, whilst B adheres to 100; it is evident, that a much smaller force will destroy the cohesion of the 50 particles to which A adheres with the rest of the liquid, than what will be required to destroy the cohesion of the 100 particles united to B with the same liquid.*

* *Morveau, Encycl. Method. Chim.* art. *Adhesion.*

The method of Mr Morveau, then, may be applied with accuracy in both cases; and *when* they occur can only be determined by experiment. It cannot, however, be applied indiscriminately even then; for unless the solid and the fluid be presented in such a state that no gas is extricated when the adhesion takes place, an accurate judgment cannot be formed of the force of adhesion. When marble (carbonat of lime), for instance, is applied to the surface of sulphuric acid, there is an extrication of gas, which very soon destroys the adhesion, and prevents an accurate result. Were it possible to employ quicklime instead of marble, this would be prevented; or if this cannot be accomplished, why might not lime be employed, united with some acid that would not assume a gaseous form, and at the same time has a weaker affinity than sulphuric acid for lime? Why might not the phosphat of lime, for instance, be used, which may be reduced to a state of hardness sufficiently great for the purpose? The extrication of gas, during the application of metals to the surfaces of acids, might be prevented by oxydating their surfaces. It is true, indeed, this could not be done with all the metals, on account of the nature of the oxyd, but it might with several; copper, for instance, and silver. It cannot be doubted, that by these methods, and other contrivances that might be fallen upon, a sufficient number of results might be obtained to render this method of the greatest importance. It is rather surprising, therefore, that it has never been prosecuted.

576 And Kirwan.

Mr Kirwan has proposed another method of solving the problem. While he was engaged in his experiments on the strength of acids, he observed that the quantity of real acid necessary to saturate a given quantity of each of the bases was inversely as the affinity between the respective bases and the acid; and that the quantity of each of the bases necessary to saturate a given quantity of acid was directly as the affinity between the base and the acid. Thus 100 grains of each of the acids require more alkali for saturation than lime, and more lime than magnesia, as may be seen in the following table:

100 grains of	Potass.	Soda.	Lime.	Amm.	Mag.	Alum.
Sulphuric acid	215	165	110	90	80	75
Nitric acid	215	165	96	87	75	65
Muriatic acid	215	158	89	79	71	55

He concluded, therefore, that the affinity between acids and their bases may be estimated by the quantity of bases necessary for saturation. Thus the affinity between potass and sulphuric acid is 215, and that between nitric acid and lime 96.*

* *Phil. Tran.* 1783.

We have mentioned formerly, that the principle on which Mr Kirwan calculated the strength of the acids was founded on a mistake. It must follow of course, therefore, that the numbers which result from it must also be wrong. This Mr Kirwan has acknowledged, and seems to have given up all thoughts of ascertaining the strength of affinities by this method. But before it be abandoned altogether, we wish the following observations were considered.

577 Attempt to remedy the defects of his method.

Bergman long ago established as a principle, under the name of a chemical paradox, that *the stronger any salt was, the less of any other it required for saturation.* Thus, according to him,

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(D) Strictly speaking, this is owing not so much to a decrease of the force of adhesion, as of that of the cohesion of the fluid itself.

Affinity.

100 parts of potafs require 78,5 Sulphuric acid,
64 Nitric;
51,5 Muriatic,
42 Carbonic,
100 parts of foda - - 177 Sulphuric,
135,5 Nitric,
125 Muriatic,
80 Carbonic.

This propofition, which has been admirably illuftrated by Morveau†, evidently refolves itfelf into the two following:

† Encycl. Method. Chim. i. 597.

1. A *bafe* requires the *more* of an acid for faturation *the ftronger* its affinity for that acid is.

2. An *acid* requires *the more* of any bafe for faturation *the greater affinity* it has for that bafe.

In order to judge of the truth of the firft of thefe propofitions, let us examine the following table, drawn up from the experiments of Bergman, Wenzel, and Kirwan.

	Bergman.			Wenzel.			Kirwan.		
100 parts of	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.
Barytes	15,4		30,8						
Potafs	78,6	64	51,5	82,4	107,7	54	81,8	87,1	78,2
Soda	175	135,5	125	125,8	166,6	83	129,4	136,1	114,2
Lime	143,7	134,4	70,45	147,74	195,6	103,6	141	180	86
Magnefia	173,67	159,25	82,92	181,8	257,15	122,27	170,5	255	104,275
Ammonia				142,42	201,22	96,25	187,5	233	116
Alumina	211,11		220,2	77,7	68,7	38,6			

It is evident at firft fight, that Bergman's experiments correfpond exactly with the propofition. To faturate, according to him, 100 parts of potafs, requires 78,6 of fulphuric acid, 64 of nitric, and 51,5 of muriatic acid. There is only one deviation from the propofition in the whole table, and this regards barytes, which, according to him, is faturated with 15,4 of fulphuric and 30,8 of muriatic acid. But Mr Morveau has fhewn, by feveral accurate experiments, that barytes requires much more fulphuric acid for faturation than Bergman fuppofed§. And Klaproth has fhewn, that 100 parts of barytes require 49,2 of ftrong fulphuric acid for faturation*. And Dr Withering's calculation† agrees almoft exactly with this; nor does that of Fourcroy differ much from it‡. Inftead of 15,4 of fulphuric acid, therefore, which, according to Bergman, are neceffary to faturate 100 of barytes, it fhould be 42,8.

§ Encycl. Method. Chim. i. 591.
* Chim. Ann. ii. 1785.
† Phil. Tran. 1784.
‡ Ann. de Chim. iv. 65.

The firft and laft columns of Wenzel and Kirwan's experiments agree equally well with the propofition, but the fecond deviates from it completely. Wenzel probably might have been mifled by the manner of performing his experiments; but the fame objection does not feem to lie againft thofe of Kirwan.

It can fcarcely be doubted, however, to whatever caufe the error is to be imputed, that the numbers in the fecond column of Mr Kirwan's table are too large. The following experiment of Morveau is fufficient to fhew this.

According to Mr Kirwan's experiments, the proportions of acid and alkali in the four following falts are as under:

Sulphat of potafs	Acid	100
	Potafs	108,7
Sulphat of lime	Acid	100
	Lime	80,6
Nitrat of potafs	Acid	100
	Potafs	83,33
Nitrat of lime	Acid	100
	Lime	34,4

Now when fulphat of potafs and nitrat of lime are mixed together, a double decompofition takes place, and fulphat of lime and nitrat of potafs are formed. Let thefe two falts be mixed together; let the quantity of fulphat of potafs be fuch, that the acid contained in it amounts to 100; and let a more than fufficient quantity of nitrat of lime be added, to faturate the fulphuric acid with lime. It is evident that for that purpofe 80,6 of lime muft be prefent; and the quantity of nitric acid combined with thefe 80,6 muft be 234,4. This quantity would require for faturation 195,32 of potafs, but there are only 108,7 in the mixture; confequently there ought to exift in the mixture, after the mutual decompofition of the falts, 64,87 of nitric acid in a ftate of liberty. Such would be the refult, provided Mr Kirwan's numbers were accurate; but the fact is, that no fuch excefs of acid exifts in the mixture*; and confequently the quantity of nitric acid contained in nitrat of lime is ftated too high by Mr Kirwan. Although therefore Mr Kirwan's tables do not coincide with the propofition which we are confidering, this is not to be confidered as a proof of its falfehood; as there is reafon, from the experiment above defcribed, to fufpect fome error in the data from which Mr Kirwan calculated the ftrength of the acids.

* Ann. de Chim. xiv. 295.

The truth of the fecond propofition may be judged of by the following tables:

According to Bergman.

100 parts of	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid	646	127,5	56,5	69,5	578	42	473
Nitr. acid		148,4	74,4	74,4	62,8		
Mur. acid	324,7	194	78	141,9	120,5		40

According to Wenzel.

100 parts of	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid		120,8	79,16	67,2	55	70,2	128
Nitr. acid		92,7	60	51,1	38,8	49,7	147,8
Mur. acid		183,8	119,2	96,5	81,7	103,9	259

According to Kirwan.

100 parts of	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amm.	Alum.
Sulp. acid		122,2	77,2	70,4	57,3	53,3	
Nitr. acid		112	73,8	55,5	39,2	44,8	
Mur. acid		168,6	133	112,7	89,9	78,5	

It appears that all the table of Bergman agrees with the propofition except the numbers which correfpond to fulphat of foda, fulphat of alumina, nitrat of lime, and muriat of foda, which the late experiments of Mr Kirwan have fufficiently fhewn to be inaccurate.

Wenzel's table correfponds exactly, except the columns under ammonia and alumina, which Morveau has proved to be inaccurate.

Kirwan's table correfponds exactly, except with regard to the quantity of ammonia neceffary to faturate muriatic acid, which does not appear to have been accurately determined by experiment.

Let us therefore take the truth of thefe two propofitions for granted, and let us confider every deviation from them as an error; and let us fee whether they will enable us to difcover the abfolute affinity of fulphuric, nitric, and muriatic acids, for their refpective bafes.

Table I. *Quantity of Bafe neceffary to Saturate* 100 *Parts of the three Acids.*

100 parts	Barytes	Potafs.	Soda.	Lime.	Magn.	Amm.
Sulph. acid	233,3	123,3	78,7	68,3	56,8	49,3
Nitric acid	258,4	148,4	95,6	74,4	62,8	54,8
Muri. acid	324,7	188,8	126,1	116,7	97,3	78,5

Table II. *Quantity of Acid neceffary to Saturate* 100 *Parts of the fix Bafes.*

100 parts	Sulph. acid.	Nitric acid.	Mur. Acid.
Barytes	42,8	38,7	30,8
Potafs	81	64	52,9
Soda	126,7	101,4	79
Lime	145,7	134,4	87,5
Magnefia	176,2	159,25	105,4
Ammonia	202,6	182,4	127,25

The firft of thefe tables reprefents the affinity between the fame acid and its various bafes; and the fecond that of the bafes for the different acids. If it were required to know the ratios of the affinity which different bafes have for any particular acid, the firft table, fuppofing it accurate, would give it exactly. In like manner, if it were required to know the ratios of the affinity of the acids for the various bafes, we would find them in the fecond table.

But if we wifhed to know what was the affinity between one acid and bafe, compared with that between another acid and a different bafe; or if we wanted to have not the relative but the abfolute affinity between two bodies—it is plain that we could not find it in either of the tables; for the abfolute affinity muft confift of two things, the affinity which the acid has for the bafe, and the affinity which the bafe has for the acid. Now the firft table gives us the one of thefe, and the fecond the other; fo that in order to reprefent affinity in abfolute numbers, the two tables muft be multiplied into one another. This was the miftake into which Mr Kirwan fell. His method confifted merely in conftructing a table like our firft, which (fuppofing the numbers accurate) gave only the affinity between the bafes and the fame acid, but left out the affinity between the different acids and the fame bafe; confequently the different columns could not be compared with each other.

578 And to conftruct tables of affinity.

It is evident, however, that if the tables were multiplied together in their prefent ftate, they could not poffibly give an accurate table of affinities. For that purpofe, it is neceffary to put the fame number in the firft column of each table, and then to fubftitute other numbers in the remaining columns, having the fame ratio to one another with the numbers in the original columns. This is done in the following tables.

Table I. *Ratios of the Affinity of fix Bafes for three Acids.*

	Barytes.	Potafs.	Soda.	Lime.	Magn.	Amm.
Sulp. acid	100,00	52,85	33,73	29,27	24,34	21,12
Nitric acid	100,00	57,43	36,98	28,77	24,28	19,59
Mur. acid	100,00	58,11	38,81	35,70	29,94	24,15

Table

Affinity.

TABLE II. *Ratios of the Affinity of three Acids for six Bases.*

	Sulp. acid	Nitr. acid	Mur. acid
Barytes	100,00	90,42	74,54
Potafs	100,00	79,01	65,30
Soda	100,00	80,03	62,35
Lime	100,00	92,24	60,05
Magnefia	100,00	90,34	59,68
Ammonia	100,00	90,02	62,77

TABLE III. *Affinity between three Acids and six Bases in Absolute Numbers.*

	Sulp. acid	Nitr. acid	Mur. acid
Barytes	10000	9042	7454
Potafs	5285	4537	3794
Soda	3373	2969	2419
Lime	2927	2653	2143
Magnefia	2434	2193	1786
Ammonia	2112	1763	1515

On the fuppofition that the two propofitions mentioned above were ftrictly true, and that the numbers which we fixed upon were precifely the quantities of acid and bafe neceffary to faturate each other reciprocally, this laft table would reprefent accurately in numbers the ftrength of the affinities of the three acids for each of the fix bafes refpectively.

We muft acknowledge, however, that the truth of thefe propofitions has not hitherto by any means been fufficiently proved; but a great number of facts concur to render them exceedingly probable, and highly worthy of the attention of chemical philofophers. And we hope that the method propofed by Morveau, and which had been previoufly practifed by Richter, of verifying theoretical calculations of the compofition of the falts, by mixing together two falts which mutually decompofe each other, and afcertaining whether the refult correfponds with calculation, will be followed out, and that it will be the means of enfuring more accuracy than it has hitherto been poffible to obtain.

No one will fufpect that any thing which has here been faid is meant as a reflection on the ingenious chemifts who have attempted to folve this moft difficult of all chemical problems, the proportion of the ingredients which enter into the compofition of the falts. Mr Kirwan, in particular, is entitled to the greateft praife for the perfevering induftry with which he has profecuted the fubject, for the candour which he has difplayed, and for the new route which he has opened to the chemical philofopher. Though this problem has not hitherto been folved, and though the difficulties which furround it are almoft infurmountable, we may hope much from the general fenfe which is at prefent entertained of its importance, and from the zeal and abilities of thofe philofophers who have particularly turned their attention to it.

Affinity.

579 Morveau's table of affinity.

In the mean time, the following table of the ftrength of affinities by Morveau, though the numbers be arbitrary, will be found of very great ufe†.

† *Encycl. Method. Chim.* i. 773.

	Sulph. acid.	Nitric acid.	Muriat acid.	Acet. acid.	Carbo. acid.
Barytes	66	62	36	28	14
Potafs	62	58	32	26	9
Soda	58	50	31	25	8
Lime	54	44	24	19	12
Ammonia	46	38	21	20	4
Magnefia	50	40	22	17	6
Alumina	40	36	18	15	2(D)

580 Three claffes of affinity,

5. Although every chemical combination is produced by the fame general law, yet as their phenomena vary fomewhat according to circumftances, affinities have, for the fake of greater perfpicuity, been divided into claffes. Thefe claffes may be reduced to *three—fimple*, *compound*, and *difpofing* affinities.

581 Viz. fimple affinity,

The *firft clafs*, comprehends all thofe cafes in which only *two bodies combine* together; as, for inftance, fulphuric acid and potafs, oxygen and carbon. The affinities which belong to this clafs are known by the name of *fimple* or *fingle affinities*. Although one of the fubftances to be combined happens to be already united with another body, the combination is ftill reckoned a cafe of fingle affinity. Thus fuppofe the fulphuric acid previoufly combined with magnefia, and forming with it the falt called *fulphat of magnefia*, as foon as potafs is prefented, the acid leaves the earth (which is precipitated), and unites with the alkali. Even when three bodies combine, it often happens that the union is produced merely by fingle affinity. Thus, when fome potafs is dropped into tartarous acid, part of the acid unites with the alkali, and forms tartrite of potafs; after this the remainder of the acid combines with the tartrite juft formed, and compofes a new falt known by the name of *acidulous tartrite of potafs*, or *tartar*. This is evidently nothing elfe than two inftances of fimple affinity immediately following each other.

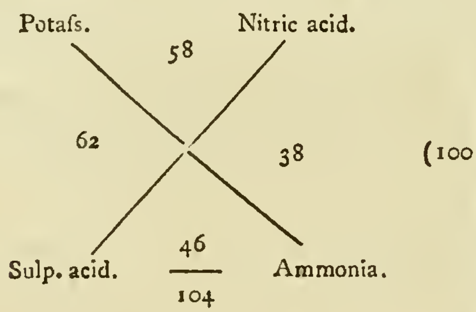
582 Compound affinity,

When more than three bodies are mixed, decompofitions and new combinations often take place, which could

(D) This table, however, does not correfpond quite accurately to all the phenomena. For inftance, according to it, fulphat of barytes is not decompofed by carbonat of foda, although the contrary takes place in fact.

Affinity.

could not have been produced had the bodies been presented in a different ftate. If, for inftance, into a folution of fulphat of potafs there be poured nitric acid, no decompofition is produced, becaufe the fulphuric acid has a ftronger affinity for potafs than nitric acid has. For the very fame reafon, ammonia may be poured into the folution without producing any change. But if nitrat of ammonia be poured in, a decompofition inftantly takes place, and two new bodies, *fulphat of ammonia* and *nitrat of potafs*, are formed. Such cafes of decompofition form the *fecond clafs of affinities*. They were called by Bergman cafes of *double elective attraction;* a name which is exceedingly proper when there are only four bodies concerned. But as there are often more than four, it is neceffary, as Mr Morveau has obferved, to employ fome more comprehenfive term. We fhall therefore call the affinities belonging to this clafs *compound affinities* (E); and comprehend under the term all cafes where more than three bodies are prefent, and produce combinations which would not have been formed without their united action. In thefe cafes the affinity of all the various bodies for each other acts, and the refulting combination is produced by the action of thofe affinities which are ftrongeft. The manner in which thefe combinations and decompofitions take place, was firft clearly explained by Dr Black. Let the affinity between potafs and fulphuric acid be = 62; that between nitric acid and ammonia = 38; that between the fame acid and potafs = 58; and that between the fulphuric acid and ammonia = 46. Now, let us fuppofe that all thefe forces are placed fo as to draw the ends of two cylinders croffing one another, and fixed in the middle in this manner,



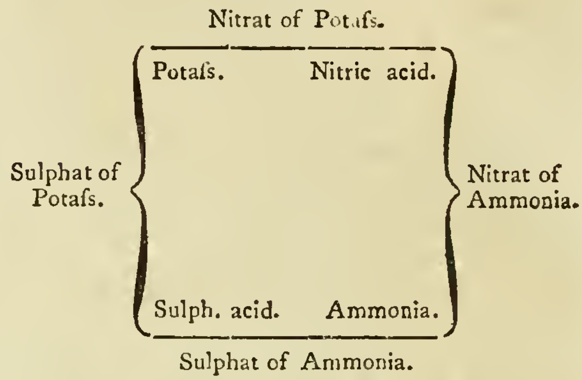
It is evident, that as 58 and 46 = 104, are greater than 62 + 38 = 100, they would overcome the other forces and fhut the cylinders. Juft fo the affinity between potafs and nitric acid, together with that between fulphuric acid and ammonia, overcomes the affinity between potafs and fulphuric acid, and that between nitric acid and ammonia, and produces new combinations.

In all cafes of compound affinity, there are two kinds of affinities to be confidered; *1ft*, Thofe affinities which tend to preferve the old compound, thefe Mr Kirwan has called *quiefcent* affinities; and thofe which tend to deftroy them, which he has called *divellent* affinities.

Thus, in the inftance above given, the affinity between potafs and fulphuric acid, and that between nitric acid and ammonia, are quiefcent affinities, which endeavour to preferve the old compound; and if they are ftrongeft, it is evident that no new compound can take place. On the contrary, the affinity between potafs and nitric acid, and that between fulphuric acid and ammonia, are divellent affinities; and as they are in this cafe ftrongeft, they actually deftroy the former combinations and form new ones.

Affinity.

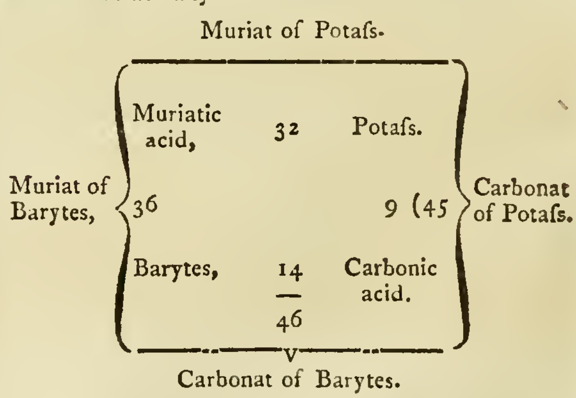
Bergman, who publifhed a great many cafes of compound affinities, employed to explain them a method fomewhat different from this. He would have reprefented the above cafe in the following manner:



At the four corners of an imaginary fquare are placed the four fubftances, fo that one acid fhall be diagonally oppofite to another. On the right and left fide of the fquare are placed the old compounds, each on the fide of its own ingredients, and above and below are placed the new compounds.

Mr Elliot improved this method of Bergman, by adding numbers expreffive of the affinity of the various fubftances. It is in cafes of compound affinity that the ratios of affinities, if we were poffeffed of them, would be peculiarly ufeful. For it is evident, that if we knew the ftrength of affinities in abfolute numbers, we would be able to determine before hand all the cafes of compound affinity.

If we knew, for inftance, that the affinity between the muriatic acid and barytes were = 36; that between the fame acid and potafs = 32; the affinity between potafs and carbonic acid = 9; and that between the fame acid and barytes = 14;—we would be certain, previous even to experiment, that when muriat of barytes and carbonat of potafs are mixed, a double decompofition would take place; which we know from experiment to be actually the cafe.

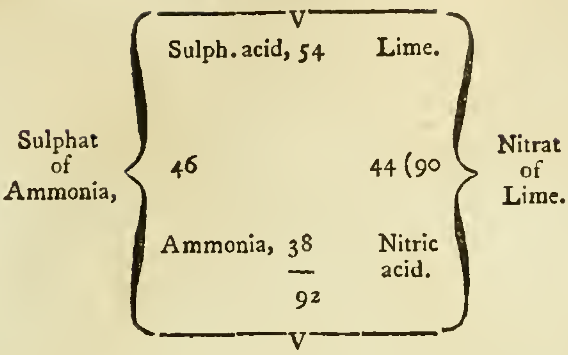


Another inftance of decompofition by compound affinities.

Sulphat

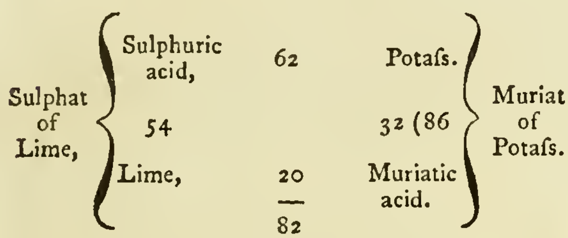
(E) Morveau called them *affinité par concours*.

Sulphat of Lime.



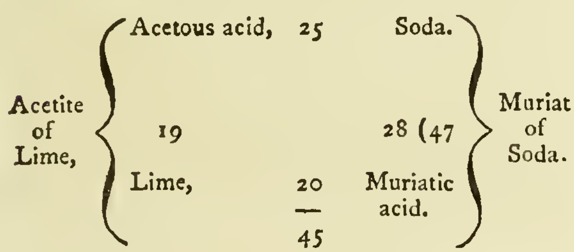
Nitrat of Ammonia.

Suppofing Morveau's numbers exact, it follows alfo, even prior to experiment, that no decompofition takes place when fulphat of lime and muriat of potafs are mixed;



for the quiefcent affinities are 86 and the divellent only 82.

Nor when acetite of lime and muriat of foda are mixed;



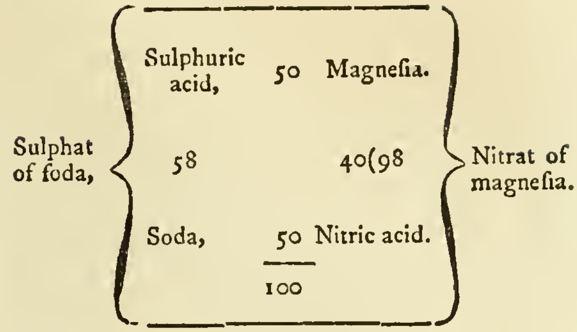
becaufe the quiefcent affinities are 47, and the divellent only 45. Thefe cafes where no decompofition takes place, have been called by Morveau cafes of *inverfe* compound affinity.

Morveau has propofed the following improvements in reprefenting thefe cafes of compound affinities‡:

When decompofition does not take place, nothing is to be written above and below the fquare, as in the two laft examples. When a new compound remains diffolved, a ftraight line is to be placed between it and the fquare, as in the following fcheme.

* Encycl. Method. Chim. i. 555.

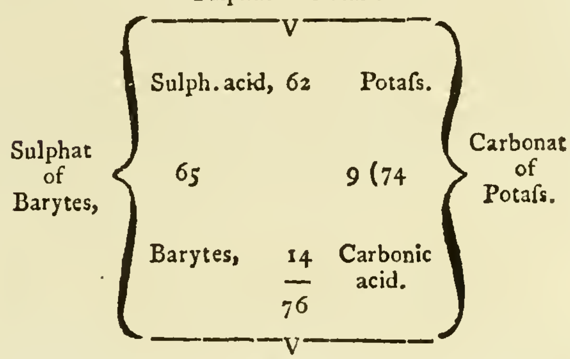
Sulphat of Magnefia.



Nitrat of Soda.

When a new compound is precipitated, a line bent downwards in the middle is to be placed between it and the fquare, as in the following fcheme:

Sulphat of Potafs.



Carbonat of Barytes.

When a new compound is fublimed, the line between it and the fquare is to be pointed upwards in the middle, thus ——^——.

When a new compound is partly diffolved and partly precipitated, the line placed between it and the fquare is to affume the following fhape: ————.

When it is partly diffolved and partly fublimed, the following is the line to be ufed: ————.

583 And difpofing affinity.

The third clafs of affinities has been called by Mr Morveau *difpofing affinities*, becaufe they *difpofe* fubftances to combine that would not otherwife have done it. Suppofe, for inftance, that fulphur is prefented to oxygen gas, it does not manifeft any affinity for it; but combine it previoufly with potafs, and it unites with oxygen with avidity. Its previous union with potafs, in this cafe, *difpofed* it to unite with oxygen. The caufe of this curious affinity is not yet well underftood. If we confider what it was that prevented the fulphur and oxygen from combining, we fhall find, that it can only be its own attraction of cohefion, and the affinity between the oxygen and caloric which are combined. Whatever then diminifhes this attraction of cohefion, or of *aggregation* as it has been called, muft facilitate the union of of the fulphur with oxygen. This is done in fome meafure by the potafs. Befides, if affinity depends upon the figure of particles, it is evident, that there muft be an affinity between the new compound and oxygen; but the moment the oxygen approaches within a certain diftance of the fulphur, it unites with it, as its affinity is much greater for that fubftance than for the compound.

The following is another inftance of this curious affinity: Sugar, as Lavoifier has proved, is compofed of oxygen, hydrogen and carbon: Now if concentrated fulphuric acid be poured upon fugar, the oxygen and hydrogen combine and form water, which unites with the acid, and the carbon is precipitated. In this cafe the prefence of the acid *difpofed* the oxygen and hydrogen to combine. In what manner this new combination is produced it would not be eafy to explain: not by weakening the attraction of cohefion; for we do not fee how the acid could produce that effect. The only explanation that can be given, is to fuppofe that the fulphuric acid, when it approaches within a certain diftance of the oxygen and hydrogen, attracts them; and that this attraction, together with the affinity between the oxygen and hydrogen, is greater than that which produces the combination between the ingredients of the fugar themfelves: the confequence of which muft be decompofition.

584 Why bodies require different temperatures to unite,

6. We come now to one of the moft difficult queftions in chemiftry—Why do bodies require different temperatures in order to unite? and why does the prefence of caloric in many cafes favour, or rather produce union, while it prevents or deftroys it in others?

Thefe queftions were propofed at the end of the fecond chapter of this article; and we referved them for this place, not becaufe we hoped to be able to anfwer them in a fatisfactory manner, but becaufe no intelligible anfwer could be given till the nature of affinity had been previoufly confidered. Some fubftances, phofphorus, for inftance, combine with oxygen at the common temperature of the atmofphere; others, as carbon, require a higher temperature; and others, as hydrogen and azotic gas, do not combine except at a very high temperature. To what are thefe differences owing?

In anfwer to this queftion we obferve that the attraction of *cohefion* evidently oppofes that of *affinity*. Thofe bodies which we prefent to combine together are generally aggregates, or, which is the fame thing, confift of many fimilar particles united by cohefion: for we have no method of feparating bodies into their integrant particles except *affinity*. Now we can conceive the attraction of cohefion between the particles of a body to be fo great as to prevent them altogether from obeying the impulfe of affinity. That this actually happens in fome cafes cannot be doubted; for if pure alumina be formed into a pafte, and heated fufficiently, it becomes fo hard that no acid can act upon it; yet its nature is not in the leaft changed: by proper trituration it may be again rendered foluble; and when precipitated from this new folution it has recovered all its original properties. The effect of the fire, then, was merely to increafe the cohefion, by feparating all the water, and allowing the particles to approach nearer each other.

It is evident, that whatever diminifhes the cohefion which exifts between the particles of any body, muft tend to facilitate their chemical union with the particles of other bodies: this is the reafon that bodies combine more eafily when held in folution by water, or when they have been previoufly reduced to a fine powder. Now caloric poffeffes the property of diminifhing cohefion. And one reafon why fome bodies require a high temperature to caufe them to combine is, that at a low temperature the attraction of *cohefion* is in them fuperior to that of affinity; accordingly, it becomes neceffary to weaken that attraction by caloric till it becomes inferior to that of affinity. The quantity of caloric neceffary for this purpofe muft vary according to the ftrength of the cohefion and of the affinity; it muft be inverfely as the affinity, and directly as the cohefion. Wherefore, if we knew precifely the force of the cohefion between the particles of any body, and of the affinity between the particles of that body and of any other, we could eafily reduce the temperature neceffary to calculation.

That caloric or temperature acts in this manner cannot be doubted, if we confider, that other methods of diminifhing the attraction of cohefion may be fubftituted for it with fuccefs. A large lump of charcoal, for inftance, will not unite with oxygen at fo low a temperature as the fame charcoal will do when reduced to a very fine powder; and charcoal will combine with oxygen at a ftill lower temperature, if it be reduced to its integrant particles by precipitating it from alcohol, as Dr Prieftley did by paffing the alcohol through red hot copper. And to fhew that there is nothing in the nature of oxygen and carbon which renders a high temperature neceffary for their union, if they be prefented to each other in different circumftances, they combine at the common temperature of the atmofphere; for if nitric acid, at the temperature of 60°, be poured upon charcoal powder, well dried, in a clofe crucible, the charcoal takes fire, owing to its combining with the oxygen of the acid*: And in fome other fituations, carbon is fo completely divided, that it is capable of combining with the oxygen of the atmofphere, or, which is the fame thing, of catching fire at the common temperature: this feems to be the cafe with it in thofe pyrophori that are formed by diftilling to drynefs, feveral of the neutral falts which contain acetous acid‡. Thefe obfervations are fufficient to fhew, that caloric is in many cafes neceffary in order to diminifh the attraction of *cohefion*.

* *Prouft and Morveau, Encycl. Method. Chim.* i. 474.

‡ *Morveau, ibid.*

But there is a difficulty ftill remaining, How comes it that certain bodies will combine with oxygen without the affiftance of any foreign heat, provided the combination be once begun, though a quantity of caloric is neceffary to begin the combination? and that other bodies require to be furrounded by a great quantity of caloric during the whole time of their combining with oxygen? Alcohol, for inftance, if once kindled, burns till it is quite confumed; and this is the cafe with oils alfo, provided they be furnifhed with a wick.

We muft obferve in the firft place, that we would err very much were we to fuppofe that a high temperature is not as neceffary to thefe fubftances during the whole of their combuftion as at the commencement of it; for Mr Monge found, on making the trial, that a candle would not burn after the temperature of the air around it was reduced below a certain point.

All fubftances which continue to burn after being once kindled are *volatile*, and they burn the eafier in proportion

Affinity.

proportion to that volatility. The application of a certain quantity of caloric to alcohol volatilizes part of it; that is to fay, diminifhes the attraction of its cohefion fo much that it combines with oxygen. The oxygen which enters into this combination gives out as much heat as volatilizes another portion of the alcohol; which combines with oxygen in its turn; more heat is given out; and thus the procefs goes on. Oils and tallow exhibit the very fame phenomena; only as they are lefs volatile, it is neceffary to affift the procefs by means of the capillary attraction of the wick, which confines the action of the caloric evolved to a fmall quantity of oil, and thus enables it to produce the proper effect. In fhort, then, every fubftance which is capable of continuing to burn after being once kindled, is volatile, or capable of being converted into vapour by the degree of heat at firft applied. The reafon that a live coal will not burn when fufpended infulated in the air, is not, as Dr Hutton fuppofed§, becaufe its *light* is diffipated, but becaufe the coal cannot be converted into vapour by the degree of heat which it contains, and becaufe the cohefion of its particles is too great to allow it to combine with oxygen without fome fuch change. There are fome coals, however, which contain fuch a quantity of bitumen, that they will burn even in the fituation fuppofed by Dr Hutton, and continue to burn, provided they be furnifhed with any thing to act as a wick. It is needlefs to add, that bitumen, like oil, is eafily converted into vapour.

§ On *Light* and *Heat*.

But this explanation, inftead of removing our difficulties, has only ferved to increafe them: For if caloric only acts by diminifhing the attraction of cohefion, and converting thefe fubftances into vapour, why do not all elaftic fluids combine at once without any additional caloric? why do not oxygen and hydrogen, when mixed together in the ftate of gas, unite at once and form water? and why do not oxygen and azot, which are conftantly in contact in the atmofphere, unite alfo and form nitrous gas? Surely it cannot be the attraction of cohefion that prevents this union. And if it be afcribed to their being already combined with caloric, how comes it that an additional dofe of one of the ingredients of a compound decompofes it? Surely, as Mr Monge has obferved, this is contrary to all the other operations in chemiftry.

That the particles of fluids are not deftitute of an attraction for each other, is evident from numberlefs facts. The particles of water draw one another after them in cafes of capillary attraction, which is probably owing to the attraction of cohefion. It is owing to the attraction of cohefion, too, that fmall quantities of water form themfelves into fpheres: Nor is this attraction fo weak as not to be perceptible. If a fmall plate of glafs be laid upon a globule of mercury, the globule, notwithftanding the preffure, continues to preferve its round figure. If the plate be gradually charged with weights one after another, the mercury becomes thinner and thinner, and extends itfelf in the form of a plate; but as foon as the weights are removed, it recovers its globular figure again, and pufhes up the glafs before it. Here we fee the attraction of cohefion, not only fuperior to gravitation, but actually overcoming an external force*. And if the workman, after charging his plate of glafs with weights, when he is forming mirrors, happen to remove thefe weights, the mercury which had been forced from under the glafs, and was going to feparate, is drawn back to its place, and the glafs again pufhed up. Nor is the attraction of cohefion confined to folids and liquids; it cannot be doubted, that it exifts alfo in gafes; at leaft it is evident that there fubfifts an attraction between gafes of a different kind: for although oxygen and azotic gas are of differen gravities, and ought therefore to occupy different parts of the atmofphere, we find them always mixed together; and this can only be afcribed to an attraction. And were we to allow, with Humbolt and feveral other chemifts, that thefe two gafes are chemically combined in atmofpherical air, an opinion contradicted by a late experiment in France (F); ftill the exiftence of carbonic acid gas in every part of the atmofphere can only be afcribed (if the inaccuracy of the expreffion may be tolerated) to a kind of cohefion. And whoever has been accuftomed to pneumatic experiments muft have obferved, that fmall portions of *air*, as well as water, form themfelves into fpheres, and that the attraction of cohefion is fo ftrong in gafes, that large globules of them often adhere by a fingle point to the bottom of veffels filled with heavy fluids; whereas, had there been no attraction of cohefion, every part of the globule ought to have afcended to the furface of the fluid, except the particles immediately in contact with the veffel. Allowing, then, that there is an attraction of cohefion between the particles of gafes, let us fee whether that will not affift us in removing the difficulty. 585

* *Morveau, Affinité.* p. 543.

Explained.

It feems evident, in the firft place, that the affinity between the bafes of the gafes under confideration and oxygen is greater than their affinity for that dofe of caloric which produces their elaftic form; for when they are combined with oxygen, the fame dofe will not feparate them again. Let us take hydrogen for an inftance: the affinity of hydrogen is greater for oxygen than for the caloric which gives it its gafeous form; but the oxygen is alfo combined with caloric, and there exifts an attraction of cohefion between the particles of the hydrogen gas; the fame attraction fubfifts between thofe of oxygen gas. Now the fum of all thefe affinities, namely, the affinity between hydrogen and caloric, the affinity between oxygen and caloric, the cohefion of the particles of the hydrogen, and the cohefion of the particles of oxygen—is greater than the affinity between the hydrogen and oxygen; and therefore no decompofition can take place. Let the affinity between

Oxygen and caloric be	50
Hydrogen and caloric	50
Cohefion of oxygen	4
Cohefion of hydrogen	2
Sum of quiefcent affinities,	106
The affinity of oxygen and hydrogen,	105

The quiefcent affinities being greater than the divellent affinities, no decompofition can take place.

Let

(F) Air brought by means of a balloon from a great height in the atmofphere was found to contain lefs oxygen gas than the fame quantity of air near the ground.

Let now a quantity of caloric be added to the oxygen and hydrogen gas, it has the property of expanding them, and of courfe of diminifhing their cohefion; while its affinity for them is fo fmall that it may be neglected. Let us fuppofe that it diminifhes the cohefion of the oxygen 1, and of the hydrogen alfo 1, their cohefion will be now 3 and 1; and the quiefcent affinities being only 104, while the divellent are 105, decompofition would of courfe take place, and a quantity of caloric would thus be fet at liberty to produce the fame effects upon the neighbouring particles.

Thus, then, caloric acts only by diminifhing cohefion: And the reafon that it is required fo much in gafeous fubftances, and in thofe combinations into which oxygen enters, is the ftrong affinity of oxygen and the other bafes of the gafes for caloric; for, owing to the repulfion which exifts between the particles of that fubtile fubftance, an effect is produced by adding large dofes of it contrary to what happens in other cafes. The more of it is accumulated, the ftronger is the repulfion between its particles; and therefore the more powerful is its tendency to fly off: and as this tendency is oppofed by its affinity for the body and the cohefion of its particles, it muft diminifh both thefe attractions.

Though we have thus attempted to explain what has been always confidered as one of the moft difficult problems in chemiftry, we are far from fuppofing that we have removed every difficulty. Much ftill remains to be done before the action of light and caloric can be fully underftood: and there may be other agents, of whofe exiftence we have not yet even conceived the idea.

One difficulty ftill remains to be examined. Heat not only produces the combination of fome bodies, but alfo occafions the decompofition of others. How does it act in thefe cafes?

586 How heat decompofes bodies.

That many of thefe decompofitions are produced by chemical affinity, will be evident from the following examples.

When fulphur and arfenic acid are expofed to heat, fulphuret of arfenic is formed† evidently by a kind of compound affinity.

† *Pelletier.*

Oxygen Gas.

Caloric	12	Oxygen	Arfenic Acid.
		60	
Sulphur	50	Arfenic	

Sulphuret of Arfenic.

In the fame manner when nitrat of potafs and boracic acid are expofed to heat, the nitric acid is volatilized, and borat of potafs is left behind.

Nitric Acid in Vapour.

Caloric	4	Nitric acid	Nitrat of Potafs.
		58	
Boracic acid	55	Potafs	

Borat of Potafs.

By the fame compound affinity boracic acid and heat decompofe muriat of foda.

Muriatic Acid Gas.

Caloric	10	Muriatic acid	Muriat of Soda.
		31	
Boracic acid	24	Soda	

Borat of Soda.

In the fame manner it would be eafy to explain how all the decompofitions by the *dry way*, as it is called, are produced.

But how comes caloric to decompofe water after having produced the union of oxygen and hydrogen? The union, we have feen, was probably brought about by the play of oppofite affinities; but in the feparation, caloric feems to act by its peculiar power, or the repulfion which exifts between its particles. When caloric combines with an integrant particle of water, this repulfion muft feparate the component parts fomewhat from one another; confequently it muft weaken their affinity; for every increafe of diftance produces that effect. Now let us fuppofe that the affinity between oxygen and hydrogen is 105, and that the affinity between caloric and each of thefe bodies is 50: as foon as the particles of oxygen and hydrogen are fo far feparated from each other that their affinity is lefs than 100, they will unite with caloric in preference, becaufe the fum of their affinities for caloric is equal to 100; confequently, whenever that takes place, water will be decompofed. Hence we fee the reafon why more heat is always neceffary to produce the decompofition of bodies than what produced their union.

Caloric poffeffes another fingular property, that of changing the compound affinities of bodies, even when it

Affinity.

it does not appear to enter as an ingredient. What we mean will appear evident from the following examples:

Muriat of ammonia, Carbonat of magnesia, } decompose each other at the ordinary temperature of the atmosphere, and form muriat of magnesia and carbonat of ammonia: but, on the contrary,

Muriat of magnesia, and Carbonat of ammonia, } decompose each other at a high temperature; for instance, at 212°. The products are muriat of ammonia and carbonat of magnesia*.

Again, if muriat of soda and sulphat of magnesia be mixed together at a low temperature, for instance, at zero, they decompose each other, and muriat of magnesia and sulphat of soda are formed; but no decomposition takes place at a temperature above 32°.—Muriat of soda, and sulphat of alumina, exhibit precisely the same phenomena†.

Lastly, sulphat of magnesia and carbonat of ammonia decompose each other at the ordinary temperature; but at 212° the carbonic acid flies off, and the remaining substances form a triple salt‡.

The last of these phenomena appears owing to the affinity between carbonic acid and caloric, and the two first to the affinity between muriat of ammonia and caloric, for that salt is volatilized.

It would not be so easy to explain the mutual decomposition of muriat of soda and sulphat of magnesia at a low temperature. It is probably connected with the alterations in the distance of the ingredients of chemical compounds, which are produced by the presence and absence of caloric.

* *Westrum*, *Ann. de Chim.* ii. 118.

† *Scheele* and *Gren*, *Ann. de Chim.* xxiii.

‡ *Fourcroy*, *Ann. de Chim.* ii. 291.

587 Of Count Rumford's opinion respecting affinity.

From the important part which caloric acts in chemical combinations, Count Rumford has been lately induced to suspect that this subtile fluid is the *only agent* by which they are produced.

That caloric is a *necessary* agent in all chemical decompositions and new combinations, we very readily allow; because we know no other cause except caloric to prevent the particles of bodies from actual contact; in which case decomposition would be impossible: and if this be the sense in which that ingenious philosopher ascribes chemical combinations to caloric, we very readily agree with him; but if he supposes that caloric is the *agent* by which the particles of bodies are brought near each other, and the *force* by which they adhere to one another, we cannot help thinking that he is mistaken: For that bodies, chemically combined, are kept near each other by some force, cannot possibly be denied. Now, what is that force? We have said, after Newton, an *attraction between the particles themselves;* acknowledging, at the same time, that we are unable to explain what that is.

Count Rumford seems to suppose that there is no such thing as attraction between the particles themselves, but that caloric is the agent which keeps them together. If so, how does caloric perform this office? For our part, we do not pretend to understand it any more than the nature of attraction; nor do we see that it is possible to render it more intelligible. But there is another question of still greater importance, What are the proofs that caloric is the only agent in all cases of chemical combinations? For our part, we can think of no proof that can render this opinion in the smallest degree plausible.

Has this celebrated and candid philosopher considered this subject with his usual accuracy? If heat be a body, it cannot surely be the cause of affinity unless it be possessed of properties which, so far from being proved, have not even been suspected. On the contrary, if it be a property of matter, what property is it? If it be a peculiar motion, as Count Rumford suspects, we would ask if it be possible for any motion whatever, independent of attraction, to produce the permanent union of two bodies?

PART III. OF DOUBLY COMPOUND BODIES.

THE bodies which consist of combinations of those substances that have been denominated *compound*, and which, for that reason, we have ventured to call *doubly compound bodies*, may be reduced to three classes:

Soaps,
Neutral salts,
Hydrosulphurets.

These shall form the subject of the three following chapters; and we shall finish this part of the article with some observations on *crystallization*.

CHAP. I. *Of* SOAPS.

THE compounds into which *oils* enter without decomposition have been denominated *soaps*.

Oils are capable of combining with alkalies, earths, and metallic oxyds; they are capable also of combining with several of the acids. There are therefore two classes of soaps; 1. Alkaline, earthy, and metallic soaps, which for the sake of brevity we shall call *alkaline soaps;* and, 2. Acid soaps. These two classes form the subject of the two following sections.

SECT. I. *Of Alkaline Soaps.*

As there are a great number of oils, all or most of which are capable of combining with alkalies, earths, and oxyds, it is natural to suppose that there are as many genera of alkaline soaps as there are oils. That there are differences in the nature of soaps corresponding to the oil which enters into their composition, is certain; but these differences are not of sufficient importance to require very particular description. We shall therefore describe all the alkaline soaps together, and notice, as we go along, some of the most important differences resulting from the oily ingredients. 588

Common hard soap.

1. Soap of soda, or common soap. The word *soap* (*sapo*, σαπων) first occurs in the works of Pliny and Galen, and is evidently derived from the old German word *sepe* (G). Pliny informs us, that soap was first discovered by the Gauls; that it was composed of tallow and

(G) *Beckmann's History of Inventions*, III. 239.—A similar word is still used by the common people of Scotland.

Alkaline Soaps.

and aſhes; and that the German ſoap was reckoned the beſt.*

* Pliny, lib. xviii. c. 51.

589 Method of forming it.

Soap may be prepared by the following proceſs. A quantity of the ſoda of commerce, which is a carbonat of ſoda, and which is often called *barilla* from the name of a plant, by burning which it is procured in great quantities in Spain, is pounded and mixed in a wooden veſſel, with about a fifth part of its weight of lime, ſlacked and paſſed through a ſieve immediately before. Upon this mixture a quantity of water is poured, conſiderably more than what was ſufficient to cover it, and allowed to remain on it for ſeveral hours. The lime attracts the carbonic acid from the ſoda, and the water becomes ſtrongly impregnated with the pure alkali. This water is then drawn off by means of a ſtop-cock, and called the *firſt ley*. Its ſpecific gravity ſhould be about 1,200.

Another quantity of water is then to be poured upon the ſoda, which, after ſtanding two or three hours, is alſo to be drawn off by means of the ſtop-cock, and called the *ſecond ley*.

Another portion of water is poured on; and after ſtanding a ſufficient time, is drawn off like the other two, and called the *third ley*.

Another portion of water may ſtill be poured on, in order to be certain that the whole of the ſoda is diſſolved; and this weak ley may be put aſide, and employed afterwards in forming the firſt ley in ſubſequent operations.

A quantity of oil, equal to ſix times the weight of the ſoda uſed, is then to be put into the boiler, together with a portion of the *third* or *weakeſt ley*, and the mixture muſt be kept boiling and agitated conſtantly by means of a wooden inſtrument. The whole of the third ley is to be added at intervals to the mixture; and after it is conſumed, the *ſecond ley* muſt be added in the ſame manner. The oil becomes milky, combines with the alkali, and after ſome hours it begins to acquire conſiſtence. A little of the *firſt ley* is then to be added, not forgetting to agitate the mixture conſtantly. Portions of the firſt ley are to be added at intervals; the ſoapy ſubſtance acquires gradually greater conſiſtency, and at laſt it begins to ſeparate from the watery part of the mixture. A quantity of common ſalt is then to be added, which renders the ſeparation much more complete. The boiling is to be continued ſtill for two hours, and then the fire muſt be withdrawn, and the liquor muſt be no longer agitated. After ſome hours repoſe the ſoap ſeparates completely from the watery part, and ſwims upon the ſurface of the liquor. The watery part is then to be drawn off; and as it contains a quantity of carbonat of ſoda, it ought to be reſerved for future uſe.

The fire is then to be kindled again; and, in order to facilitate the melting of the ſoap, a little water, or rather weak ley, is to be added to it. As ſoon as it boils, the remainder of the firſt ley is to be added to it at intervals. When the ſoap has been brought to the proper conſiſtence, which is judged of by taking out ſmall portions of it and allowing it to cool, it is to be withdrawn from the fire, and the watery part ſeparated from it as before. It is then to be heated again, and a little water mixed with it, that it may form a proper paſte. It is then to be poured into the veſſels proper for cooling it; in the bottom of which there ought to be a little chalk in powder, to prevent the ſoap from attaching itſelf to it. In a few days the ſoap will have acquired ſufficient conſiſtence to be taken out, and formed into proper cakes (H).

The uſe of the common ſalt in the above proceſs is to ſeparate the water from the ſoap; for common ſalt has a ſtronger affinity for water than ſoap has.

Olive oil has been found to anſwer beſt for making ſoap, and next to it perhaps tallow may be placed: but a great variety of other oils may be employed for that purpoſe, as appears from the experiments of the French chemiſts above quoted. They found, however, that lintſeed oil and whale oil were not proper for making *hard ſoaps*, though they might be employed with advantage in the manufacture of *ſoft ſoaps*. Whale oil has been long uſed by the Dutch for this laſt purpoſe.

Soap may alſo be made without the aſſiſtance of heat; but in that caſe a much longer time and a larger proportion of alkali is neceſſary.

590 Its ſophiſtication.

Manufacturers have contrived various methods of ſophiſticating ſoap, or of adding ingredients which increaſe its weight without increaſing its value. The moſt common ſubſtance uſed for that purpoſe is water; which may be added in conſiderable quantities, eſpecially to ſoap made with tallow (the ingredient uſed in this country), without diminiſhing its conſiſtency. This fraud may be eaſily detected, by allowing the ſoap to lie for ſome time expoſed to the air. The water will evaporate from it, and its quantity will be diſcovered by the diminution of the weight of the ſoap. As ſoap ſophiſticated in this manner would loſe its water by being kept, manufacturers, in order to prevent that, keep their ſoap in ſaturated ſolutions of common ſalt; which do not diſſolve the ſoap, and at the ſame time, by preventing all evaporation, preſerve, or rather increaſe, the weight of the ſoap. Meſſrs Darcet, Lelievre, and Pelletier, took two pieces equal in weight of ſoap ſophiſticated in this manner, and placed the one in a dry place in the open air, and the other in a ſaturated ſolution of common ſalt. After a month, the firſt had loſt $\frac{56}{100}$ of its weight, the other had gained about $\frac{10}{100}$ parts.* Various other methods have been fallen upon to ſophiſticate ſoap; but as they are not, we hope, generally known, it would be doing an injury to the public to deſcribe them here.

* Ann. de Chim. xix. 336.

591 Proportion of its ingredients.

Different chemiſts have analyſed ſoap, in order to aſcertain the proportions of its ingredients; but the reſult of their experiments is various, becauſe they uſed ſoap containing various quantities of water. From the experiments of Darcet, Lelievre, and Pelletier, it appears that ſoap newly made and expoſed to ſale contains

9,75 Oil,
1,37 Alkali,
4,87 Water.

Soap is ſoluble both in water and in alcohol. Its properties as a detergent are too well known to require any deſcription.

It

(H) See the *Memoir of Darcet, Lelievre, and Pelletier*, in the *Ann. de Chim.* XIX. 253.

Alkaline Soaps.

It is decomposed by lime, and by compound affinity(1) by sulphat of lime, nitrat of lime, muriat of lime, and probably all the salts which contain lime.

592 Soft soap.

2. Soap of potass. Potass may be substituted for soda in making soap, and in that case precisely the same process is to be followed. It is remarkable, that when potass is used, the soap does not assume a solid form; its consistence is never greater than that of hog's lard. This is what in this country is called *soft soap*. Its properties as a detergent do not differ materially from those of *hard soap*, but it is not nearly so convenient for use. The alkali employed by the ancient Gauls and Germans in the formation of soap was potass; hence we see the reason that it is described by the Romans as an unguent.

Some persons have affirmed that they knew a method of making hard soap with potass. Their method is this: After forming the soap in the manner above described they add to it a large quantity of common salt, boil it for some time, and the soap becomes solid when cooled in the usual way. That this method may be practised with success has been ascertained by Messrs Darcet, Lelievre and Pelletier; but then the hard soap thus formed does not contain potass but soda: for when the common salt (muriat of soda) is added, the potass of the soap decomposes it, and combines with its muriatic acid, while at the same time the soda of the salt combines with the oil and forms hard soap: and the muriat of potass formed by this double decomposition is dissolved in the water and drawn off along with it*.

Chaptal has lately proposed to substitute wool in place of oil in the making of soap. The ley is formed in the usual manner and made boiling hot, and shreds of woollen cloth of any kind are gradually thrown into it; they are soon dissolved. New portions are to be added sparingly, and the mixture is to be constantly agitated. When no more cloth can be dissolved, the soap is made†. This soap is said to have been tried with success. It might doubtless be substituted for soap with advantage in several manufactories, provided it can be obtained at a cheaper rate than the soaps at present employed.

* Ann. de Chim. xix. 322.

† Ann. de Chim. xxi. 27.

Fish, too, have been lately substituted for oil with equal success. The only disadvantage which soap made in this manner is liable to, is a disagreeable smell, from which it cannot easily be freed.

593 Soap of ammonia.

3. Soap of ammonia. This soap was first particularly attended to by Mr Berthollet. It may be formed by pouring carbonat of ammonia on soap of lime. A double decomposition takes place, and the soap of ammonia swims upon the surface of the liquor in the form of an oil; or it may be formed with still greater ease by pouring a solution of muriat of ammonia into common soap dissolved in water. We have formed it often by mixing caustic ammonia and oil*.

It has a more pungent taste than common soap. Water dissolves a very small quantity of it; but it is easily dissolved in alcohol. When exposed to the air, it is gradually decomposed.

* Berthollet, Mem. Par. 1780, or Nicholson's Journal, i. 170.

594 Soap of lime.

4. Soap of lime. This soap may be formed by pouring lime-water into a solution of common soap. It is insoluble both in water and alcohol. Carbonat of fixed alkali decomposes it by compound affinity†. It melts with difficulty, and requires a strong heat.

† Thouvenel.

595 Soap of magnesia,

5. Soap of magnesia. This soap may be formed by mixing together solutions of common soap and sulphat of magnesia.

It is exceedingly white. It is unctuous, dries with difficulty, and preserves its whiteness after desiccation. It is insoluble in boiling water. Alcohol and fixed oil dissolve it in considerable quantity. Water renders its solution in alcohol milky. A moderate heat melts it; a transparent mass is formed, slightly yellow, and very brittle*.

* Berthollet, ibid.

596 Of alumina,

6. Soap of alumina. This soap may be formed by mixing together solutions of alum and of common soap. It is a flexible soft substance, which retains its suppleness and tenacity when dry. It is insoluble in alcohol, water and oil. Heat easily melts it, and reduces it to a beautiful transparent yellowish mass†.

† Ibid.

597 Of barytes,

7. Soap of barytes resembles almost exactly the soap of lime‡.

‡ Ibid.

598 Of mercury,

8. Soap of mercury.—This soap may be formed by mixing together a solution of common soap and of corrosive muriat of mercury. The liquor becomes milky, and the soap of mercury is gradually precipitated. This soap is viscid, not easily dried, loses its white colour when exposed to the air, and acquires a slate colour, which gradually becomes deeper, especially if exposed to the sun or to heat. It dissolves very well in oil, but sparingly in alcohol. It readily becomes soft and fluid when heated*.

* Ibid.

599 Of zinc.

9. Soap of zinc.—This soap may be formed by mixing together a solution of sulphat of zinc and of soap. It is of a white colour, inclining to yellow. It dries speedily, and becomes friable†.

† Ibid.

600 Of cobalt,

10. Soap of cobalt.—This soap made by mixing nitrat of cobalt and common soap is of a dull leaden colour, and dries with difficulty, though its parts are not connected.

601 Of nickel,

Mr Berthollet observed, that towards the end of the precipitation there fell down some green coagula, much more consistent than soap of cobalt. These he supposed to be a soap of nickel, which is generally mixed with cobalt‡.

‡ Ibid.

602 Of tin,

11. Soap of tin.—It may be formed by mixing common soap with a solution of tin in nitro-muriatic acid. It is white. Heat does not fuse it like other metallic soaps, but decomposes it‖.

‖ Ibid.

603 Of iron,

12. Soap of iron—Formed by means of sulphat of iron. It is of a reddish brown colour, tenacious, and easily fusible. When spread upon wood, it sinks in and dries. It is easily soluble in oil, especially of turpentine. Berthollet proposes it as a varnish¶.

¶ Ibid.

604 Of copper,

13. Soap of copper—Formed by means of sulphat of copper. It is of a green colour, has the feel of a resin, and becomes dry and brittle. Hot alcohol renders its colour deeper, but scarcely dissolves it. Ether dissolves it, liquifies it, and renders its colour deeper and more beautiful. It is very soluble in oils, and gives them a pleasant green colour§.

§ Ibid.

605 Of lead,

14. Soap of lead.—It may be formed by means of acetite

(1) In this and the following chapter, *compound affinity* is not taken always in its strict and proper sense, but is applied to all those decompositions in which the affinities of more than three bodies act.

Alkaline Soaps.

acetite of lead. It is white, tenacious, and very adheſive when heated. When fuſed, it is tranſparent, and becomes ſomewhat yellow if the heat be increaſed*.

* Berthollet, ibid.

606 Of ſilver, 15. Soap of Silver.—It may be formed by means of nitrat of ſilver. It is at firſt white, but becomes reddiſh by expoſure to the air. When fuſed, its ſurface becomes covered with a very brilliant iris; beneath the ſurface it is black.†

† Ibid.

607 Of gold, 16. Soap of gold.—It is at firſt white, and of the conſiſtence of cream. It gradually aſſumes a dirty purple colour, and adheres to the ſkin, ſo that it is difficult to efface the impreſſion‡.

‡ Ibid.

608 And of mangaueſe. 17. Soap of mangaueſe.—It is at firſt white, but it aſſumes in the air a reddiſh colour, owing evidently to the abſorption of oxygen. It ſpeedily dries to a hard brittle ſubſtance, and by liquefaction aſſumes a brown blackiſh colour*.

* Ibid.

We owe the following reſinous ſoaps to Mr Mezaize.

609 Soap of turpentine and potaſs. 18. Soap of turpentine and potaſs.—576 grains of turpentine were diſſolved in 9216 grains of alcohol, and then 576 grains of potaſs were added. The alcohol was diſtilled off at a boiling water heat. There remained in the retort 648 grains of a browniſh ſoapy matter, which when ſpread on glaſs appeared tranſparent. There remained alſo nearly the ſame quantity of potaſs diſſolved in water. This ſoap was put in a veſſel for ſix weeks; during which time 72 grains of ſolution of potaſs ſeparated from it. It had aſſumed the conſiſtence of honey. Its colour was browner. It was completely ſoluble in water: The ſolution was milky. It diſſolved alſo in alcohol. It had no diſagreeable taſte. Vinegar decompoſed it.

610 Soap of benzoin. 19. Soap of benzoin and potaſs.—By treating 9216 grains of alcohol, 1728 grains of benzoin, and 576 grains of potaſs, as above, 1728 grains of a ſoap were obtained, browner than that of turpentine, of an odour a little aromatic. When left in a cellar for ſix weeks, it became ſolid. Its ſolution in water was yellowiſh. Vinegar decompoſed it. This compound is the ſame with Starkeys ſoap.

611 Of balm of Peru. 20. Soap of balm of Peru and potaſs.—1152 grains of balm, 2304 grains of potaſs, and 9216 grains of alcohol, produced a ſoap of a reddiſh colour, and pretty conſiſtent.

612 Of guaiac, 21. Soap of guaiac and potaſs.—1728 gr. of guaiac were diſſolved in 18648 grains of alcohol and the ſolution filtered, and to this 1728 grains of potaſs were added, and the ſoap obtained as above. It was ſolid, of a brown colour at firſt, which afterwards became green on the ſurface, but remained unaltered within. Its ſolution in water was greeniſh. It had no diſagreeable taſte. It diſſolved in alcohol, and formed a green tincture. Vinegar decompoſed it.

613 And of ſcammony. 22. Soap of ſcammony and potaſs.—By the above proceſs a ſoap was obtained with ſcammony pretty conſiſtent, of a brown colour, ſoluble in water, and not decompoſed by the water of pits from which ſelenites is obtained. It has no diſagreeable taſte. Its ſolution in alcohol is of a deep amber colour‡.

‡ Journ. de Phyſ. xv. 441.

Sect. II. *Of Acid Soaps.*

614 Method of forming acid ſoaps. Sulphuric acid may be combined with oils in the following manner: Put two ounces of it into a glaſs mortar, and add, by little and little, three ounces of the oil, nearly boiling hot, triturating it conſtantly. A ſubſtance is obtained of the conſiſtence of turpentine. Diſſolve it in about ſix ounces of boiling water, and the ſoap will unite into a maſs as the water cools. If it ſtill contain an exceſs of acid, diſſolve it again in boiling water, and continue this proceſs till the ſoap is perfectly neutraliſed.

Acid Soaps.

1. Soap of ſulphuric acid and lintſeed oil.—It diſſolves entirely in water. The ſolution is opaque, of a bluiſh white colour, viſcid, and frothes when agitated. Alcohol diſſolves it. The ſolution is tranſparent and brown. Potaſs decompoſes it, forming ſulphat of potaſs. The oil ſwims on the top, of the conſiſtence of wax. Ammonia decompoſes it; and if too much be added it forms ſoap of ammonia. Magneſia, lime, nitric acid, and muriatic acid, alſo decompoſe it. Diſtilled, it yielded a few drops of water and an oil, which coagulated, and was of the conſiſtence of wax. 615 Acid ſoap of lintſeed oil.

2. Soap of ſulphuric acid and oil of almonds.—Soluble in water; ſolution milky.—Frothes.—Soluble in alcohol; ſolution brown and tranſparent. Potaſs, lime, nitric acid, muriatic acid, ſulphurous acid (the oil ſeparated aſſumed the conſiſtence of turpentine), tartar, acidulous oxalat of potaſs, ſal ammoniac, muriat of lead and zinc decompoſe it. It is not decompoſed by vinegar, boracic acid, acetite of ammonia, borax, copper, tin nor lead. When diſtilled, there paſſed over a little water and an oil, which coagulated and ſmelt very rancid: there remained behind a coal. 616 Of almond oil.

3. Soap of ſulphuric acid and olive oil.—It is brown, and of the conſiſtence of wax. Solution in hot water white, opaque, viſcid; frothes. Solution in alcohol tranſparent and brown. Potaſs, ammonia, magneſia, nitric acid, muriatic acid, vinegar, nitre, ſal ammoniac, acetite of lead, and white oxyd of lead decompoſe it. 617 Of olive oil,

4. Soap of ſulphuric acid and butter of cocao.—It is hard, and marbled like Venice ſoap. Solution in water grey, opaque, viſcid; frothes. Solution in alcohol yellow and tranſparent. Potaſs, ammonia, nitric, muriatic, and acetous acids, tartar, ſal ammoniac, tartrite of potaſs, acetite of lead, and zinc in powder, decompoſe it. When diſtilled, there came over water, an oil that coagulated, and a few drops of a black oil, which alſo congealed: both were rancid. 618 Of butter of cocao,

5. Soap of ſulphuric acid and wax.—It is white, and becomes very hard. Its ſolution in water is white, and opaque, and frothes: Its ſolution in alcohol is yellow and tranſparent. Potaſs, ammonia, nitric and muriatic acids decompoſe it. 619 Of wax,

6. Soap of ſulphuric acid and ſpermaceti.—It is brown. It diſſolves in water: the ſolution is milky, viſcid, and frothes on agitation. It diſſolves in alcohol; the ſolution is tranſparent and yellow. It is decompoſed by as much alkali as ſaturates the acid: if more be added, it unites with the oil and forms a new ſoap. Lime and magneſia decompoſe it. The oil is alſo ſeparated, and appears in the form of a coagulum on adding to the ſolution nitric acid, muriatic acid, tartar, nitre, nitrat of ſoda, common ſalt, and zinc in powder; but not on adding vinegar, tin, lead. 620 Of ſpermaceti,

7. Soap of ſulphuric acid and oil of eggs.—Its ſolution in water is white, opaque, viſcid; frothes: that in alcohol yellow and tranſparent. Alkalies decompoſe it; but if too much be added a new ſoap is formed. Nitric and muriatic acids ſeparate the oil of the conſiſtence of wax, 621 Of oil eggs.

Neutral Salts.

wax, the first yellow, the last a deep brown. Nitre, sal ammoniac, acetite of lead, iron filings, zinc powder, decompose it; vinegar, borax, filings of lead do not.

To unite this acid with the essential oils, three ounces were put into a glass mortar, and four ounces of the oil were added, drop by drop, and care taken to prevent its becoming hot: equal parts of water were then poured on, and the whole heated slowly nearly to the temperature of boiling water: on cooling, the soap united into a brown mass.

622 Of turpentine,

8. Soap of sulphuric acid and turpentine. It is brown, and of the consistence of soft wax. Its solution in water is grey, opaque, viscid; frothes: Its solution in alcohol is brown and transparent. Alkalies decompose it: with too much it forms at the boiling heat a new soap.

Nitric and muriatic acids separated the oil thickened, as did also white oxyd of lead, muriat of lead, muriat of soda, and iron filings; but acetous acid, boracic acid, tartrite of potass, and tin filings, produced no such effect.

623 And of amber oil.

9. Soap of sulphuric acid and amber oil.—Its solution in water and alcohol as in the last soap. Alkalies, magnesia, and lime, decomposed it. Nitric and muriatic acids separated the oil of the consistence of wax. Tartar, sal ammoniac, muriat of antimony, acetite of lead, iron filings, decomposed it; vinegar, acetite of ammonia, and lead did not.

Mr Achard, to whom we owe these soaps†, could not succeed in his attempts to form soaps with nitric and muriatic acids.

† *Journ. de Phys.* xvi. 409.

Chap. II. *Of* Neutral Salts.

624 Salt explained.

The word *salt* has been used in chemistry in a very extensive, and not very definite sense. Every body which is sapid, easily melted, soluble in water, and not combustible, has been called a *salt*.

Salts were considered by the older chemists as a class of bodies intermediate between earths and water. Many disputes arose about what bodies ought to be comprehended under this class, and what ought to be excluded from it. Acids and alkalies were allowed by all to be salts; but the difficulty was to determine concerning earth and metals. Several of the earths possess all the properties which have been ascribed to salts; and the metals are capable of entering into combinations which possess saline properties. It is needless for us to enter into this dispute at present, as we have taken the liberty, in imitation of some of the best modern chemists, to expunge the class of salts altogether, and to arrange those subordinate classes, which are usually referred to it, under distinct heads.

625 Neutral salt explained.

The word *neutral salt* was originally applied exclusively to combinations of acids and alkalies, which were considered as substances possessing neither the properties of acids nor alkalies, but properties intermediate between the two. But the word is now always taken in a more extensive sense, and signifies all compounds formed by the combination of acids with alkalies, earths, or metallic oxyds. In these compounds, the earth, alkali, or oxyd, is denominated the *base*. Each order of salts is denominated after the acid which enters into its composition; and every individual salt is distinguished by subjoining the name of its base. Thus all the salts into which sulphuric acid enters are called *sulphats*, and the salt formed by the combination of sulphuric acid and potass is called *sulphat of potass*.

Sulphats.

It is evident, then, that there must be as many orders of neutral salts as there are acids; and as many salts in each order as there are alkalies, earths, and metallic oxyds, supposing every acid capable of combining with every one of these substances. But besides these simple combinations of one acid and one base, there are others more complex, composed of two acids combined with one base, or two bases combined with one acid, or a neutral salt combined with an acid or a base. These combinations have been called *triple salts*; and they increase the number of neutral salts very considerably.

In the following sections we shall take a short view of the properties of the principal neutral salts at present known; for this wide and important region of chemistry is still very far from being completely explored.

Sect. I. *Of Sulphats.*

Sulphuric acid is capable of combining with all the alkalies, with alkaline earths, alumina, jargonia, and the greater number of the metallic oxyds. The principal neutral salts which it forms are as follows:

626 Sulphat of potass.

1. Sulphat of potass.—This salt may be formed by saturating diluted potass with sulphuric acid, and then evaporating the solution gently till crystals are formed. It seems to have been known at a very early period by chemists, and a great variety of names were given to it, according to the manner of forming it, or the fancy of the operator. Some of these names were, *specificum purgans*, *nitrum fixum*, *arcanum duplicatum*, *panacea holsatica*, *sal de duobus*, *sal polychrest glaseri*, &c.; but it was commonly known by the name of *vitriolated tartar* till the French chemists called it *sulphat of potass*, when they formed their new nomenclature in 1787 (K).

627 Its properties.

When the solution of sulphat of potass is sufficiently diluted, it affords by evaporation hexahedral pyramids, or short hexangular prisms, terminated by one or more hexangular pyramids. But these crystals vary much in their figure, according to the care with which they are prepared.

It has a very disagreeable bitter taste. Its specific gravity is 2,298*.

* *Brisson.*

It is soluble in the temperature of 60° in 16 times its weight of water; in a boiling heat, it is soluble in 5 times its weight†.

† *Bergman.*

According to Bergman, it is composed of 40 parts of acid, 52 parts of alkali, and 8 of water; but according to Kirwan, whose experiment has been already described, it is composed of 45 parts of acid and 55 of alkali.

It suffers no alteration in the air.

When placed upon burning coals, it breaks into pieces with a noise resembling a number of small explosions succeeding each other at short intervals (L), but suffers no other alteration. In a red heat it melts.

It has hitherto been applied to little use. It is a purgative,

(K) Bergman called it *alkali vegetabile vitriolatum*, and Morveau *vitriol of potass*.

(L) This is called *decrepitation*.

Sulphats.

purgative, but its disagreeable taste prevents it from being much employed for that purpose.

It often has an excess of acid, owing, as Mr Bergman and Morveau have very ingeniously explained, to an affinity which exists between this salt and sulphuric acid.

It is decomposed by compound affinity by the following salts:

Nitrat of soda (M),	Nitrat of silver,
———— lime,	———— lead,
———— barytes*,	Acetite of barytes,
———— strontites‡,	Muriat of lime†,
———— ammonia,	———— lead‖,
———— magnesia,	———— magnesia?
———— mercury,	———— soda ¶.

* Kirwan. ‡ Id. † Bergman. ‖ Id. ¶ Fuchs, Ann. de Chim. vi. 29.

It is sometimes luminous in the dark, as Mr Giobert has observed*.

* Ann. de Chim. x. 40.

628 Sulphat of soda.

2. Sulphat of soda.—This salt was first discovered by Glauber a German chemist, and for that reason was long known by the name of *Glauber's salt*. He himself called it *sal mirabile*. It may be prepared by saturating soda with sulphuric acid, but is more usually obtained by decomposing common salt in order to procure muriatic acid.

Its crystals are transparent, and when formed by slow evaporation, are six-sided prisms terminated by dihedral summits.

Its taste at first has some resemblance to that of common salt, but soon becomes very disagreeably bitter.

It is soluble in 2,67 times its weight of water at the temperature of 60°, and in 0,8 of boiling water.

It is composed, according to Bergman, of 27 parts of acid, 15 of alkali, and 58 of water; but, according to the experiments of Kirwan, of 22 parts of acid, 17 of alkali, and 61 of water.

When exposed to the air, it loses great part of its water, and falls into a white powder (N).

When exposed to heat it first undergoes the *watery fusion* (O), then its water is evaporated, it is reduced to a white powder, and at last in a red heat it melts. Mr Kirwan has observed, that part of the acid, as well as the water, is driven off by the application of a strong heat†.

† Irish Transf. iv.

This salt is used as a purgative.

It often combines with an excess of acid.

It is decomposed by compound affinity by the following substances.

Nitrat of lime,	Acetite of barytes,
———— magnesia,	———— potass,
Muriat of potass,	———— lime,
———— soda,	Carbonat of barytes,
———— magnesia,	———— potass,
———— lime ‡.	

‡ Scheele.

629 Sulphat of ammonia.

3. Sulphat of ammonia.—This salt was discovered by Glauber, and called by him *secret sal ammoniac*. It was also called *vitriolated ammoniac*. It may be prepared by saturating ammonia with sulphuric acid.

Its crystals are generally small six-sided prisms, whose planes are unequal, terminated by six-sided pyramids.

It has a sharp bitter taste.

It is soluble in twice its own weight of water at the temperature of 60°, and in its own weight of boiling water.

According to Mr Kirwan, it is composed of 29,7 of alkali, 55,7 of sulphuric acid, and 14,16 of water‖.

‖ Irish Transf. ibid.

When exposed to the air, it slowly attracts moisture.

When heated, it first decrepitates, then melts, and in close vessels sublimes, but with some loss of its alkali†.

† Kirwan's Mineral. ii. 11.

It has not hitherto been applied to any use.

It is apt to contain an excess of acid.

It is decomposed by compound affinity by the following salts:

Nitrat of lime,	Acetite of soda,
———— magnesia,	———— barytes,
———— mercury?	———— lime,
Muriat of potass,	———— magnesia,
———— soda,	Carbonat of potass,
———— barytes,	———— soda,
———— lime,	———— barytes,
———— magnesia.	———— lime,
———— mercury*,	———— magnesia,
Acetite of potass,	Phosphat of lime†.

* Bergman. † Delkestamp Ann. de Chim. vi. 37.

630 Sulphat of barytes.

4 Sulphat of barytes. This substance was first discovered by Scheele. It abounds in nature. It is generally in the form of a hard very heavy stone.

It is sometimes found crystallized; but the variety of forms is so great that they baffle all description.

It is soluble in 43,000 times its weight of water at the temperature of the atmosphere*.

* Kirwan's Mineralogy, i. 136.

Sulphuric acid dissolves it when concentrated and boiling, but it is precipitated by the addition of water.

When exposed to heat it melts, and, if the heat be very strong, gradually dissipates.

631 Bologna stone.

After being heated red hot, it has the property of being luminous in the dark. This was first observed in a variety of this substance known by the name of Bologna stone. Lemery informs us, that this property was first discovered by an Italian shoemaker named Vincenzo Casciarolo. This man found a Bologna stone at the foot of Mount Paterno, and its brightness and gravity made him suppose that it contained silver. Having exposed it to the fire, doubtless in order to extract from it the precious metal, he observed that it was luminous in the dark. Struck with the discovery, he repeated the experiment, and it constantly succeeded with him.

From an experiment of Mr Klaproth, it appears to be composed of 33 parts of acid and 77 of barytes.

It is decomposed by compound affinity by the following salts:

Nitrat of soda,	Nitrat of magnesia,
———— lime,	Carbonat of potass,
———— ammonia,	———— soda*.

* Afzwelius.

632 Sulphat of lime.

5. Sulphat of lime. This substance was well known to the ancients under the name of *gypsum*; but the composition of gypsum was not known till Margraf and Macquer analysed it, and proved that it was composed of sulphuric acid and lime. The artificial compound

(M) Most of these double decompositions in this and the following sections are inserted on the authority of Morveau. See his table of *Affinity*, page 399 of this article.

(N) This is called *efflorescing*.

(O) When substances melt by means of the water they contain on the application of heat, they are said to undergo the watery fusion.

Sulphats. pound formed by the union of these two bodies was formerly called *selenite*.

It is found crystallized in various forms, sometimes transparent and sometimes opaque; and when pure it is of a white colour.

It has a slightly nauseous taste, scarcely perceptible except by drinking a glass of water impregnated with it.*

* Macquer.

It is soluble in 500 parts of water at the temperature of 60°, but much more soluble in boiling water.

It is composed, according to Bergman, of 46 parts of acid, 32 of earth, and 22 of water; according to the late experiments of Mr Kirwan, when so far dried as still to retain its glassy appearance, it contains 48 of acid, 34 of earth, and 18 of water; which differs very little from the determination of Bergman.

It is not affected by exposure to the air.

It is soluble in sulphuric acid.

When exposed to heat, it undergoes a kind of watery fusion, but afterwards it cannot be melted by the strongest heat. In a clay crucible indeed it fuses at 130° Wedgewood, owing evidently to the presence of the clay.

633 Plaster of Paris. When heated red hot and cooled, it is called *plaster of Paris*; a substance so useful for casting moulds, &c. on account of its property of becoming solid almost immediately when reduced into a paste with water.

By compound affinity it is decomposed by the following substances:

Acetite of barytes,	Carbonat of potass,
——— potass,	——— soda,
Carbonat of barytes,	——— magnesia?
	——— alumina.*

* Bergman.

634 Sulphat of strontites. 6. Sulphat of strontites. This salt, first formed by Dr Hope, is a white powder destitute of taste. It is soluble in 3840 parts of boiling water. Sulphuric acid dissolves it readily when assisted by heat, but it is precipitated by the addition of water to the solution †.

† Dr Hope, Transf. Edin. iv. 10.

635 Sulphat of magnesia. 7. Sulphat of magnesia. This salt was first observed in the springs at Epsom in England by Grew in 1675; but Dr Black was the first who accurately ascertained its composition. It has been called *Epsom salt*, *sal catharticus amarus*, and *Seydler salt*.

It crystallizes in quadrangular prisms, whose plains are equal, surmounted by quadrangular pyramids.

It has an excessively bitter taste.

At the temperature of 60° it is soluble in its own weight of water, and in ¾ths of its weight of boiling water. The volume of water is increased ¼th by adding the salt ‡.

‡ Bergman.

It is insoluble in alcohol.

It is composed, according to Bergman, of 19 parts of earth, 33 of acid, and 48 of water; according to Mr Kirwan, of 17 parts of earth, 29,46 of acid, and 53,54 of water.

When exposed to the air it effloresces, and is reduced to powder.

When exposed to heat it undergoes the watery fusion, and by increasing the temperature its water is evaporated, but it cannot be decomposed by means of heat. Sulphats.

It is sometimes employed as a cathartic, but its chief use is to furnish magnesia by its decomposition.

It is decomposed by compound affinity by the following salts.

Muriat of potass,	Acetite of lime,
——— soda (P),	Carbonat of barytes,
——— lime,	——— potass,
Acetite of barytes,	——— soda,*
——— potass,	——— ammonia (Q).

* Id.

636 Sulphat of ammonia and magnesia. 8. Sulphat of ammonia and magnesia. This triple salt was discovered by Mr Fourcroy. Into the solution of 100 parts of sulphat of magnesia in 500 parts of water, 12 parts of ammonia being poured, a very small quantity of magnesia was precipitated, and a considerable quantity more on the addition of another dose of ammonia; but farther additions had no effect. From the magnesia precipitated, it appeared that 38 parts of the sulphat had been decomposed. There remained, therefore, 62 parts in solution, mixed with a large quantity of ammonia. By evaporation, 92 parts of a white transparent rhomboidal salt were obtained, evidently composed of sulphuric acid, ammonia, and magnesia, in the proportions that would have formed 62 parts of sulphat of magnesia and 30 of sulphat of ammonia, and probably consisting of a combination of these two sulphats †.

† Ann. de Chim. iv. 211.

637 Sulphat of alumina. 9. Sulphat of alumina. This salt may be formed by dissolving alumina in sulphuric acid. It has an astringent taste, is very soluble in water, and crystallizes in thin plates which have very little consistence.* Little attention has hitherto been paid to this salt, which was never properly distinguished from *alum* till two memoirs, one by Vauquelin and another by Chaptal, on the nature of alum, made their appearance in the 22d volume of the *Annales de Chimie*. This salt generally contains an excess of acid, and is not neutralized without considerable difficulty †.

* Vauquelin, Ann. de Chim. xxii. 277. and Chaptal, ibid. 294.

† Ibid. p. 277.

638 Alum. 10. Sulphat of alumina and potass, or alum. The *στυπτηρια* of the Greeks, and the *alumen* of the Romans, was a native substance, which appears to have been nearly related to *green vitroil* or *sulphat of iron*; and which consequently was very different from what we at present denominate *alum*. From the researches of Professor Beckmann, it appears that we owe the discovery of alum to the Asiatics; but at what period, or by what means, the discovery was made, is altogether unknown.

It continued to be imported from the East till the 15th century, when a number of alum works were established in Italy. In the 16th century it was manufactured in Germany and Spain; and during Queen Elizabeth's reign an alum work was established in England by Thomas Chalomer.

The alum of commerce is usually obtained from earths containing sulphur and clay, or sulphuric acid and clay.

639 Its composition. The composition of alum has been but lately understood

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(P) Only below the temperature of 32°. *Scheele, Gren, Ann. de Chim.* xxiii.

(Q) Only below the temperature of 212°. *Fourcroy, Ann. de Chim.* ii. 291.

Sulphats.

ſtood with accuracy. It has been long known, indeed, that one of its ingredients is ſulphuric acid (R); and the experiments of Geoffroy, Hellot, Pott, Margraf, and Macquer, proved inconteſtibly that alumina is another ingredient. But ſulphuric acid and alumina are incapable of forming alum: Manufacturers knew, that the addition of a quantity of potaſs, or of ammonia, or of ſome ſubſtance containing theſe alkalies, is almoſt always neceſſary; and it was proved, that in every caſe in which ſuch additions are unneceſſary, the earth from which the alum is obtained contained already a quantity of potaſs. Various conjectures were made about the part which potaſs acts in this caſe; but Chaptal and Vauquelin appear to have been the firſt chemiſts that aſcertained by deciſive experiments that alum was a triple ſalt, compoſed of ſulphat of alumina and of potaſs united together (S).

640 And properties.

Alum cryſtallizes in large octahedrons, compoſed of two tetrahedral pyramids, applied to each other at their baſes.

It has a ſweetiſh and aſtringent taſte, and always reddens the tincture of turnſol.

It is ſoluble at the temperature of 60°, in from 10* to 15 † times its own weight of water, according to its purity; pure alum being moſt inſoluble. Seventy-five parts of boiling water diſſolve 100 of alum ‡.

* Neumann and Chaptal.
† Kirwan and Chaptal.
‡ Bergman.

A hundred parts of alum contain, according to Kirwan, 17,62 parts of acid, 18 of earth (and alkali), and 64,38 of water ‖.

‖ Kirwan's Min. ii. 14.

When expoſed to the air it effloreſces ſlightly.

When expoſed to a gentle heat it undergoes the watery fuſion. A ſtrong heat cauſes it to ſwell and foam, and to loſe about 44 *per cent.* of its weight, conſiſting chiefly of water of cryſtallization §. What remains is called *calcined* or *burnt alum*, and is ſometimes uſed as a corroſive.

§ Ibid.

Alum is of great importance as a mordant in dyeing, and is uſed alſo in ſeveral other arts.

By compound affinity it is decompoſed by the following ſalts.

Nitrat of ſoda,	Acetite of potaſs,
——— lime,	——— ſoda,
——— ammonia,	——— lime,
——— magneſia,	——— ammonia,
Muriat of barytes,	——— magneſia,
——— potaſs,	Carbonat of barytes,
——— ſoda,	——— potaſs,
——— lime,	——— ſoda,
——— ammonia,	——— lime,
——— magneſia.	——— ammonia,
Acetite of barytes,	——— magneſia.

641 Homberg's pyrophorus.

If three parts of alum and one of flour or ſugar be melted together in an iron ladle, and the mixture dried till it becomes blackiſh and ceaſes to ſwell; if it be then pounded ſmall, put into a glaſs phial, and placed in a ſand-bath till a blue flame iſſues from the mouth of the phial, and after burning for a minute or two be allowed to cool (T), a ſubſtance is obtained known by the name of *Homberg's pyrophorus*, which has the property of catching fire whenever it is expoſed to the open air, eſpecially if the air be moiſt.

This ſubſtance was accidentally diſcovered by Homberg about the beginning of the 18th century, while he was engaged in his experiments on the human fæces. He had diſtilled a mixture of human fæces and alum till he could obtain nothing more from it by means of heat; and four or five days after, while he was taking the reſiduum out of the retort, he was ſurpriſed to ſee it take fire ſpontaneouſly. Soon after Lemery the Younger diſcovered that honey, ſugar, flour, or almoſt any animal or vegetable matter, could be ſubſtituted for human fæces; and afterwards Mr Lejoy de Suvigny ſhewed that ſeveral other ſalts containing ſulphuric acid might be ſubſtituted for alum.* Scheele proved, that alum deprived of potaſs was incapable of forming pyrophorus, and that ſulphat of potaſs might be ſubſtituted for alum †. And Mr Prouſt has ſhewn, that a number of neutral ſalts, compoſed of vegetable acids and alkalies, or earths, when diſtilled by a ſtrong fire in a retort, left a reſiduum which took fire ſpontaneouſly on expoſure to the air.

* See Macquer's Dict.
† Scheele on Fire, and on Pyrophorus.

Theſe facts have thrown a great deal of light on the nature of Homberg's pyrophorus, and enabled us in ſome meaſure to account for its ſpontaneous inflammation. It has been aſcertained, that part of the ſulphuric acid is decompoſed during the formation of the pyrophorus, and of courſe a part of the alkaline baſe becomes uncombined with acid, and the carbon, which gives it its black colour, is evidently divided into very minute particles. It has been aſcertained, that during the combuſtion of the pyrophorus a quantity of oxygen is abſorbed. The inflammation ſeems to be owing to a *diſpoſing affinity*. Part of the carbon and of the ſulphur attract oxygen from the atmoſphere, in order to combine with the potaſs, and the caloric diſengaged produces a temperature ſufficiently high to kindle the reſt of the carbon.

Alum is capable of combining with alumina, and of forming what has been called *alum ſaturated with its earth*, which is an inſoluble, taſteleſs, earthy-like ſubſtance.

It is capable alſo, as Chaptal informs us, of combining with ſeveral other baſes, and of forming many triple ſalts, which have never yet been examined with attention.*

* Ann. de Chimie, xxii. 293.

11.

(R) Some chemiſts have thought proper to call the ſulphuric acid, obtained by diſtilling alum, *ſpirit of alum.*

(S) This they did in the two memoirs above quoted, and which were firſt publiſhed in the 22d volume of the *Annales de Chimie*. An account of Vauquelin's memoir has been already given under the article ALUM in this *Supplement*. Chaptal's memoir is no leſs intereſting. This celebrated chemiſt appears, from the facts ſtated in the 23d volume of the *Annales*, p. 222. to have made his diſcovery before Vauquelin; who, however, was ignorant of what Chaptal had done, as he informs us in the *Ann. de Chim.* xxv. 107. that his paper was read to the Inſtitute a fortnight before that of Chaptal's came to Paris. He informs us, too, that Deſcroiſilles had long before made the ſame diſcovery, and that he had publiſhed it in Berthollet's *Art de la Teinture*.

(T) Care muſt be taken not to keep it too long expoſed to the heat.

Sulphats.

642 Sulphat of jargonia.

11. Sulphat of jargonia (υ). In order to combine jargonia with acids, they should be poured upon it while it is yet moist, after being precipitated from some of its solvents; for after it is dry, acids do not act upon it without difficulty. By this method sulphat of jargonia is easily formed. It is white, and without sensible taste. Heat expels the acid from it, and the jargonia remains in a state of purity. At a high temperature charcoal converts it into a sulphuret, which is soluble in water, and which, by evaporation, furnishes crystals of hydrosulphuret (τ) of jargonia †.

† Vauquelin, Ann. de Chim. xxii. 199.

Klaproth informs us, that with excess of acid sulphat of jargonia forms transparent stelliform crystals, soluble in water, and having an astringent taste †.

† Journ. de Phys. xxxvi. 187.

12. Sulphat of iron. There are two sulphats of iron, which were first accurately distinguished by Mr Proust. The one contains the green oxyd, the other the red oxyd of iron. We shall, in imitation of Mr Proust, denominate them from their colours.

643 Green sulphat of iron.

The *green sulphat of iron*.—This salt, which is composed of sulphuric acid and green oxyd of iron, is found native, and was known to the ancients. It is mentioned by Pliny under the names of *misy*, *sory*, *calchantum*.* It was formerly called *green vitriol*.

* Lib. xxxiv. c. 12.

It is generally prepared by exposing native sulphuret of iron, a very abundant mineral, to air and moisture.

Its crystals are of a light green colour, and in the form of rhomboidal parallelopipeds.

It has a sharp astringent taste.

It is soluble in six times its weight of water at the temperature of 60°, and in $\frac{3}{4}$ths of its weight of boiling water †.

† Bergman.

It is insoluble in alcohol.

According to Bergman, it is composed of 39 parts of acid, 23 of oxyd, and 38 of water; but according to Mr Kirwan, of 26 parts of acid, 28 (υ) of oxyd, and 46 of water.

When exposed to the air, it effloresces; but if it be moistened, it is gradually converted into red sulphat of iron.

When heated, it first assumes a yellow colour, loses its water and its acid; if the heat be increased, nothing remains but a yellow powder.

The Prussic alkali precipitates from the solution of this salt a white powder, which gradually becomes blue by attracting oxygen §.

§ Proust.

It is used in dyeing, and in making ink, &c.

It is decomposed by compound affinity, by

Nitrat of silver,
Muriat of soda.*

* Ballen and Tuthen, Ann. de Chim. xi. 320.

644 Red sulphat of iron.

The *red sulphat of iron* may be formed by exposing a solution of green sulphat to the air, or by treating it with nitric acid. It was formerly called *mother water of vitriol*.

Little is known of its properties, except that it is deliquescent, incrystallizable, and soluble in alcohol.

It was first accurately examined by Mr Proust.

The green sulphat of iron generally contains some of it, which may be separated by means of alcohol.

It is alone capable of forming Prussian blue with the Prussic acid, and of striking a black colour with the gallic acid †.

† See Proust's paper, Nicholson's Journal, i. 453.

We have observed, that when it is diluted with water, and an excess of sulphuric acid is poured in, it is again slowly converted into green sulphat.

645 Sulphat of zinc.

13. Sulphat of zinc.—This salt, according to the best accounts, was discovered at Rammelsberg in Germany, about the middle of the 16th century. Many ascribe

(υ) *Jargonia*, or, as the French chemists call it, *zirconia*, has been discovered in great abundance in France by Morveau, who found that the hyacinths of Expailly contained more than half their weight of it. From Vauquelin's analysis they appear to be composed of

32 parts of silica,
64 jargonia,
2 oxyd of iron.

Jargonia has been examined with great care by these two philosophers, the experiments of Klaproth have been confirmed, and several new properties of it have been discovered. Perhaps a more detailed account than we have hitherto given of this new earth may not be unacceptable to our readers.

Jargonia is a white powder, its specific gravity is considerable, it has a feel resembling that of silica, it has no taste, and is insoluble in water. When separated from its solutions by pure alkalies, it retains, when exposed to the air to dry, a pretty considerable quantity of water, which renders it transparent, and gives it a resemblance to gum arabic both in its colour and fracture.

When exposed to the heat of the blow-pipe it does not melt; but Vauquelin melted it by exposing it surrounded with charcoal in a porcelain crucible to an intense heat for an hour and a half. Its specific gravity was then 4,35, its colour was grey, and its hardness such that it was capable of scratching glass. It melts with borax, and forms a transparent and colourless glass; but phosphat of soda and the fixed alkalies do not attack it.

It is insoluble in the fixed alkalies, has very little affinity for carbonic acid, and is precipitated from its solutions together with iron by the Prussic alkali.

Its affinities, as far as they have been ascertained by Vauquelin, are as follows:

Vegetable acids, order unknown,
Sulphuric acid,
Muriatic,
Nitric.

See upon this subject the Memoirs of Morveau and Vauquelin, *Ann. de Chim.* xxi. 72, and xxii. 179.

(τ) These curious salts form the subject of the next chapter.

(υ) Perhaps the quantity of oxyd is somewhat over-rated here; for before it was examined by Mr Kirwan, it had assumed a red colour: it must therefore have been converted into the brown or red oxyd by attracting oxygen from the atmosphere.

Sulphats.

ascribe the invention to Julius Duke of Brunswick. Henkel and Newmann were the first chemists who proved that it contained zinc; and Brandt first ascertained its composition completely ‡. It is generally formed for commercial purposes from sulphuret of zinc or *blende*, as it is called. This salt is called also *white vitriol*.

‡ *Beckmann's Hist. of Inventions*, art. *Zinc*.

It is of a white colour, and its crystals are rhomboidal prisms, terminated by quadrangular pyramids: there is generally a slight defect in two of the opposite angles of the prism, which produces a quadrangular section §. Its specific gravity is 2,000.

§ *Bergman*, ii. 327.

It has a sharp styptic taste.

It is soluble in 2,28 parts of water at the temperature of 60°; but in a much smaller quantity of boiling water.*

* *Ibid.*

It is composed, according to Bergman, of 40 (v) parts of acid, 20 of oxyd, and 40 of water: Kirwan supposes, that it is composed of 12 parts of acid, 26,4 of zinc, 20 of oxyd, 41,6 of water (w).

According to Bergman, this salt is not altered in the air; others affirm that it effloresces. This, no doubt, depends upon the place where it is kept.

646 Heat decomposes this salt.

Sulphat of manganese. 14. Sulphat of manganese.—This salt was first obtained by Scheele (x): It is composed of sulphuric acid and white oxyd of manganese.

Its crystals are oblique parallelopipeds; they are of a white colour, and very bitter.*

* *Scheele.*

These crystals are decomposed by a strong red heat, and the sulphuric is converted into sulphurous acid by the oxyd attracting its oxygen, and being changed into black oxyd ‡.

‡ *Id.*

647 Sulphat of nickel. 15. Sulphat of nickel.—This salt, which is composed of sulphuric acid and oxyd of nickel, was first described by Bergman. Its crystals are in the form of decahedrons, composed of two quadrangular truncated pyramids; they are of a green colour †.

† *Bergman*, ii. 268.

648 Sulphat of cobalt. 16. Sulphat of cobalt.—This salt was first mentioned by Mr Brandt. Its crystals are of a reddish colour; but if any nickel be present, they are green.

649 Sulphat of lead. 17. Sulphat of lead.—This salt has been long known: it is composed of sulphuric acid and white oxyd of lead. The crystals are white, small, and most commonly needle-shaped: according to Sage, they are tetrahædral prisms.

It is soluble in 18 parts of water.

Heat decomposes it.—It is very caustic.

18. Sulphat of tin.—Nothing is known concerning this salt, except that it crystallizes in fine needles interlaced with one another §.

§ *Monnet.*

650 Sulphat of copper. 19. Sulphat of copper.—This salt appears to have been known to the ancients. It is generally obtained by evaporating those waters which naturally contain it. It is called also *blue vitriol*.

Its crystals are of a deep blue colour; they are in the form of oblong rhomboids. It specific gravity is 2,230.

It has a very strong styptic taste; and indeed is employed as a caustic.

It is soluble in four parts of water at the temperature of 60°; but in a much smaller quantity of boiling water.*

* *Bergman.*

It is composed, according to Bergman, of 46 parts of acid, 26 of oxyd of copper, and 28 of water. Kirwan supposes it to contain 27,68 of acid, 35 of oxyd, and 37,32 of water ‡.

‡ *Miner.* ii. 23.

When exposed to the air, it effloresces, and is covered with a yellowish grey powder.

It requires a very strong heat to decompose it.

It has the property of communicating a green colour to flame.

It is used in the preparation of several paints, and for a variety of other purposes.

It is decomposed by compound affinity, by acetite of lead.

651 Sulphat of bismuth. 20. Sulphat of bismuth.—Little is known of this salt, except that it is with difficulty crystallized, and is very deliquescent.

652 Antimony. 21. Sulphat of antimony.—This salt does not crystallize. It is easily decomposed by heat.

653 Arsenic. 22. Sulphat of arsenic.—This salt is scarcely known. It does not appear to be crystallizable. It is decomposed by water.

654 White sulphat of mercury. 23. White sulphat of mercury.—This salt may be formed by boiling together two parts of mercury and three of concentrated sulphuric acid, and stopping the process whenever the mercury is converted into a white mass. This mass, in order to remove the excess of acid, is to be washed repeatedly with small portions of water, till it ceases to redden turnsole. The sulphat of mercury, thus obtained, is very white. Its crystals are either small plates or prisms. Its taste is not very caustic. It is soluble in 500 parts of water at the temperature of 55°, and in 287 parts of boiling water. It is composed of 83 parts of white oxyd of mercury, 12 of sulphuric acid, and 5 of water.* It is not altered by exposure to the air. Heat decomposes it.

* *Fourcroy, Ann. de Chim.* x. 299.

This sulphat is capable of combining with a new portion of acid: It was in that state before it was washed with water. This salt, which may be called *acidulous white sulphat of mercury*, has a very caustic taste, and is corrosive. It reddens vegetable blues. It is soluble in 157 parts of water at the temperature of 55°, and in 33 parts of boiling water †.

† *Fourcroy, ibid.*

655 Yellow sulphat of mercury. 24. Yellow sulphat of mercury.—This salt may be obtained by continuing to boil the preceding mixture of mercury and sulphuric acid till the mercury assumes a yellow colour. It appears to be composed of yellow oxyd of mercury and a small portion of sulphuric acid. It is soluble in 2000 parts of water at the temperature of 55°, and in 600 parts of boiling water. The solution is colourless. It was formerly called *turbith mineral* ‡.

‡ *Fourcroy, ibid.*

656 Sulphat of ammonia and mercury. 25. Sulphat of ammonia and mercury.—This triple salt may be formed by pouring ammonia into a solution of sulphat of mercury. If only a small quantity of ammonia be used, a copious blackish precipitate takes place, part of which is converted into running mercury by exposure to light; and consequently is black oxyd of mercury; the remaining part is the triple salt. If a large quantity of ammonia be used, only the black oxyd is

(v) There is evidently some mistake in this statement; it does not correspond with what he says elsewhere.
(w) *Mineralogy*, ii. 24. We do not understand this statement.
(x) Westfeld, indeed, obtained it; but he mistook it for sulphat of magnesia.

Sulphats. is precipitated; for the triple salt is rendered much more soluble by an excess of ammonia. As this excess evaporates, the salt crystallizes. The crystals are polygons, very brilliant and hard. It has a sharp, austere, metallic taste. It has no peculiar odour. It is scarcely soluble, except with excess of ammonia. It is composed, according to Fourcroy's analysis, of 18 parts of sulphuric acid, 33 of ammonia, and 39 of oxyd of mercury. Heat decomposes it. The products obtained by distilling it are, a little ammonia, azotic gas, a little pure mercury, some *sulphite of ammonia*; and there remains yellow sulphat of mercury.*

This triple salt may be formed also by pouring ammonia upon acidulous sulphat of mercury, or on yellow sulphat of mercury†.

* Fourcroy, ibid.

† Ibid.

657 Sulphat of silver. 26. Sulphat of silver.—This salt is formed by pouring sulphuric acid on oxyd of silver. Its crystals are small needles. It melts when exposed to a strong heat, but does not sublime.

It is decomposed by muriat of lead‡.

‡ Bergman.

27. Sulphat of gold.—This salt is unknown.

28. Sulphat of platinum.—Unknown.

29. Sulphat of tungsten.—Probably no such combination is possible.

658 30. Sulphat of molybdenum.—Probably impossible.

Sulphat of uranium, 31. Sulphat of uranium.—This salt was first formed by Mr Klaproth. He formed it by pouring sulphuric acid on the oxyd of uranium. Nothing farther is known of it, except that its crystals are small, and of a yellow colour.

659 Titanium, 32. Sulphat of titanium.—This salt was first formed by Mr M'Gregor. It does not appear, from Klaproth's experiments, to be crystallizable.

660 Tellurium. 33. Sulphat of tellurium.—When one part of tellurium is mixed cold in a well stopped vessel with an hundred parts of concentrated sulphuric acid, the latter gradually assumes a beautiful crimson red colour: when a small quantity of water is added, drop by drop, the colour disappears, and the metal is precipitated in the form of black flakes. The solution is destroyed by heat, the colour disappears, and the metal separates in the state of a white oxyd. When sulphuric acid is diluted with two or three parts of water, and a small quantity of nitric acid is added, it dissolves a considerble quantity of tellurium. The solution is transparent and colourless, and is not decomposed by the addition of a larger quantity of water‡.

‡ Klaproth, Philosophical Mag. i. 80.

Sect. II. *Of Sulphites.*

Salts composed of sulphurous acid united respectively with alkalies, earths, or oxyds, are called *sulphites*. Those hitherto examined are the following:

661 Sulphite of potass. 1. Sulphite of potass.—This salt was first formed by Stahl; but was first accurately described by Berthollet, Fourcroy, and Vauquelin.

It may be formed by passing sulphurous acid into a saturated solution of carbonat of potass till all effervescence ceases. The solution becomes hot, and crystallizes by cooling.*

Its crystals are white and transparent; their figure that of rhomboidal plates. Its crystallization often presents small needles diverging from a common centre†.

* Fourcroy, and Vauquelin, Nicholson's Jour. i. 317.

† Ibid.

Its taste is penetrating and sulphurous. At the common temperature of the atmosphere, it is soluble in its own weight of water, but much more soluble in boiling water.

Sulphites. When exposed to the air, it effloresces, becomes opaque and hard, and is gradually converted into *sulphat of potass* by absorbing oxygen.

When exposed to a sudden heat, it decrepitates, loses its water: at a red heat some sulphurous vapours are emitted; at last a portion of sulphur separates, and the residuum is sulphat of potass, with a slight excess of alkali.

Nitric and oxy-muriatic acids convert it into sulphat of potass by imparting oxygen.

It decomposes the oxyds of gold, silver, mercury, the red oxyd of lead, the black oxyd of manganese, and the brown oxyd of iron. When the green oxyd of iron and the white oxyd of iron are boiled with it in water, and an acid added, a precipitate takes place of these bodies united to some sulphur, and the salt is converted into a sulphat: at the same time sulphurated hydrogen gas is emitted.

By compound affinity it is decomposed by

All salts with base of soda, except the borat and carbonat;

All metallic salts except carbonats;

All neutral salts whose acid has a stronger affinity for potass than sulphurous acid has†.

† Ibid.

662 Sulphite of soda. 2. Sulphite of soda.—This salt was first accurately described by Fourcroy and Vauquelin.

It is white and perfectly transparent. Its crystals are four-sided prisms, with two very broad sides and two very narrow ones, terminated by dihedral pyramids.

Its taste is cool and sulphurous.

It is soluble in four times its weight of cold water, but it is more soluble in hot water.

It is composed of 18,8 parts of soda, 31,2 of acid, and 50 of water.

By exposure to air, it effloresces, and is slowly converted into a sulphat.

When exposed to heat, it undergoes the watery fusion, and afterwards exhibits precisely the same phenomena as the sulphite of potass.

Metallic oxyds and salts affect it precisely as they do sulphite of potass.

It is decomposed by compound affinity by carbonat of potass, and the other salts which decompose sulphite of potass‖.

‖ Ibid.

663 Sulphite of ammonia. 3. Sulphite of ammonia.—This salt was first described by Fourcroy and Vauquelin¶.

It crystallizes in six-sided prisms terminated by six-sided pyramids.

¶ Fourcroy and Vauquelin, Nicholson's Jour. i. 317.

Its taste is cool and penetrating like that of the other ammoniacal salts, but it leaves a sulphurous impression in the mouth.

It is soluble in its own weight of cold water. Its solubility is increased by heat.

It is composed of 29,07 parts of ammonia, 60,06 of acid, and 10,87 of water.

When exposed to the air, it attracts moisture, and is soon converted into a sulphat.

Heat volatilizes it without decomposition.

Its habitudes with metallic oxyds and salts are nearly the same with those of the above described sulphites, only it is capable of forming with several of them triple salts†.

† Ibid.

664 Sulphite of barytes. 4. Sulphite of barytes.—This salt was first described by Berthollet‡.

It is incrystallizable; it has no perceptible taste; and is perfectly insoluble in water*.

‡ Ann. de Chim. ii. 57.

* Fourcroy and Vauquelin.

It

Sulphites.

It is compoſed of 59 parts of barytes, 39 parts of acid, and 2 of water.

It does not eaſily change into a ſulphat by expoſure to air; but heat produces this effect‡.

‡ *Ibid.*

665 Sulphite of lime.

5. Sulphite of lime.—This ſalt was firſt deſcribed by Berthollet||.

|| *Ann. de Chim. ibid.*

Its cryſtals are ſix-ſided priſms, terminated each by a very long pyramid*.

* *Fourcroy and Vauquelin.*

It has ſcarcely any taſte; however, when kept long in the mouth, it communicates to the tongue a taſte which is manifeſtly ſulphurous.

It is very ſparingly ſoluble in water, except with exceſs of acid.

It is compoſed of 47 parts of lime, 48 of ſulphurous acid, and 5 of water.

By contact of air it is converted into a ſulphat, but very ſlowly.

Heat converts it into a ſulphat by depriving it of a portion of ſulphur.

It is decompoſed by compound affinity by

Carbonats of alkalies, Fluats of alkalies,
Phoſphats of alkalies, Moſt metallic ſalts*.

* *Ibid.*

666 Sulphite of magneſia.

6. Sulphite of magneſia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin.

Its cryſtals are white and tranſparent, and in the form of depreſſed tetrahedrons.

Its taſte is mild and earthy at firſt, and afterwards ſulphurous.

It is ſparingly ſoluble in water, except when there is an exceſs of acid.

It is compoſed of 16 parts of magneſia, 39 of acid, and 45 of water.

It becomes opake when expoſed to the air; is very ſlowly converted into a ſulphat.

By expoſure to heat, it ſoftens, ſwells up, and becomes ductile like gum; a ſtrong heat decompoſes it altogether.

It is decompoſed by

Alkaline ſalts,
Earthy ſalts, except thoſe of alumina†.

† *Fourcroy and Vauquelin.*

667 Sulphite of alumina.

7. Sulphite of alumina.—Firſt formed by Berthollet.

It does not cryſtallize, but is converted into a ſoft ductile maſs. It is not ſoluble in water, but becomes abundantly ſo when there is an exceſs of acid.

It is compoſed of 44 parts of alumina, 32 of acid, and 24 of water.

Heat decompoſes it¶.

¶ *Fourcroy and Vauquelin.*

668 Sulphite of iron.

8. Sulphite of iron.—It was firſt formed by Berthollet.

Its cryſtals are white, and have but very little of the ſtyptic taſte of iron ſalts*.

Berthollet alſo formed the ſulphites of zinc and tin, but he has not deſcribed them.

* *Ann. de Chim.* ii. 58.

Sect. III. *Of Nitrats.*

Those ſalts, in the compoſition of which the nitric acid forms one ingredient, are called *nitrats*.

669 Nitre.

1. Nitrat of potaſs, nitre, or ſaltpetre.—As this ſalt is produced naturally in conſiderable quantities, particularly in Egypt, it is highly probable that the ancients were acquainted with it; but ſcarcely any thing certain can be collected from their writings. If Pliny mentions it at all, he confounds it with ſoda, which was known by the names of *nitron* and *nitrum*. It is certain, however, that it has been known in the eaſt from time immemorial. Roger Bacon mentions this ſalt in the 13th century under the name of *nitre*.

Nitrats.

It cryſtallizes in ſlender oblong hexagonal priſms, often ſtriated, terminated by hexagonal pyramids obliquely truncated. Its ſpecific gravity is 1,920.

Its taſte is ſharp, bitteriſh, and cooling.

It is ſoluble in ſeven times its weight of water at the temperature of 60°, and in nearly its own weight of boiling water†.

† *Bergman.*

According to Bergman, it is compoſed of 31 parts of acid, 61 of potaſs, and 8 of water; but this proportion of acid is undoubtedly too ſmall. According to Mr Kirwan, it is compoſed of 41,2 of acid, 46,15 of alkali, and 12,65 of water‡.

‡ *Mineral.* ii. 27.

It is not altered by expoſure to the air.

When expoſed to a ſtrong heat, it melts; and congeals by cooling into an opake maſs, which has been called *mineral cryſtal*. If the heat be continued, the acid is gradually decompoſed and driven off. When the ſolution of nitre is expoſed to a boiling heat, part of the ſalt is evaporated along with the water, as Wallerius, Kirwan, and Lavoiſier, obſerved ſucceſſively. When nitre is expoſed to heat along with many combuſtible ſubſtances, its acid is decompoſed; the combuſtible ſeizes the oxygen, and at the ſame time a lively white flame appears, attended with a decrepitation: this is called the *detonation of nitre*.

Nitre mixed with charcoal and ſulphur in proper proportions forms *gunpowder*.

Nitre is decompoſed by compound affinities by

Acetite of barytes.

670 Reproduction of nitre.

No phenomenon has excited the attention of chemical philoſophers more than the continual reproduction of nitre in certain places after it had been extracted from them. Prodigious quantities of this ſalt are neceſſary for the purpoſes of war; and as Nature has not laid up great magazines of it as ſhe has of ſome other ſalts, this annual reproduction is the only ſource from which it can be procured. It became, therefore, of the utmoſt conſequence, if poſſible, to diſcover the means which Nature employed in forming it, in order to enable us to imitate her proceſſes by art, or at leaſt to accelerate and facilitate them at pleaſure. Numerous attempts accordingly have been made to explain and to imitate theſe proceſſes.

Stahl, ſetting out on the principle that there is only one acid in nature, ſuppoſed that nitric acid is merely ſulphuric acid combined with phlogiſton; and that this combination is produced by putrefaction: he affirmed accordingly, that nitre is compoſed by uniting together potaſs, ſulphuric acid, and phlogiſton. But this opinion, which was merely ſupported by very far-fetched analogies, could not ſtand the teſt of a rigorous examination.

Lemery the Younger accordingly advanced another; affirming, that all the nitre obtained exiſts previouſly in animals and vegetables, and that it is formed in theſe ſubſtances by the proceſſes of vegetation and animalization. But it was ſoon diſcovered that nitre exiſts, and is actually formed, in many places where no animal nor vegetable ſubſtance had been decompoſed; and conſequently this theory was as untenable as the former. So far indeed is it from being true that nitre is formed alone by theſe proceſſes, that the quantity of nitre in plants has been found to depend entirely on the ſoil in which they grow*.

* *Bouillon.*

At

Nitrats.

At last by the numerous experiments of several French philosophers, particularly by those of Thouvenel, it was discovered that nothing else is necessary for the production of nitre but a basis of lime, heat, and an open, but not too free communication with dry atmospheric air. When these circumstances combine, the acid is first formed, and afterwards the alkali makes its appearance. How the air furnishes materials for this production is easily explained, now that the component parts of the nitric acid are known to be oxygen and azot. But how lime contributes to their union it is not so easy to see. It is a disposing affinity, which, like most others referred to that singular class, our present knowledge of the nature of affinity does not enable us to explain. The appearance of the potass is equally extraordinary. If any thing can give countenance to the hypothesis, that potass is composed of lime and azot, it is this singular fact.

671 Nitrat of soda.

2. Nitrat of soda. This salt was called formerly *cubic nitre*.

It forms rhomboidal crystals. Its specific gravity is 1,870.

It has a cool sharp taste, and is somewhat more bitter than nitre.

It is soluble in about three parts of water at the temperature of 60°, and is scarcely more soluble in boiling water.

It is composed, according to Bergman, of 43 parts of acid, 32 of soda, and 25 of water. From an experiment formerly described, Mr Kirwan concludes, that it contains 57,65 of acid, and 42,35 of alkali; but perhaps the proportion of acid may be somewhat over-rated, as no direct proof has been brought that the salt contains no water.

When exposed to the air it rather attracts moisture.

Its phenomena in the fire are the same with those of nitre, only it does not melt so easily.

It is decomposed by compound affinity by the following salts:

Sulphat of barytes,	Muriat of ammonia,
——— potass,	Acetite of barytes,
——— alumina,	——— potass,
Muriat of barytes,	Carbonat of barytes,
——— potass,	——— potass.
——— lime,	

672 Nitrat of ammonia.

3. Nitrat of ammonia. This salt crystallizes with difficulty into regular needles. It was formerly called *nitrum semivolatile*, and *nitrum flammans*.

It has a sharp, acrid, somewhat urinous taste.

It is soluble in about half its weight of boiling water.

It is composed of 58 parts of acid, about 26 of alkali, and 16 of water*.

* Kirwan.

When exposed to the air it deliquesces.

When exposed to heat, it first undergoes the watery fusion, afterwards detonates, and is completely decomposed. Berthollet has shewn, that this phenomenon is owing to the hydrogen of the alkali entering into combination with the oxygen of the acid, and forming water, while the acid flies off in a gaseous form.

By compound affinity it is decomposed by the following substances:

Sulphat of barytes,	Acetite of barytes,
——— potass,	——— potass,
——— alumina,	——— soda,
Acetite of lime,	Muriat of lime,
——— magnesia,	——— magnesia,
——— alumina,	——— alumina,
Muriat of barytes,	Carbonat of barytes,
——— potass,	——— potass,
——— soda,	——— soda.

673 Nitrat of barytes.

4. Nitrat of barytes. This salt may be formed into hexagonal crystals, but it requires great address to produce them.

It attracts moisture from the atmosphere.

Heat decomposes it and leaves pure barytes. The decomposition of this salt by heat is the most convenient method of procuring pure barytes yet known. It was first proposed by Mr Vauquelin.

By compound affinity it is decomposed by

Alkaline carbonats,
Oxalat of ammonia*.

* Bergman.

674 Nitrat of lime.

5. Nitrat of lime. This salt forms by crystallization six sided prisms, terminated by dihedral pyramids, but more commonly small regular octahedral needles.

It has a sharp bitterish taste.

It is soluble in two parts of cold water, and in its own weight of boiling water.

Boiling alcohol dissolves its own weight of it†.

† Bergman.

According to Bergman it is composed of 43 parts of acid, 32 of lime, and 25 of water. Kirwan has found, that 100 parts of lime require for saturation 180 parts of acid‡.

‡ Miner. ii. 29.

Nitrat of lime deliquesces when exposed to the air. Heat decomposes it like all other nitrats.

By compound affinity it is decomposed by

Sulphat of barytes,	Acetite of potass,
——— potass,	Carbonat of barytes,
——— soda,	——— potass,
——— ammonia,	——— soda,
——— alumina,	——— ammonia,
Muriat of barytes,	——— alumina,
——— potass,	——— magnesia,
Acetite of barytes,	Tungstat of ammonia§.

§ Scheele.

675 Nitrat of strontites.

6. Nitrat of strontites. This salt, first formed by Dr Hope, crystallizes readily, but the crystals are very irregular in their shape; sometimes they are hexagonal truncated pyramids; sometimes octahedrons, consisting of two four-sided pyramids united at their bases.

It is soluble in its own weight of water at the temperature of 60°, and in little more than half its weight of boiling water. It has a strong pungent taste.

In a dry air it effloresces, but in a moist air it deliquesces.

It deflagrates on hot coals. Subjected to heat in a crucible, it decrepitates gently, and then melts. In a red heat it boils, and the acid is dissipated. If a combustible substance be at this time brought into contact with it, a deflagration with a very vivid red flame is produced*.

* Hope, Transf. Edin. iv. 12.

676 Nitrat of magnesia.

7. Nitrat of magnesia. The composition of this salt was first ascertained by Dr Black.

Its crystals are quadrangular prisms. It has a very bitter taste. It is very soluble in water. Alcohol dissolves $\frac{1}{9}$th of its own weight of it†.

† Bergman, ii. 381.

One hundred parts of magnesia require 255 of nitric acid for saturation‡.

‡ Kirwan.

It deliquesces in the air, according to Bergman; but Dijonval affirms, that he has procured it in crystals which rather effloresce.

It

Nitrats.

It is decompofed by heat.

By compound affinity it is decompofed by

Sulphat of barytes,	Muriat of lime,
——— potafs,	Acetite of barytes,
——— foda,	——— potafs,
——— ammonia,	——— foda,
——— alumina,	——— lime,
Muriat of barytes,	Carbonat of barytes,
——— potafs,	——— potafs,
——— foda,	——— lime.

677 Nitrat of ammonia and magnefia.

8. Nitrat of ammonia and magnefia. This triple falt was difcovered by Mr Fourcroy. Into a faturated folution of nitrat of magnefia, containing 73 grains of magnefia, he poured ammonia as long as any precipitate could be obtained. Twenty-one grains of magnefia were precipitated, 52 grains remained combined with the acid and the ammonia. He found that 52 grains of magnefia produced, when faturated with nitric acid, 288 grains of nitrat; and that the quantity of nitric acid neceffary to faturate 21 grains of magnefia, when faturated with ammonia, produced 84 grains of nitrat of ammonia. He concludes, therefore, though the data are not quite fatisfactory, that the triple falt is compofed of 288 grains of nitrat of magnefia, and 84 of nitrat of ammonia*.

* *Ann. de Chim.* iv. 215.

678 Nitrat of alumina.

9. Nitrat of alumina. This feems to have been firft attended to by Baumé.

Its cryftals are pyramidal. It has a very aftringent tafte. It is foluble in water, and deliquefces in the air.

679 Nitrat of jargonia.

10. Nitrat of jargonia. This falt may be eafily formed by pouring nitric acid on newly precipitated jargonia.

It always contains an excefs of acid. By evaporation a yellowifh tranfparent matter is obtained, exceedingly tenacious and vifcid, and which dries with difficulty. It has an aftringent tafte, and leaves on the tongue a vifcid matter, owing to its being decompofed by the faliva. It is only very fparingly foluble in water; the greateft part remains under the form of gelatinous and tranfparent flakes. Like all the other falts into which jargonia enters, it is decompofed by heat. It is decompofed alfo by fulphuric acid, which occafions a white precipitate, foluble in excefs of acid; by carbonat of ammonia, which produces a precipitate foluble by adding more carbonat; and by an infufion of nut galls in alcohol, which produces a white precipitate foluble in an excefs of the infufion, unlefs the jargonia contains iron, in which cafe the precipitate is a greyifh blue, and part of it remains infoluble, giving the liquor a blue colour. This liquor, mixed with carbonat of ammonia, produces a matter purple by tranfmitted light, but violet by reflected light. Gallic acid alfo precipitates nitrat of jargonia of a greyifh blue, but the colour is not fo fine. Moft of the other vegetable acids decompofe this falt, and form combinations infoluble in water†.

† *Vauquelin, Ann. de Chim.* xxii. 199.

680 Nitrat of iron.

11. Nitrat of iron. The green oxyd of iron decompofes, but does not combine with nitric acid. The brown oxyd forms with it a red or brown folution, which by evaporation may be reduced to a jelly, but will not cryftallize.

681 Nitrat of zinc.

12. Nitrat of zinc. The oxyd of zinc combines with nitric acid, and forms with it a falt which cryftallizes in compreffed and ftriated tetrahedral prifms, terminated by four-fided pyramids.

Its folution is exceedingly cauftic. When placed on burning coals, it melts and detonates as it dries. It can fcarcely be dried without being in fome meafure decompofed.

It deliquefces in the air*.

* *Fourcroy.*

682 Nitrat of manganefe.

13. Nitrat of manganefe. This falt, compofed of oxyd of manganefe and nitric acid, was firft examined by Scheele. Its cryftals are fmall and fhining, of a very bitter tafte, and foluble in water†.

† *Scheele on Manganefe.*

683 Nitrat of cobalt.

14. Nitrat of cobalt. It is of a pale red colour, and cryftallizes in needles. It deliquefces when expofed to the air. Heat decompofes it. When nickel is prefent, this falt affumes a green colour.

684 Of nickel,

15. Nitrat of nickel. Its cryftals are of a green colour, and in the form of rhomboidal cubes. They are deliquefcent, and are gradually decompofed when expofed to the air, the acid leaving them‡.

‡ *Bergman,* ii. 268.

685 Of lead,

16. Nitrat of lead. Nitric acid combines with the white oxyd of lead. The cryftals of this falt are of a white colour; their form an irregular octagon, or rather truncated hexahedral pyramid. When expofed to heat it decrepitates, and melts with a yellowifh flame. By compound affinity it is decompofed by

Muriat of potafs,
——— foda,
——— ammonia,
Carbonat of foda§.

§ *Bergman.*

686 Of tin,

17. Nitrat of tin. Tin is converted into an acid by nitric acid. It is not probable, therefore, that any permanent nitrat of tin can be formed.

687 Of copper,

18. Nitrat of copper. This falt appears to have been firft obtained by Macquer.

Its form, when properly cryftallized, is an oblong parallelogram. It is of a fine blue colour. It is exceedingly cauftic. It melts at 77°¶.

¶ *Sage.*

It is deliquefcent in a moift air, but in a dry place is covered with a green efflorefcence. It is very foluble in water. Heat decompofes it.

688 Of bifmuth,

19. Nitrat of bifmuth. This falt cryftallizes in various forms. Fourcroy obtained it in flattened rhomboids. It efflorefces in the air. Water decompofes it. It detonates in the fire.

689 Of antimony,

20. Nitrat of antimony. Little is known concerning this falt, except that it is very deliquefcent, and is decompofed by heat.

690 Of arfenic,

21. Nitrat of arfenic. With white oxyd of arfenic nitric acid forms a falt which cryftallizes. It is very deliquefcent. It does not detonate.

691 Of mercury,

22. Nitrat of mercury. This falt may be formed by diffolving mercury in nitric acid. It cryftallizes in the cold in regular flat 14-fided figures; but their form differs according to the manner in which the cryftallization has been performed.

It is foluble in water.

This falt is exceedingly cauftic. It detonates on coals. When heated in a crucible it melts, and is decompofed. The oxyd attracts oxygen from the acid, which flies off in the form of nitrous gas, and red oxyd of mercury remains behind.

It is flowly decompofed alfo in the air. It is decompofed by compound affinity by

Sulphat of copper, and a great many other fulphats,
Phofphat of foda,
Borax.

692 Of ammonia and mercury.

23. Nitrat of ammonia and mercury. This triple falt may be formed by pouring ammonia into a folution of

Muriats.

of nitrat of mercury. If only enough of ammonia to saturate the acid be used, the triple salt precipitates in the form of a white powder; but with an excess of ammonia it remains dissolved, and forms by evaporation very bright polyhedral crystals.

It has a very sharp taste. It is soluble in 1200 parts of water at the temperature of 55°. Hot water separates a little ammonia which renders it still more insoluble. It turns vegetable blues green. Muriatic acid dissolves it.

According to Fourcroy's analysis, it is composed of 68,20 parts of oxyd of mercury, 16 of ammonia, and 15,80 of nitric acid and water.

When distilled it yields ammonia, azotic gas, oxygen gas, yellow oxyd of mercury, and pure mercury.*

* Fourcroy, Ann. de Chim. xiv. 37.

693 Nitrat of silver.

24. Nitrat of silver. This salt may be formed by dissolving silver in nitric acid.

It forms flat transparent crystals composed of needles. It is exceedingly caustic. When melted it forms a grey mass called *lapis infernalis*, from its great corrosiveness.

It is very soluble in water. It is not altered by exposure to the air. Light decomposes it.

By compound affinity it is decomposed by
The sulphats,
The muriats.

694 Nitrat of uranium.

25. Nitrat of uranium. This salt was first formed by Klaproth. Its crystals are hexagonal plates of a greenish yellow colour. The largest were $\frac{3}{4}$ths of an inch in length and $\frac{1}{4}$th in breadth †.

† Klaproth, Journ. de Phys. xxxvii. 158.

695 Titanium.

26. Nitrat of titanium. It is capable of crystallizing.

696 Tellurium.

27. Nitrat of tellurium. The solution of tellurium in nitric acid is transparent and colourless. When concentrated, it produces in time small white light crystals in the form of needles, which exhibit a dendritic aggregation ‡.

‡ Klaproth, Phil. Mag. i. 80.

Sect. IV. *Of Nitrites.*

The salts which the nitrous acid forms with alkalies, earths, and metallic oxyds, are denominated *nitrites*. Very few of them have been examined; we shall not therefore attempt a description of them.

Sect. V. *Of Muriats.*

Salts into which the muriatic acid enters are called *muriats*.

697 Muriat of potass.

1. Muriat of potass. This salt was formerly called *febrifuge* or *digestive salt of Sylvius*, and *regenerated sea salt*.

Its crystals are cubes, but rather irregular.

It has a disagreeable bitter taste. Its specific gravity is 1,836 §.

§ Kirwan.

It is soluble in three times its weight of water at the temperature of 60°, and in double its weight of boiling water ¶.

¶ Bergman.

It is composed, according to Bergman, of 31 parts of acid, 61 of potass, and 8 of water. Kirwan has found it to contain 36 of acid, 46 of alkali, and 18 of water ||.

|| Kirwan's Mineral. ii. 30.

It suffers little alteration from exposure to the air.

When exposed to heat, it first decrepitates, then melts, and at last is volatilized, but without decomposition.

The following salts decompose it by compound affinity:

Sulphat of soda,	Nitrat of ammonia,
——— ammonia,	——— magnesia,
——— alumina,	——— alumina,
Nitrat of soda,	——— lead.
——— lime,	

698 Muriat of soda.

2. Muriat of soda, common or sea salt. This salt has been known, and in common use, from the earliest ages. It is sometimes called also *sal gem*.

Its crystals are cubes, but they often assume other forms. Its specific gravity is 2,120.*

* Kirwan.

Its taste is universally known, and is what is strictly speaking denominated *salt*.

It is soluble in $2\frac{1}{7}$ times its weight of water at the temperature of 60°, and in $2\frac{1}{7}$ its weight of boiling water †.

† Bergman.

According to Bergman, it is composed of 52 parts of acid, 42 of alkali, and 6 of water. According to the late experiments of Mr Kirwan, of 40 parts of acid, 35 of alkali, and 25 of water.

It is not affected by exposure to the air. It ought to be observed, however, that the muriat of soda in common use contains, besides other impurities, a quantity of muriat of magnesia, which renders it deliquescent.

When heated it decrepitates. Heat volatilizes, but does not decompose it.

The following salts decompose it by compound affinity:

Sulphat of ammonia,	Nitrat of silver §,
——— alumina,	Acetite of barytes,
——— potass,*	Pyrolignite of barytes ‖,
——— iron †,	——— lead ‖,
Nitrat of ammonia,	Carbonat of potass (*a*),
——— magnesia,	Alum (*b*),
——— alumina,	Red oxyd of lead (*c*).
——— lead ‡,	

* Fuchs, Ann. de Chim. vi. 29.
† Bullen, ibid. xi. 320.
‡ Morveau.
§ Bergman.
‖ Morveau. Ann. de Chim. xix. 109.
(*a*) Bergman
(*b*) Crell, Ann. de Chim. xxvi. 297.
(*c*) Scheele.

699 How decomposed by red oxyd of lead.

That the red oxyd of lead decomposes this salt is a well known fact, and it has been considered as contrary to the laws of affinity. Mr Hassenfratz endeavoured to account for it by supposing that the oxyd is combined with carbonic acid, and that therefore it is a case of compound affinity. Mr Curaudau has proved that carbonic acid, instead of promoting, impedes the decomposition; and that, in fact, carbonat of lead is incapable of decomposing muriat of soda. He concludes, therefore, that the phenomenon cannot be accounted for by the commonly received laws of affinity.* We cannot, however, think, that the phenomenon is so unaccountable as Mr Curaudau supposes; for muriatic acid is capable of decomposing the red oxyd of lead, of combining with part of its oxygen, and of being converted into oxy-muriatic acid. Now if oxy-muriatic and nitro-muriatic acids be merely the same substance in a different form, as there is the strongest reason for supposing, the white oxyd of lead has a stronger affinity for it than soda has, and ought therefore to decompose it.

* Ann. de Chim. xiv. 15.

700 Muriat of ammonia.

3. Muriat of ammonia, or sal ammoniac. This salt was known to the ancients, and was called by them *sal ammoniac*, because it was found in great quantities near the temple of Jupiter Ammon in Africa.*

* Pliny, lib. xxxi. c. 7. See Sal Ammoniac, Encyc.

It assumes the form of plumose crystals. The individual crystals are long hexahedral pyramids. Its specific gravity is 1,420 †.

† Kirwan.

It has an acrid, poignant, urinous taste.

It dissolves in about three times its weight of water at the temperature of 60°, and in a much smaller quantity of boiling water.

It is composed, according to Kirwan, of 35 parts of acid, 30 of alkali, and 45 of water ‡.

‡ Kirwan's Mineral. ii. 34.

In its common form (which is an opaque mass) it is not affected by the air, but its crystals are liable to deliquesce.

Heat

Heat volatilizes without decompoſing it.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,	Acetite of magneſia,
Nitrat of ſoda,	——— alumina,
——— lead,	——— lead,
Acetite of barytes,	Carbonat of barytes,
——— potaſs,	——— potaſs,
——— ſoda,	——— magneſia (y)
——— lime,	

When this ſalt is ſublimed with gold leaf, there is found in the neck of the retort an amethyſt coloured matter, bordering on purple, ſoluble in water, and forming a purple ſolution. When filtered there remains behind a purple powder. This ſalt ſeems from this to be capable of oxydating gold.*

* *Storr, Crell's New Diſcoveries*, &c. Part ii. p. 41.

701 Muriat of barytes,

4. Muriat of barytes. This ſalt was firſt deſcribed by Bergman, but it has been moſt particularly attended to by Dr Crawford.

It affords oblong ſquare cryſtals.

It has an unpleaſant aſtringent taſte.

It is not very ſoluble in water. It is ſoluble in alcohol.

It is not altered by expoſure to the air, nor does heat in all probability decompoſe it.

Dr Crawford wrote a treatiſe on it in 1790, in which he recommended its uſe internally for ſcrofulous complaints. Care ought to be taken not to give it in too large quantities, as, like the other compounds of barytes, it is poiſonous.

The following ſalts decompoſe it by compound affinity (z):

Sulphat of ſoda,	Nitrat of lime,
——— ammonia,	——— ammonia,
——— magneſia,	——— magneſia,
——— alumina,	——— alumina,
Nitrat of ſoda,	Phoſphat of lime.*

* *Dr Pearſon.*

702 Muriat of ammonia and barytes,

5. Muriat of ammonia and barytes. This triple ſalt was firſt diſcovered by Fourcroy. It may be formed by pouring a carbonat of ammonia into a ſolution of muriat of barytes. It is eaſily decompoſed by heat, but none of the alkalies nor their carbonats are capable of altering it †.

† *Ann. de Chim.* iv. 8.

703 Muriat of lime,

6. Muriat of lime. This ſalt was formerly called *fixed ammoniac*, becauſe it was commonly obtained by decompoſing ſal ammoniac by means of lime.

Its cryſtals are four-ſided ſtriated priſms, terminated by a very ſharp pyramid; but it is not eaſily cryſtallized.

Its taſte is very bitter.

It is ſoluble in about $1\frac{1}{2}$ parts of cold water, and in leſs than its own weight of boiling water. Alcohol diſſolves its own weight of it.

According to Bergman, it is compoſed of 31 parts of acid, 44 of lime, and 25 of water. According to Kirwan, 100 parts of lime require for ſaturation 86 parts of muriatic acid.

It very ſpeedily deliqueſces when expoſed to the air. By heat it melts into a very hard vitreform ſubſtance.

The following ſalts decompoſe it by compound affinity:

Sulphat of ſoda,	Carbonat of potaſs,
——— ammonia,	——— ſoda,
——— magneſia,	——— ammonia,*
——— alumina,	——— barytes,
Nitrat of ſoda,	——— magneſia,
——— ammonia,	——— alumina,
——— magneſia,	Acetite of barytes,
——— alumina,	——— potaſs,
	——— ſoda.

* *Bergman.*

704 Muriat of ſtrontites,

7. Muriat of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are very long, ſlender, hexagonal priſms. It has a peculiar, ſharp, penetrating taſte.

Three parts of theſe cryſtals are ſoluble in two parts of water at the temperature of 60°. Boiling water diſſolves any quantity of them whatever.

They contain 42 *per cent.* of water of cryſtallization.

They ſuffer no change when expoſed to the air except it be very moiſt; in which caſe they deliqueſce.

When heated, they firſt undergo the watery fuſion, and are then reduced to a white powder. A very violent heat decompoſes this ſalt.

Muriatic acid precipitates this ſalt from its ſolution in water. That acid, therefore, has a ſtronger affinity for water than the ſalt has.*

* *Hope, Tranſ. Edin.* iv. 12.

705 Muriat of magneſia,

8. Muriat of magneſia. This ſalt abounds in ſea water.

It is not eaſily cryſtallized. Bergman's method was to evaporate it by a conſiderable heat to the proper degree of concentration, and then to expoſe it to a ſudden cold. By this method he obtained it in ſmall needles †.

It has a very bitter taſte. It is ſoluble in its own weight of water ‡, and in five parts of alcohol §.

A ſaturated ſolution of it quickly forms a jelly; on which if hot water be poured, ſpongy maſſes are formed not even ſoluble in muriatic acid.*

It is compoſed, according to Bergman, of 34 parts of acid, 41 of earth, and 25 of water. According to Kirwan, 100 parts of magneſia require for ſaturation 104,275 of acid †.

It deliqueſces very ſpeedily when expoſed to the air.

A ſtrong heat decompoſes it. When dried in a high temperature, it is very cauſtic ‡.

† *Bergman*, ii. 383.
‡ *Fourcroy.*
§ *Bergman*, ii. 383.
* *Bergman, ibid.*
† *Iriſh Tranſ.* iv.
‡ *Weſtrum, Ann. de Chim.* ii. 135.

The following ſubſtances decompoſe it by compound affinity:

Sulphat of ſoda,	Acetite of potaſs,
——— ammonia,	——— ſoda,
——— alumina,	——— ſilver,*
Nitrat of ammonia,	

* *Bergman.*

Carbonat

(y) Only at the common temperature. At a high temperature carbonat of ammonia decompoſes muriat of magneſia. See *Weſtrum, Ann. de Chim.* ii. 118.

(z) Bergman affirmed, that this ſalt decompoſed all the ſulphats, and propoſed it therefore as a certain means of diſcovering the preſence of ſulphuric acid, however combined in any ſolution; for the ſulphat of barytes is almoſt entirely inſoluble in water. But Mr Piſſis has obſerved, that it does not decompoſe ſulphat of lime nor of potaſs. See *Ann de Chim.* xv. 317.

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Carbonat of barytes,	Carbonat of soda,
———— potass,	———— ammonia (Y)

706 Muriat of ammonia and magnesia,

9. Muriat of ammonia and magnesia. This triple salt was first mentioned, we believe, by Bergman. It may be formed by pouring ammonia into a solution of muriat of magnesia. Part of the magnesia is precipitated, but great part of it remains dissolved, and combined with the acid and the ammonia. This triple salt is composed according to Fourcroy, of 73 parts of muriat of magnesia and 27 of muriat of ammonia†.

† Ann. de Chim. iv. 222.

707 Muriat of alumina,

10. Muriat of alumina. This salt crystallizes with difficulty. It has an astringent taste. Its solution is gelatinous, and cannot be filtrated without much dilution in water. It is deliquescent. When evaporated to dryness, it forms a gummy mass: in a strong heat it is decomposed.

The following salts decompose it by compound affinity:

Nitrat of ammonia,	Acetite of magnesia,
Acetite of barytes,	Carbonat of barytes,
———— potass,	———— potass,
———— soda,	———— soda,
———— lime,	———— ammonia.

708 Muriat of jargonia,

11. Muriat of jargonia.—This salt is easily formed by pouring muriatic acid on newly precipitated jargonia. It is colourless; its taste is very astringent: by evaporation it furnishes small transparent crystals in needles, which lose their transparence in the air. Muriat of jargonia is very soluble in water and in alcohol; to the flame of which it does not communicate any particular colour. Heat decomposes it; and it is decomposed likewise by the saliva when taken into the mouth.

When muriat of jargonia contains a little silica, it forms cubic crystals without consistence, and resembling a jelly. These crystals, when exposed to the air, gradually lose their transparency, and diminish in volume, and there are formed in the middle of the salt white silky needle-shaped crystals.

Muriat of jargonia is decomposed by sulphuric acid; part of the sulphat precipitates, and part remains dissolved in the muriatic acid. When this acid is driven off by heat, the remainder of the sulphat is gradually deposited: if the evaporation be stopped before the mass be reduced to dryness, it forms a kind of jelly when cold. It is also decomposed by the phosphoric, citric, tartarous, oxalic and saccholactic acids, which form with jargonia insoluble compounds that precipitate in white flakes.

The gallic acid poured into muriat of jargonia produces a white precipitate; but a green, bordering on grey, if the jargonia contain iron; and this last precipitate becomes, when dry, of a bright black colour, and resembles China ink. The liquid preserves a greenish colour; new portions of gallic acid produce no farther precipitation; but carbonat of ammonia separates in great abundance a flaky matter of a purplish colour, not unlike that of the leys of wine. From these experiments it follows, that gallic acid has a greater affinity for jargonia than muriatic acid has; and that the gallats of jargonia and iron are soluble in muriatic acid.

Carbonat of potass decomposes muriat of jargonia, and part of the carbonic acid combines with the earth, and renders it easily soluble in acids though dried.

Carbonat of ammonia occasions a precipitate, which is mostly dissolved by adding more carbonat.

Prussiat of mercury produces an abundant precipitate, which is soluble in muriatic acid; and which consequently is not muriat of mercury.

A plate of zinc, introduced into a solution of muriat of jargonia, occasions a slight effervescence; the liquor becomes milky, and in a few days becomes a white semitransparent jelly.

Alumina decomposes muriat of jargonia with the assistance of a slight heat: the alumina dissolves, the liquor becomes milky, and assumes the form of a jelly. When the muriat contains iron, it remains in the solution, and the precipitated jargonia is quite pure. Here, then, is a method of freeing jargonia from iron.*

* Vauquelin, Ann. de Chim. xxii. 201.

709 Muriat of iron,

12. Muriat of iron.—Muriatic acid forms with the green oxyd of iron a salt which crystallizes in flat needles. When exposed to the air, they deliquesce, and the green oxyd attracts oxygen, and is gradually converted into a brown oxyd. Heat decomposes this salt.

710 Muriat of zinc,

13. Muriat of zinc. This salt, procured by dissolving zinc or its oxyd in muriatic acid, does not crystallize. Its solution is colourless. When heated, it becomes of a blackish brown. By distillation, a part of the acid is separated, and muriat of zinc remains behind of a milk white colour, solid, and formed of small radiated needles. It attracts moisture in the air.

711 Muriat of manganese,

14. Muriat of manganese. Muriatic acid dissolves the white oxyd of manganese. Its solution affords by evaporation angular shining crystals†: They are deliquescent and soluble in alcohol‡.

† Scheele on Manganese.
‡ Kirwan's Mineral. ii. 37.

712 Cobalt,

15. Muriat of cobalt. The solution of oxyd of cobalt in muriatic acid is of a pale red, except it be contaminated with nickel or iron, when it is greenish. It crystallizes in small needles, which are very deliquescent. Heat decomposes it.

713 Nickel,

16. Muriat of nickel. This salt is deliquescent, and loses its acid when exposed to the air¶.

¶ Bergman, ii. 268.

714 Lead,

17. Muriat of lead. Muriatic acid combines with oxyd of lead easily enough: but this salt is more readily procured by pouring muriatic acid into a solution of nitrat of lead; the muriat immediately precipitates in the form of a white powder. It is soluble in 30 times its weight of boiling water; and the solution yields by evaporation small, slender, brilliant needles in bundles.

It is somewhat deliquescent. When exposed to heat, it melts into a brown mass, formerly called *corneous lead*.

It is decomposed by compound affinity by

Sulphat of silver*,
Carbonat of soda.

* Bergman.

715 Tin,

18. Muriat of tin. This salt may be formed by dissolving tin in hot muriatic acid. By evaporation, it affords needle-shaped crystals, which are deliquescent.

This salt has a strong affinity for oxygen. It decomposes oxy-muriatic, nitric, sulphurous, arsenic, molybdic and tungstic acids, the red oxyd of mercury, black oxyd of manganese, oxyd of antimony, zinc, sil-

(Y) Only at a high temperature. See *Muriat of Ammonia*.

Muriats.

ver, and gold; and by that means is converted into oxy-muriat of tin. It even abforbs oxygen when expofed to the air*. Thefe compofitions are doubtlefs produced by *difpofing affinity*.

* *Pelletier, Ann. de Chim.* xii. 225.

716 Muriat of copper,

19. Muriat of copper. This falt may be formed by diffolving copper or its oxyd in muriatic acid.

Its cryftals are prifmatic. It is of a beautiful grafs green colour. It has a very aftringent and cauftic tafte. It deliquefces when expofed to the air. A moderate heat is fufficient to melt it; and when cooled it congeals into a mafs. It requires a ftrong heat to volatilize it. It is decompofed by nitrat of filver†.

† *Bergman.*

717 Muriat of bifmuth,

20. Muriat of bifmuth. This falt cryftallizes with difficulty. By fublimation it forms a foft fufible fubftance, formerly called *butter of bifmuth*.

718 Antimony,

21. Muriat of antimony. This falt is found native. It cryftallizes in prifms. When heated, it evaporates.

719 Arfenic,

22. Muriat of arfenic. This falt cryftallizes; it is very volatile, and not very foluble, in water‡.

‡ *Bergman,* ii. 293.

720 Mercury,

23. Muriat of mercury. This falt may be prepared by pouring diluted muriatic acid into a diluted folution of nitrat of mercury: the muriat of mercury is immediately precipitated in the form of a white powder. Common falt may be ufed inftead of muriatic acid. This falt was formerly called *white mercurial precipitate* and *calomel*.

It cryftallizes; but the form of the cryftals, which are very fmall, has not been determined.

It has little tafte. It is almoft infoluble in water. It is ufed as a medicine.

It is decompofed by fulphat of ammonia.*

* *Bergman.*

721 Muriat of ammonia and mercury,

24. Muriat of ammonia and mercury. This triple falt was firft difcovered by Fourcroy. It may be formed by pouring ammonia into a folution of corrofive muriat of mercury. It has the appearance of a white powder. Its tafte is at firft earthy, afterwards metallic. It is nearly infoluble in water. According to Fourcroy's analyfis, it is compofed of 81 parts of oxyd of mercury, 16 of muriatic acid, and 3 of ammonia.

Heat decompofes it; producing ammonia, azotic gas, and muriat of mercury.

Sulphuric, nitric, and muriatic acids decompofe it†.

† *Fourcroy, Ann. de Chim.* xiv. 47.

722 Muriat of filver,

25. Muriat of filver. This falt may be formed by diffolving oxyd of filver in muriatic acid, or, which is better, by pouring muriatic acid into nitrat of filver; muriat of filver immediately precipitates. It is very little foluble in water; according to Monnet, one part of it requires 3072 parts of water.

When expofed to a fmall heat, it melts into a grey femitranfparent mafs, not unlike horn; hence it was formerly called *luna cornea*. A long continued heat decompofes it. This falt is very cauftic: it is employed as an efcharotic under the name of *lunar cauftic*.

723 Muriat of titanium.

26. Muriat of titanium has been formed by Mr Klaproth.

Sect. VI. *Of Oxy-muriats.*

Those falts, into which the oxy-muriatic acid enters as an ingredient, are called *oxy-muriats*. As we confider the nitro-muriatic acid to be precifely the fame with the oxy-muriatic, its combinations of courfe muft receive the fame name.

Oxy-muriats.

724 Oxy-muriat of potafs,

1. Oxy-muriat of potafs. This fingular falt was difcovered by Mr Berthollet in 1786. It may be formed by faturating a folution of potafs with oxy-muriatic acid gas. By evaporating this folution in the dark, common muriat of potafs is firft obtained: When it is feparated, and the liquor allowed to cool, oxy-muriat of potafs cryftallizes.

Its cryftals are rhomboids, of a filvery brilliancy.

It has an infipid cooling tafte, refembling that of nitre. It is foluble in 17 parts of water at the temperature of 60, and in $2\frac{1}{2}$ parts of boiling water ¶. It does not deliquefce in the air; but light converts it into common muriat by feparating oxygen. When heated, it melts, and gives out oxygen gas; and this is the beft method hitherto difcovered of obtaining that gas in a ftate of purity. According to Mr Hoyle, it contains about half its weight of concrete oxygen.*

¶ *Hoyle, Nicholfon's Journal,* ii. 292.

* *Ibid.*

When mixed with charcoal, iron, and many other combuftibles, and heated, it detonates with aftonifhing violence. This property induced the French chemifts to propofe it as a fubftitute for nitre in the preparation of gunpowder. The attempt was made at Effons in 1788; but no fooner had the workmen begun to triturate the mixture of charcoal, fulphur and oxy-muriat, than it exploded with violence, and proved fatal to Mr Letors and Mademoifelle Chevraud. The force of this gunpowder when it is prepared is much greater than that of the common fort of powder; but the danger of preparing it, and even of ufing it after it is prepared, is fo great, that it can hardly ever be fubftituted with advantage for common gunpowder.

Fourcroy and Vauquelin afcertained by experiment, that this falt exploded when triturated with fulphur, charcoal, antimony, arfenic, cinnabar, fugar, gums, oils, alcohol, ether, and fulphuret of iron. When thefe fubftances were mixed, and ftruck with a hammer, the explofion took place. The theory of thefe explofions was firft pointed out by Mr Berthollet. The oxygen of the oxy-muriatic acid combines with the combuftible, and at the fame time lets go a quantity of caloric; and trituration or percuffion acts merely by bringing the particles which combine within the fphere of each others attraction.

725 Oxy-muriat of foda,

2. Oxy-muriat of foda. This falt was difcovered at the fame time by Mr Berthollet. Its properties are the fame with the laft, except that it is too deliquefcent to be ufed.

3. Oxy-muriat of ammonia. This combination is impoffible. The oxy-muriatic acid and ammonia decompofe each other.

726 Oxy-muriat of barytes, lime, magnefia,

4. Oxy-muriat of barytes.
5. ———— lime.
6. ———— magnefia.

These falts were difcovered by Berthollet alfo. They all poffefs the property of detonating with combuftibles, and of being reduced by that means to the ftate of common muriats. Mr Tennant has lately propofed the oxy-muriat of lime as a fubftitute for the other fubftances formerly ufed in the new mode of bleaching; particularly for bleaching printed cottons: And, as far as we can learn, it anfwers the purpofe remarkably well (z).

727 Oxy-muriat of mercury,

7. Oxy-muriat of mercury. This falt was formerly called *corrofive fublimate*, and afterwards *corrofive muriat of*

(z) We have been informed, that this falt had been ufed by bleachers in Scotland fome years before Mr Tennant propofed it.

Oxy-muriats. *of mercury*. Berthollet first pointed out the nature of its composition.

This salt was mentioned by Rhases in the 10th century. And it seems to have been known in the east at a much earlier period(A). The methods of preparing it used by the older chemists, were numerous, complicated, and generally concealed as secrets. We shall not attempt, therefore, to give any account of them; and the methods used by later chemists have been described at considerable length in the article CHEMISTRY (*Encycl.* n° 815).

It may be prepared by dissolving mercury in a sufficient quantity of oxy-muriatic acid, or by dissolving red oxyd of mercury in common muriatic acid.

When carefully crystallized, this salt assumes the form of cubes or oblique parallelopipeds, or rather quadrangular prisms, with sides alternately narrower and terminated by two inclined planes meeting together.

It has an exceedingly disagreeable metallic taste.

It is soluble in 19 times its weight of water at the temperature of 50°‡. Boiling water, according to Macquer, dissolves half its weight of it. Alcohol, at the temperature of 70°, dissolves $\frac{3}{8}$ths of its weight of this salt.*

‡ Spielman.

* Macquer.

It does not attract moisture from the air.

It is soluble in sulphuric, nitric and muriatic acids.

When triturated with $\frac{3}{4}$ths of its weight of mercury and a little water, and then sublimed, it forms a white insipid salt, called formerly *calomel* or *sweet mercury*: This, as Scheele has proved, is precisely the same with common muriat of mercury.

The theory of these two preparations is now pretty obvious. The experiments of Adet and Pelletier have shewn that oxy-muriatic acid may be obtained from corrosive muriat of mercury¶. We may conclude, therefore, with confidence, that the salt is an oxy-muriat. It cannot be prepared by means of common muriatic acid, except with red oxyd of mercury, or some other substance from which it may absorb oxygen. When pure mercury is added to oxy-muriat, it seizes the oxygen from the oxy-muriat, and the whole is converted into common muriat.

¶ *Ann. de Chim.* i. 1. and xii. 225.

It is decomposed by

Tartar,

Most metals.

728 Oxy-muriat of tin,

8. Oxy-muriat of tin. When an amalgam of tin is triturated with its own weight of corrosive muriat of mercury, and the mixture is distilled in a glass retort by means of a very gentle heat, there passes over a thick white smoke, which condenses into a colourless liquor that emits copious fumes, and has been called, in consequence, *smoking liquor of Libavius*. This liquor was examined by Mr Adet. He found, that when about $\frac{1}{3}$d part of water was added to this liquor, it ceased to fume, and assumed a crystalline form; that then it might be even made red hot without subliming. It therefore owes its volatility to want of water, or rather to a strong attraction for water. He found that this substance was capable of dissolving, and therefore of oxydating more tin, without the emission of any hydrogen, and consequently without the decomposition of water; he concluded from this, that it was composed of oxy-muriatic acid and tin§. This has been completely proved by Mr Pelletier, who found, that when oxyd of tin was combined with oxy-muriatic acid, it formed a compound precisely the same with the smoking liquor of Libavius*.

§ *Ann. de Chim.* i. 3.

* *Ann. de Chim.* xii. 225.

This salt may be prepared, as Pelletier has proved, by dissolving tin in muriatic acid, and then saturating it with oxy-muriatic acid gas.

It is used in dyeing.

729 Oxy-muriat of iron.

9. Oxy-muriat of iron. This salt is deliquescent; colourless; of a pure bitter taste, without any of the sweet astringency of the common salts of iron‖.

‖ *Lambe, Manchester Mem.* v. p. 1.

Few of the other oxy-muriats have been hitherto examined with attention. Many of the metals, indeed, have been dissolved in aqua-regia; but in most of these solutions the salt produced is a common muriat. The nitric acid supplies oxygen, and the muriatic acid dissolves the oxyd.

SECT. VII. *Of Phosphats.*

THOSE salts, into which phosphoric acid enters as an ingredient, are called *phosphats*. This class of salts was first discovered by Margraf.

730 Phosphat of potass,

1. Phosphat of potass. This salt crystallizes in short tetrahædral prisms, terminated by quadrangular pyramids.

It is very soluble in cold water, and still more so in hot water.

It decrepitates on ignited coals like common salt. When a very strong heat is applied, it melts into an opaque vitreous mass, still soluble in water.

The following salts decompose it by compound affinity:

Sulphat of lime,	Muriat of mercury,
Nitrat of mercury,	Acetite of lead.

731 Phosphat of soda,

2. Phosphat of soda.—Dr Pearson, who first formed this salt, gives the following process for preparing it:

Dissolve in a long-necked matrass 1400 grains of crystallized carbonat of soda in 2100 grains of water at the temperature of 150°. Add gradually 500 grains of phosphoric acid of the specific gravity 1,85. Boil the liquor for some minutes; and while it is boiling hot, filtrate it and pour it into a shallow vessel. Let it remain in a cool place, and crystals will continue to form for several days. From the above quantities of materials, he has obtained from 1450 to 1550 grains of crystals.

Its crystals are rhomboidal prisms, of which the acute angles are 60°, and the obtuse angles 120°, terminated by a three-sided pyramid.

Its taste is almost the same with that of common salt.

It is soluble in water. When exposed to the air it effloresces.

This salt has been introduced into medicine as a purgative, and on account of its pleasant taste has of late been much used. It is usually taken in broth, which it is employed to season instead of common salt.

Hellot remarked a particular salt in urine, different from those that had usually been observed, in 1737. Haupt described it in 1740 under the name of *sal mirabile*

(A) If we listen to Juncker, the ancients applied the name *mercurium* to this salt; mercury they called *argentum vivum*.

rabile perlatum, or *wonderful perlated salt*. It was called *perlated* from the grey, opaque, pearl-like colour which it assumed when melted by the blow-pipe. Margraff described it in 1745, and found it would not yield phosphorus when treated with charcoal, as the other salts of urine did. Rouelle the Younger analysed it in 1776, and concluded from his experiments that it was a compound of phosphoric acid and soda; but Mr Proust, being unable to obtain phosphorus from it, concluded that it did not contain phosphoric acid, but another acid analogous to the boracic. To this substance, which Mr Proust actually obtained, Bergman gave the name of *perlated acid*, and Morveau afterwards called it *ouretic acid*. But Mr Klaproth soon afterwards analysed it, and proved that it consisted of soda supersaturated with phosphoric acid. Scheele soon after made the same discovery. This acid of Mr Proust, then, is merely phosphat of soda, combined with phosphoric acid or *acidulous phosphat of soda*.

732 Phosphat of ammonia, 3. Phosphat of ammonia.—This salt forms oblong-pointed crystals, or, as Mr Lavoisier affirms, crystals resembling those of alum.

It is soluble in water. Heat evaporates it so easily, that it is difficult to obtain it in crystals, except by adding an excess of alkali.

Microcosmic salt, or salt of urine, is merely a mixture of these two last described salts.

733 Of barytes, 4. Phosphat of barytes.—This salt is insoluble in water†.

† Morveau.

734 Of lime, 5. Phosphat of lime.—This salt is tasteless, and almost perfectly insoluble in water. It forms the basis of bones, and is therefore often called *earth of bones*. Wenzel observed it crystallize when held in solution by phosphoric acid.

* Delkeskamp Ann. de Chim. vi. 37.

It is decomposed by sulphat of ammonia*.

Carbonat of potass†,
———— soda‡.

† Bergman.
‡ Id.

735 Of strontites, 6. Phosphat of strontites.—This salt was first formed by Dr Hope. It is a white powder, soluble in 1920 parts of boiling water*.

* Hope, Transf. Edin. iv. 16.

736 Of magnesia, 7. Phosphat of magnesia.—This salt does not crystallize except with excess of acid, and then the crystals are very small. Somewhat longer crystals may be formed by dropping phosphoric acid into acetite of magnesia. It most commonly forms by evaporation a gummy mass. It is soluble in alcohol†.

It is insoluble in nitric acid. It melts by a strong heat into a porcelain-like substance*.

† Bergman, ii. 390.
* Wenzel.

737 Of alumina, 8. Phosphat of alumina.—This is a saline powder, insoluble in water. Dissolved in phosphoric acid, it yields a gritty powder, and a gummy solution, which by heat is converted into a transparent glass.

738 Of iron, 9. Phosphat of iron.—This salt is merely a dry adhesive mass, insoluble in water, but soluble in acids. With excess of acid it forms crystals which do not deliquesce, and by heat are converted into a garnet coloured glass¶.

¶ Id.

739 Of zinc, 10. Phosphat of zinc.—It does not crystallize, but when evaporated becomes a gummy mass, which may be melted into a transparent glass‡.

‡ Id.

740 Of manganese, 11. Phosphat of manganese.—The solution of the oxyd of manganese in phosphoric acid is reddish, but becomes white on exposure to the air.

741 Of nickel, 12. Phosphat of nickel.—It is greenish, and does not crystallize*.

* Bergman, ii. 268.

742 Of arsenic, 13. Phosphat of arsenic.—It crystallizes in small grains, hardly soluble in water†.

† Bergman, ii. 296.

743 Of uranium, 14. Phosphat of uranium.—First formed by Klaproth. It does not crystallize, but assumes the appearance of yellowish white flakes, difficultly soluble in water.

744 James's powder. 15. Phosphat of antimony and lime.—Dr Pearson has discovered that the well known medicine called *James's powder*, is a triple salt, composed of phosphoric acid, oxyd of antimony, and lime. It is very insoluble in water.

The remaining phosphats are scarcely known.

Sect. VIII. *Of Borats.*

The compounds into which the boracic acid enters are called *borats*.

745 Borat of potass, 1. Borat of potass.—This salt, formed by combining boracic acid and potass, is very little known. Baron first formed it. Borat of potass crystallizes, is soluble in water, and may be melted into a vitreous mass, soluble in water.

746 Of soda, 2. Borat of soda or borax.—This salt is brought from the East Indies in an impure state under the name of *tinkal*. When purified in Europe, it takes the name of *borax*.

Its crystals are hexangular prisms, of which two sides are much broader than the remainder, terminated by triangular pyramids. It is of a white colour. Its specific gravity is 1,740.

Its taste is styptic and alkaline.

It is soluble in 18 times its weight of water of the temperature of 60°, and 6 times its weight of boiling water.

It is composed, according to Bergman, of 17 parts of soda, 39 of acid, and 44 of water.

When exposed to the air, it effloresces slowly and slightly.

When heated it swells, loses about four-tenths of its weight, becomes ropy, and then assumes the form of a light, porous, and very friable mass, known by the name of *calcined borax*; it then melts into a transparent glass, still soluble in water.

By compound affinity it is decomposed by

Nitrat of mercury*.

* Bergman.

When two pieces of borax are struck together in the dark, a flash of light is emitted†.

† Accum, Nicholson's Journal, ii. 28.

Borax has the property of facilitating the fusion of a great number of bodies. This property renders it useful in glass making, in assaying ores, and in soldering metals.

Borax turns syrup of violets green; it appears therefore to be supersaturated with alkali.

The real borat of soda, or the salt in which boracic acid and soda saturate each other has not yet been examined with attention. According to Dr Withering, soda requires twice its weight of boracic acid to saturate it.

747 Of ammonia, 3. Borat of ammonia.—This salt has been examined only by Mr Fourcroy.

Its crystals are polyhedral pyramids.

It has a poignant urinous taste, and turns syrup of violets green. It dissolves readily enough in water. When exposed to the air it gradually loses its crystalline form, and becomes brown‡.

‡ Fourcroy's Chemistry, Part ii. ch. 4.

4. Borat

4. Borat of barytes.—Unknown.

748 Of lime, 5. Borat of lime.—It is difficultly soluble in water, and did not cryſtallize with Beaumé.

749 Of ſtrontites, 6. Borat of ſtrontites.—This ſalt was firſt formed by Dr Hope.—It is a white powder, ſoluble in about 130 parts of boiling water. The ſolution turns the ſyrup of violets green*.

* Hope, Tranſ. Edin. iv. 17.

750 Of magneſia, 7. Borat of magneſia.—It aſſumes the appearance of ſmall irregular cryſtals. It is ſoluble in acetous and formic acids. Alcohol decompoſes it. It melts eaſily in the fire without being decompoſed‡.

‡ Bergman, ii. 386.

751 Of alumina, 8. Borat of alumina.—It does not cryſtallize, and is ſcarcely ſoluble in water.

752 Of iron, 9. Borat of iron.—Its cryſtals are of a yellow colour, but the ſalt has never been examined with attention.

753 Of zinc, 10. Borat of zinc.—This ſalt does not appear to be capable of cryſtallizing.—By heat, it melts into a light green inſoluble ſlag¶.

¶ Reuſs.

754 Cobalt, 11. Borat of cobalt.—When oxyd of cobalt is melted with boracic acid, a bluiſh grey ſlag is produced. This, by lixiviation and evaporation, yields cryſtals of a reddiſh white colour and ramified form§.

§ Id.

755 Nickel, 12. Borat of nickel.—A ſaline ſubſtance difficultly ſoluble*.

* Bergman.

756 Lead, 13. Borat of lead.—When boracic acid and red oxyd of lead are melted together, the product is a fine greeniſh yellow, tranſparent, hard, inſoluble glaſs‡.

‡ Reuſs.

757 Tin, 14. Borat of tin.—When equal parts of boracic acid and tin filings are melted together, the product diſſolved in water yields by evaporation tranſparent white polygonous cryſtals.

758 Copper, 15. Borat of copper.—When borax is poured into a ſolution of ſulphat of copper, borat of copper is precipitated in the form of a pale light green jelly, which when dried is with great difficulty ſoluble in water. It eaſily melts into a dark red vitreous ſubſtance*. According to Palm, by long trituration of filings of copper and boracic acid in water, and then digeſting the mixture, it diſſolves, and cryſtals may be obtained from it.

* Bergman.

759 Biſmuth, 16. Borat of biſmuth.—A white powder, which melts into a white tranſparent permanent glaſs†.

† Wenzel.

760 Arſenic. 17. Borat of arſenic.—White oxyd of arſenic and boracic acid form a ſalt ſoluble in water and cryſtallizable*.

* Reuſs.

Sect. IX. *Of Fluats.*

Those ſalts into which fluoric acid enters are called *fluats*. They were firſt formed by Scheele.

761 Fluat of potaſs, 1. Fluat of potaſs. It forms a gelatinous maſs almoſt without taſte.

It diſſolves readily in water. When expoſed to the fire it melts without any ebullition‡.

‡ Scheele on Fluor.

762 Soda, 2. Fluat of ſoda. This ſalt reſembles exactly the fluat of potaſs†.

† Ibid.

763 Ammonia, 3. Fluat of ammonia. It cryſtallizes in ſmall priſms. It is deliqueſcent, and is partly decompoſed by heat*. It is decompoſed by

* Wiegleb.

Nitrat of mercury,
——— ſilver,
——— lead.

764 Barytes, 4. Fluat of barytes. A powder which requires a large quantity of water to diſſolve it*.

* Bergman.

765 Lime, 5. Fluat of lime. This ſalt abounds in nature. It is known by the name of fluor ſpar.

It cryſtallizes moſt commonly in the form of cubes. It is taſteleſs and nearly inſoluble in water.

It is not altered by the air. Its ſpecific gravity is about 3,1.

When expoſed to a ſudden heat it decrepitates. A very violent heat melts it into a white opaque maſs.

When reduced to powder and heated it becomes phoſphoreſcent; but it loſes this quality altogether if it be heated red hot.

6. Fluat of ſtrontites. This ſalt was formed by Dr Hope: but its properties have not been examined.

7. Fluat of magneſia. It is not ſoluble in water except there be an exceſs of acid. In that caſe, by ſpontaneous evaporation, it forms hexagonal priſms, terminated by a low pyramid compoſed of three rhomboidal ſides. 766 Magneſia,

Theſe cryſtals are hardly ſoluble in water. Alcohol diſſolves a ſmall portion of them. Heat does not decompoſe them†.

† Bergman, ii. 384.

8. Fluat of alumina. A ſaline maſs; which is ſweetiſh, clammy, and gelatinous. 767 Alumina,

9. Fluat of ſilica. Little is known concerning this ſingular combination, except that it can exiſt in a gaſeous form, and that it depoſites ſilica in cryſtals after a certain time. 768 Silica.

10. Fluat of ſilica and potaſs or ſoda. This triple ſalt may be formed by pouring fixed alkali into a ſolution of fluat of ſilica. It contains an exceſs of acid. On evaporation it yields a kind of jelly, which when dry ſeparates into gritty particles like ſand. It is ſoluble in 96 parts of hot water. In the fire it readily melts into a white maſs. If the heat be continued the acid ſeparates, and there remains a tranſparent glaſs, which is ſoluble in water, and forms a *liquor ſilicum*‡.

‡ Scheele, Crell's Journal, i. 207. Eng. tranſl.

11. Fluat of iron. It is incryſtallizable; but when evaporated leaves a hard maſs.

12. Fluat of zinc. It reſembles that of iron.

13. Fluat of mangaueſe. It may be formed by pouring fluat of ammonia into a ſolution of oxyd of zinc in any of the three mineral acids. It cryſtallizes. 769 Metallic fluats.

14. Fluat of cobalt. A yellow gelatinous maſs.

15. Fluat of nickel. It affords green cryſtals.

16. Fluat of lead. A ſweet taſted powder.

17. Fluat of tin. A nauſeous taſted jelly.

18. Fluat of copper. Blue cryſtals; ſome of them oblong, others cubic.

19. Fluat of arſenic. Small cryſtals.

20. Fluat of mercury. A powder. Before the blowpipe it melts into a yellow glaſs, moſt of which evaporates by a continued heat§.

§ Scheele on Fluor.

Sect. X. *Of Carbonats.*

The compounds into which the carbonic acid enters are called *carbonats*. They were firſt analyſed by Dr Black.

770 Carbonat of potaſs. 1. Carbonat of potaſs. This ſalt is formed by ſaturating potaſs with carbonic acid, which is beſt done by expoſing a ſolution of potaſs for a conſiderable time to carbonic acid gas.

It cryſtallizes, according to Bergman, in quadrangular priſms; the apexes of which are compoſed of two inverted triangles, converging like the roof a houſe*. According to Pelletier they are tetrahedral rhomboidal priſms, with dihedral ſummits. The complete cryſtal has eight faces, two hexagons, two rectangles, and four rhombs†.

* Bergman.

† Ann. de Chim. xv, 29.

It

Carbonats.

It has an alkaline, but not a cauſtic taſte.

It is ſoluble at the common temperature in about four times its weight of water‡. Boiling water diſſolves $\frac{5}{6}$ths of its weight§. Alcohol, even when hot, does not diſſolve above $\frac{1}{1200}$ parts of it.

‡ Bergman, i. 13.
§ Pelletier.

According to Bergman, it is compoſed of 48 parts of potaſs, 20 of acid, and 32 of water. According to Pelletier, of 43 parts of acid, 40 of potaſs, and 17 of water. Bergman under-rated the quantity of acid from not obſerving that the ſalt loſes part of its acid when heated. Even ſolution in hot water produces a ſeparation of ſome acid†.

† Id.

It is not altered by expoſure to the air.

Heat deprives it of its water and part of its acid, but does not decompoſe it completely. The following ſalts decompoſe it by compound affinity:

Sulphat of lime,	Nitrat of barytes,
——— barytes,	——— ſoda,
——— ſoda,	——— ammonia,
——— ammonia,	——— magneſia,
——— magneſia,	——— alumina,
——— alumina,	Acetite of barytes,
Muriat of barytes,	——— lime,
——— lime,	——— ammonia,
——— ammonia,	——— magneſia,
——— magneſia,	——— alumina,
——— alumina,	Oxy-muriat of mercury,
——— ſoda*,	Phoſphat of lime‖.
Nitrat of lime,	

* Bergman.
‖ Id.

When potaſs is ſaturated with carbonic acid it always lets fall a quantity of ſilica. Mr Pelletier has propoſed this ſaturation as the beſt method of purifying potaſs from that earth.

771
Carbonat of ſoda,

2. Carbonat of ſoda. This ſalt may be formed in the ſame manner with carbonat of potaſs.

Its cryſtals are five-ſided priſms, with one of the angles frequently truncated, ſurmounted by dihedral pyramids with rhomboidal faces.

Its taſte is preciſely the ſame with that of carbonat of potaſs.

It is ſoluble in double its weight of cold water.

It is compoſed, according to Bergman, of 16 parts of acid, 20 of alkali, and 64 of water.

It effloreſces when expoſed to the air. Heat is incapable of decompoſing it completely*.

* Bergman, i. 18.

The following ſalts decompoſe it by compound affinity:

Sulphat of ammonia,	Acetite of barytes,
——— barytes,	——— ammonia,
——— lime,	——— lime,
——— magneſia‡,	——— magneſia,
——— alumina,	——— alumina,
Muriat of barytes,	Nitrat of ammonia,
——— ammonia,	——— magneſia,
——— lime,	——— alumina,
——— magneſia,	——— lead†,
——— alumina,	Phoſphat of lime*.

‡ Bergman.
† Id.
* Id.

772
Carbonat of ammonia,

3. Carbonat of ammonia. This ſalt forms octahedral cryſtals, having for the moſt part their two oppoſite apexes truncated‡.

‡ Bergman, i. 21.

Its taſte and ſmell, though much weaker, are the ſame with thoſe of pure ammonia. Like all the alkaline carbonats it converts vegetable blues to green, preciſely as pure alkalies do.

It is ſoluble in rather leſs than twice its weight of cold water. Hot water diſſolves its own weight of it.

According to Bergman it is compoſed of 43 parts of alkali, 45 of acid, and 12 of water.

When expoſed to the air it becomes ſomewhat moiſt.

The ſmalleſt heat is ſufficient to evaporate it.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,	Acetite of barytes,
Nitrat of lime,	——— lime,
Muriat of lime,	——— magneſia,
——— magneſia,	——— alumina.
——— alumina,	

773
Carbonat of barytes,

4. Carbonat of barytes. This ſalt has been found native.

Its cryſtals have been obſerved to aſſume four different forms; double ſix-ſided and double four-ſided pyramids, ſix-ſided columns terminated by a pyramid with the ſame number of faces, and ſmall radiated cryſtals $\frac{1}{2}$ an inch in length, and very thin, appearing to be hexagonal priſms, rounded towards the point.

Cold water diſſolves $\frac{1}{4304}$ part, and boiling water $\frac{1}{2304}$ part of this ſalt. Water ſaturated with carbonic acid diſſolves $\frac{1}{830}$th part*.

* Fourcroy, Ann. de Chim. iv. 64.

According to Dr Withering, who firſt diſcovered it native, it is compoſed of 80 parts of barytes and 20 of acid. Bergman informs us, that artificial carbonat is compoſed of 7 parts of acid, 28 of water, and 65 of earth†.

† Bergman, i. 21.

It is not altered by expoſure to the air.

It is decompoſed by the application of a very violent heat¶.

¶ Dr Hope.

By compound affinity it is decompoſed by the following ſalts:

Sulphat of ſoda,	Nitrat of alumina,
——— lime,	Muriat of lime,
——— ammonia,	——— ammonia,
——— magneſia,	——— magneſia,
——— alumina,	——— alumina,
Nitrat of ſoda,	Acetite of lime,
——— lime,	——— magneſia,
——— ammonia,	——— alumina.
——— magneſia,	

774
Carbonat of lime.

5. Carbonat of lime. This ſubſtance, under the names of marble, chalk, lime-ſtone, &c. exiſts in great abundance in nature, variouſly mixed with other bodies.

When pure, it is of a white colour, and has very little taſte.

It is inſoluble in pure water: but water ſaturated with carbonic acid diſſolves $\frac{1}{1500}$ part of it; from this ſolution it gradually precipitates as the acid leaves it in the form of ſmall rhomboidal cryſtals*.

* Bergman, i. 21.

It is compoſed, according to Bergman, of 34 parts of acid, 11 of water, and 55 of lime.

It ſuffers little or no alteration by being expoſed to the air.

When expoſed to heat, it firſt loſes its water, and afterwards its acid ſeparates as the heat is increaſed: But to ſeparate the acid completely, a very ſtrong heat is required.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,
——— copper.

775
Carbonat of ſtrontites,

6. Carbonat of ſtrontites. This ſalt, which was firſt examined by Dr Hope, is inſipid, and ſoluble in 1536 parts

Carbonats. parts of boiling water. It is composed of 30,2 parts of acid, 69,8 of strontites. A violent heat decomposes it †.

† *Hope, Transf. Edin.* iv. 5.

776 *Carbonat of magnesia.*

7. Carbonat of magnesia. This salt may be formed by saturating the common magnesia of the shops with carbonic acid gas.

It dissolves in water saturated with carbonic acid; and forms by evaporation crystals, which are transparent hexagonal prisms, terminated by a hexagonal plane; these are partly in groups and partly solitary: their length is about six lines, their breadth two ‡. They were discovered by Mr Butini of Geneva.

‡ *Butini sur la Magnesie.*

Water at the temperature of 50 dissolves $\frac{1}{48}$ part of its weight of this salt.* When in the state of powder, and of course deprived of its water of crystallization, it is much more insoluble; and what is very remarkable, it is more soluble in cold than in hot water, impregnated with carbonic acid ‡.

* *Fourcroy, Ann. de Chim.* ii. 298.

‡ *Butini.*

It is composed, according to Fourcroy, of 50 parts of acid, 25 of magnesia, and 25 of water.

When exposed to the air, it effloresces, and falls into powder ¶.

¶ *Fourcroy, ibid.*

When heated, it decrepitates, falls into powder, and is decomposed ‡.

‡ *Id. ibid.*

The following salts decompose it by compound affinity:

Sulphat of lime,	Nitrat of lime,
——— ammonia,	Muriat of lime,
——— alumina,	Acetite of lime.

777 *Carbonat of alumina.*

8. Carbonat of alumina. Carbonic acid is capable of dissolving alumina; for if alum be decomposed by an alkaline carbonat, some alumina remains dissolved in the liquor, and may be precipitated by a heat sufficient to drive off the carbonic acid.* It cannot be doubted, then, that there may be produced a carbonat of alumina; but the salt has never been examined with accuracy.

* *Bergman,* i. 21.

778 *Metallic carbonats.*

9. Carbonat of iron. Water saturated with carbonic acid dissolves $\frac{1}{10500}$ part of its weight of iron, which gradually precipitates by exposure to the air ¶. Rust of iron is a kind of carbonat, at least it always contains carbonic acid.

¶ *Bergman,* i. 33.

10. Carbonat of zinc. Zinc is copiously dissolved by water saturated with carbonic acid ‡. As the metallic oxyds, when saturated with carbonic acid, do not differ materially in their appearance from pure oxyds, we shall not attempt to describe any of the metallic carbonats. We shall, however, present our readers with the following table, exhibiting a view of the weight which metallic oxyds gain by being saturated with this acid.

‡ *Ibid.*

	By Bergman. Precipitated by Carb. of Soda. Weight.	By Wenzel. Precipitated by Carb. of Potass. Weight.
100 parts of		
Oxyd of zinc,	100,930	100,774
iron,	100,250	100,863
manganese,	100,800	
cobalt,	100,600	
nickel,	100,350	
lead,	100,320	100,304
tin,	100,310	100,345
copper,	100,940	100,884
bismuth,	100,300	100,224
antimony,	100,400	100,395
mercury,	100,100	100,062
silver,	100,290	100,288
gold,	100,060	100,326

Acetites. Quantity of loss by driving off the gas by solution according to Wenzel:

Zinc,	0,137
Iron,	0,009
Cobalt,	0,352
Lead,	0,157
Tin,	0,000
Copper,	0,174
Bismuth,	0,056
Antimony	0,000
Mercury,	0,038
Silver,	0,158
Gold,	0,144

These determinations differ too widely from each other to be exact. It is obvious that part of the weight must be owing to adhering water, and very probably triple salts are formed, which must render the determination still more erroneous.

Sect. XI. *Of Acetites.*

The compounds which the acetous acid forms are called *acetites.*

779 *Acetite of potass.*

1. Acetite of potass. Pliny is supposed, but probably without any reason, to have been acquainted with this salt, because he recommends a mixture of vinegar and vine ashes as a cure for a particular species of tumor.* It was first clearly described by Raymond Lully. It has received a great number of names; as, for instance, *arcanum tartari, secret foliated earth of tartar, essential salt of wine, regenerated tartar, diuretic salt, digestive salt of Sylvius.*

* *Plinii,* l. xxiii. *praemium.*

Its crystals are very white, and assume the form of thin plates.

It has a sharp warm taste.

It is soluble in about ten times its weight of water at the temperature of 60° ‖. It is soluble also in alcohol.

‖ *Bergman,* v. 78.

According to Wenzel, 240 parts of acetous acid require for saturation $241\frac{4}{5}$ths of potass. And from the experiments of Dr Higgins, it appears that acetite of potass is composed of 61,5 parts of alkali and 38,5 of acetous acid and water ‡.

‡ *On Acetous Acid,* p. 8.

When exposed to the air it is very deliquescent.—When heated, it melts as readily as wax; and if a very strong heat be applied, the acid is decomposed.

The following salts decompose it by compound affinity:

Sulphat of soda,	Nitrat of ammonia,
——— lime,	——— magnesia,
——— ammonia,	——— alumina,
——— magnesia,	——— bismuth,
——— alumina,	——— mercury,
Nitrat of Soda,	Muriat of ammonia,
——— lime,	——— alumina.

780 *Acetite of soda.*

2. Acetite of soda. This salt was first described by Mr Baron.

Its crystals are striated prisms, not unlike those of sulphat of soda.

It has a sharp taste, approaching to bitter.

It is soluble in 2,86 parts of water at the temperature of 60° ‡.

‡ *Bergman, ibid.*

According to Wenzel, 440 parts of acetous acid require for saturation $157\frac{3}{7}$ths of soda.

It is not affected by exposure to the air.

When heated, it first loses its water of crystallization; in

Acetites.

in a strong heat it melts; and in a still stronger, its acid is destroyed. This salt can only be obtained in crystals when there is an excess of alkali in the solution.

The following salts decompose it by compound affinity:

Sulphat of ammonia,	Nitrat of alumina,
——— alumina,	Muriat of lime
Nitrat of ammonia,	——— ammonia,
——— magnesia,	——— magnesia.

781 Acetite of ammonia.

3. Acetite of ammonia. This salt was formerly called *spirit of Mindererus*.

It is too volatile to be easily crystallized: It may, however, by gentle evaporation, be made to deposite needle-shaped crystals. Mr de Lassone crystallized it by sublimation.* When the sublimation is slow, it forms long, slender, flatted crystals, terminating in sharp points, of a pearl white colour, and about an inch and eight-tenths in length †.

* Mem. Par. i. 775.

† Higgins on Acetous Acid, p. 183.

It impresses the tongue at first with a sense of coldness, and then of sweetness, which is followed by a taste resembling that of a mixture of sugar and nitre, in which the sweet does not predominate over the mawkish taste of the nitre ‡.

‡ Higgins, ibid. p. 192.

According to Wenzel, 240 parts of acetous acid saturate 244 of ammonia.

It is very deliquescent. It melts at 170°, and sublimes at about 250° ¶.

¶ Ibid.

When a watery solution of this salt is distilled, there comes over first a quantity of ammonia, next a quantity of acetous acid, and at last of the neutral salt itself. No such decomposition takes place when the crystals are distilled by a moderate heat.*

* Ibid.

The following salts decompose acetite of ammonia by compound affinity:

Sulphat of alumina,	Carbonat of soda,
Carbonat of potass,	Nitrat of silver ¶.

¶ Ibid. p. 193.

782 Acetite of barytes.

4. Acetite of barytes. This salt was first formed by Mr Morveau.

It is not easily crystallized. Morveau procured it in long prisms in groups.

It has a pleasant, somewhat acid taste, and always contains an excess of acid.

It is soluble in water, and does not deliquesce when exposed to the air ‡.

‡ Morveau, Encycl. Method. Chim. i. 8.

The following salts decompose it by compound affinity:

Sulphat of potass,	Nitrat of alumina,
——— soda,	Muriat of potass,
——— lime,	——— soda,
——— ammonia,	——— lime,
——— magnesia,	——— ammonia,
——— alumina,	——— magnesia,
Nitrat of potass,	——— alumina,
——— soda,	Carbonat of potass,
——— lime,	——— soda,
——— ammonia,	——— ammonia.
——— magnesia,	

783 Acetite of lime.

5. Acetite of lime. This salt was first described accurately by Crollius. The ancients, however, used a mixture of lime and vinegar in surgery.*

* Plinii, l. xxxvi. c. 24.

It crystallizes in fine needles, of a glossy appearance like satin.

Its taste is bitter and sour, because it has an excess of acid.

It is soluble in water.

According to Wenzel, 240 parts of acetous acid require for saturation 125 of lime: according to Maret, 100 parts of acetite of lime contain 50 of lime.† From the experiments of Dr Higgins, it follows, that acetite of lime is composed of 35,7 parts of lime and 64,3 of acetous acid and water ‡.

† Encycl. Method. Chim. i. 9.

‡ On Acetous Acid, p. 47.

It is not altered by exposure to the air; at least Morveau kept some of it for a whole year merely covered with paper, and even quite uncovered for a month, without its undergoing any alteration ||.

|| Ibid. Encycl. Method.

Heat decomposes it, and at the same time partly decomposes its acid.

The following salts decompose it by compound affinity:

Sulphat of soda,	Muriat of alumina,
——— ammonia,	Carbonat of barytes,
——— magnesia,	——— potass,
——— alumina,	——— soda,
Nitrat of ammonia,	——— ammonia,
——— magnesia,	——— magnesia,
——— alumina,	——— alumina.
Muriat of ammonia,	

784 Acetite of strontites.

6. Acetite of strontites. This salt was first formed by Dr Hope. It forms small crystals, which are not affected by exposure to the atmosphere. 49 parts of it are soluble in 120 parts of boiling water: It seems to be nearly as soluble in cold water. It renders vegetable colours green.*

* Dr Hope, Trans. Edin. iv. 14.

785 Acetite of magnesia.

7. Acetite of magnesia. This salt was first mentioned by Mr Wenzel.

It is not crystallizable; but forms by evaporation a viscid mass ‡.

‡ Bergman, ii. 388.

It has a sweetish taste; leaving, however, a sense of bitterness †.

† Morveau, ibid.

It is very soluble both in water and alcohol.*

* Bergman, ii. 388.

According to Wenzel, 240 parts of acetous acid require for saturation 123¾ths of magnesia.

When exposed to the air, it deliquesces. Heat decomposes it.

The following salts decompose it by compound affinity:

Sulphat of ammonia,	Carbonat of barytes,
——— alumina,	——— potass,
Nitrat of ammonia,	——— soda,
——— alumina,	——— ammonia,
Muriat of ammonia,	——— alumina.
——— alumina,	

786 Acetite of alumina.

8. Acetite of alumina. This salt can only be formed by digesting acetous acid on alumina recently precipitated.

By evaporation needle shaped crystals are obtained, which are very deliquescent. According to Wenzel, 240 parts of acetous acid require 20⅘ths of alumina for saturation.

This salt is decomposed by compound affinity by the following salts:

Nitrat of ammonia,	Carbonat of potass,
Muriat of ammonia,	——— soda,
Carbonat of barytes,	——— ammonia,

787 Acetite of jargonia.

9. Acetite of jargonia. This salt may be formed by pouring acetous acid on newly precipitated jargonia. It has an astringent taste. It does not crystallize; but when evaporated to dryness, it forms a powder, which does not attract moisture from the air as acetite of alumina does †. It is very soluble in water and in alcohol.

† Klaproth, Jour. de Phys. xxxvi. 188.

Acetites. hol. It is not so easily decomposed by heat as nitrat of jargonia, probably because it does not adhere so strongly to water*.

* Vauquelin, Ann. de Chim. xxii. 206.

788 Acetite of iron. 10. Acetite of iron. This salt was mentioned by Schrœder and Juncker. It is composed of acetous acid and brown oxyd of iron.

Its solution forms by gentle evaporation small oblong crystals. But the greatest part of the salt assumes the form of a gelatinous mass‡.

‡ Wenzel.

It has a sweetish styptic taste.

According to Wenzel, 240 parts of acetous acid require for saturation 186$\frac{1}{2}$ of iron.

Heat decomposes this salt; and it seems also to be gradually decomposed by exposure to the air.

789 Acetite of zinc. 11. Acetite of zinc. This salt was first mentioned by Glauber.

Its crystals are rhomboidal, and sometimes hexagonal plates of a white colour, and the appearance of talk.

It is soluble in water. According to Wenzel, 240 parts of acetous acid require for saturation 195$\frac{5}{8}$ths of zinc.

It is not altered by exposure to the air. Heat decomposes it. When thrown upon burning coals, it explodes with a blue flame.

12. Acetite of manganese. This salt is not crystallizable; and when evaporated to dryness, it deliquesces. Is it not an acetat?

790 Acetite of cobalt. 13. Acetite of cobalt. This salt is deliquescent. Its solution is of a fine red colour while cold; but becomes blue by being heated, and it recovers its former colour on cooling. According to Wenzel, 240 parts of acetous acid require for saturation 241$\frac{4}{7}$ths of cobalt.

791 Acetite of nickel. 14. Acetite of nickel. This salt forms rhomboidal cubes of a green colour‖. They are not deliquescent: Their taste is sweet*.

‖ Bergman.
* Monnet.

792 Acetite of lead. 15. Acetite of lead. This salt is mentioned by Isaac Hollandus and Raymond Lully. It is composed of acetous acid and white oxyd of lead.

It was formerly called *sugar of lead*, *sugar of Saturn*, *salt of Saturn*, *vinegar of Saturn*, *extract of Saturn*, &c.

Its crystals are flat parallelopipeds, terminated by two inclined planes approaching each other.

It has a sweet and somewhat astringent taste.

It is not very soluble in water; but acetous acid dissolves it abundantly.

According to Wenzel, 240 parts of acetous acid require for saturation 503 of lead.

When exposed to the air it becomes yellow, but undergoes no other alteration.

Heat decomposes it by destroying the acid. When distilled, the residuum takes fire spontaneously on exposure to the air. Paper dipped into acetite of lead forms excellent matches, which are not subject to go out, and which burn very slowly.

The following salts decompose it by compound affinity:

Muriat of ammonia,	Phosphat of ammonia,
Sulphat of copper,	Oxalat of potass‖,
Phosphat of soda,	Malat of potass†.

‖ Scheele.
† Id.

793 Acetite of tin. 16. Acetite of tin. This salt was first described by Lemery.

Its crystals are prismatic needles in groups‡. According to Wenzel 240 parts of acetous acid require for saturation 3$\frac{5}{11}$ of tin.

‡ Morveau.

794 Acetite of copper. 17. Acetite of copper. This salt was known to the ancients, and various ways of preparing it are described by Pliny¶. It was formerly known by the names of *crystals of Venus and verdigrise*.

¶ Lib. xxxiv. c. 11.

It is of a deep green colour. Its crystals are rhomboids.

It has a disagreeable coppery taste.

It is soluble in water and in alcohol.

According to Wenzel 240 parts of acetous acid require 16$\frac{1}{8}$ of copper for saturation.

It effloresces when exposed to the air. Heat decomposes it. It is used in painting.

795 Acetite of bismuth. 18. Acetite of bismuth. This salt seems to have been first mentioned by Geoffroi. He called it *sugar of bismuth*.

It is most easily procured by mixing together the solutions of nitrat of bismuth and acetite of potass. It forms brilliant, talky, silvery crystals.

It has a sweetish taste. According to Wenzel, 240 parts of acetous acid require for saturation 15$\frac{5}{9}$ of bismuth.

It does not deliquesce when exposed to the air. Heat decomposes it.

796 Acetite of antimony. 19. Acetite of antimony. It yields with difficulty small crystals†. According to Wenzel, 240 parts of acetous acid require for saturation 1$\frac{1}{7}$ of antimony.

† Wenzel.

797 Acetite of arsenic. 20. Acetite of arsenic. This salt forms small crystals in grains, hardly soluble in water*.

* Bergman.

798 Acetite of mercury. 21. Acetite of mercury. This salt is mentioned by Schrœder.

Its crystals are small thin plates.

It has a disagreeable taste, and excites coughing.

It is hardly soluble in water. According to Wenzel, 240 parts of acetous acid require for saturation 240$\frac{3}{4}$ of mercury.

When exposed to the air it becomes black, owing to the reduction of the oxyd of mercury. Heat decomposes it.

799 Acetite of silver. 22. Acetite of silver. This salt was perhaps first described by Margraf.

It is best formed by dropping acetite of soda or potass into a saturated solution of nitrat of silver†.

† Maret, ibid.

It forms small oblong crystals, easily dissolved in water‡. It has a sharp taste.

‡ Margraf.

According to Wenzel, 240 parts of acetous acid require for saturation 101$\frac{4}{9}$ of silver.

Heat decomposes it. It is decomposed by muriat of magnesia¶.

¶ Bergman.

800 Acetite of gold. 23. Acetite of gold. This salt is mentioned by Schrœder and Juncker.

801 Acetite of uranium. 24. Acetite of uranium. This salt was first formed by Klaproth.

Its crystals are regular four-sided slender prisms, terminated at both ends by regular quadrilateral pyramids: they are transparent, and of a beautiful topaz yellow colour.

Heat decomposes them: and what is singular, if they be heated gradually red hot, the oxyd which remains retains nearly the form of the crystals*.

* Klaproth on Uranium.

802 Acetats. The compounds into which the acetic acid enters, are called *acetats*. They are so imperfectly known at present, that we shall not attempt a description of them.

Sect. XII. *Of Oxalats.*

The compounds of which oxalic acid forms a part are

Oxalats. are known by the name of *oxalats*. They were first described by Bergman.

803 Oxalat of potass. 1. Oxalat of potass. This salt crystallizes with difficulty. It is very soluble in water. When heated it falls to powder†.

† Bergman, i. 262.

804 Acidulous oxalat of potass. 2. Acidulous oxalat of potass. The oxalic acid is also capable of combining with potass in excess, and forming another salt, called *acidulous oxalat* from its acid taste: or, to speak more accurately, this salt is formed by the combination of oxalat of potass with oxalic acid. This salt exists ready formed in *oxalis acetosella* or wood-sorrel; from which it is extracted in some parts of Europe in great quantities. Hence it was formerly called salt of wood sorrel. It is mentioned by Duclos in the Memoirs of the French Academy for 1668. Margraf first proved that it contained potass; and Scheele discovered that its acid is the oxalic. A great many interesting experiments had been previously made on it by Wenzel and Wiegleb.

It may be formed, as Scheele has shown, by dropping potass very gradually into a saturated solution of oxalic acid in water: as soon as the proper quantity of alkali is added, acidulous oxalat is precipitated. But care must be taken not to add too much alkali, otherwise no precipitation will take place at all.

Its crystals are small opaque parallelopipeds‡.

‡ Dr Lisle.

It has an acid, poignant, bitterish, taste.

It is soluble in about ten times its weight of boiling water, but much less soluble in cold water.

It is not altered by exposure to the air. Heat decomposes it.

This salt is sold in this country under the name of *essential salt of lemons*.

805 Oxalat of soda. 3. Oxalat of soda. This salt agrees very much with oxalat of potass. Its crystals are small, and soluble in water.

From Bergman's description, oxalic acid appears also capable of combining in excess with soda, and forming an acidulous oxalat.

806 Oxalat of ammonia. 4. Oxalat of ammonia. Its crystals are four-sided prisms, generally diverging from various points. They redden the infusion of turnsole.

They are easily soluble in water, but not in alcohol‡.

‡ Bergman.

It is decomposed by nitrat of barytes¶.

¶ Bergman, ibid.

807 Earthy oxalats. 5. Oxalat of barytes. This salt does not crystallize except with excess of acid. The addition of potass, or even of water, deprives it of this excess, and then it crumbles into powder. It is insoluble in water†.

† Bergman, ibid.

6. Oxalat of lime. This salt does not crystallize, It is insoluble in water, but somewhat soluble in acids. It is composed of 48 parts of acid, 46 of lime, and 6 of water. Heat decomposes it‡.

‡ Bergman, ibid.

7. Oxalat of Strontites. This salt was first formed by Dr Hope. It is a white insipid powder; soluble in 1920 parts of boiling water. Heat decomposes it by destroying the acid¶.

¶ Hope, Transf. Edin. iv. 14.

8. Oxalat of magnesia. This salt is in the form of a white powder. It is scarcely soluble either in water or alcohol. It is composed of 35 parts of magnesia and 65 of acid and water. Heat decomposes it‡.

‡ Bergman, ibid. and ii. 387.

9. Oxalat of alumina. It is uncrystallizable; but furnishes on evaporation a yellowish pellucid mass. It is sparingly soluble in alcohol. It has a sweet astringent taste. It is composed of 44 parts of alumina and 56 of acid and water. When exposed to the air it deliquesces; and if it has been previously well dried, its weight is increased by $\frac{2}{7}$. It reddens turnsol¶.

¶ Bergman, ibid.

808 Metallic oxalats. 10. Oxalat of iron. This salt forms prismatic crystals of a yellowish-green colour.

It has an astringent and sweet taste. It is very soluble in water.

It is composed of 45 parts of green oxyd, and 55 of acid and water. When exposed to heat it falls to powder†.

† Ibid.

From Bergman's description, the brown oxyd of iron appears also capable of combining with oxalic acid. The compound does not crystallize, and is nearly insoluble in water‡.

‡ Ibid.

11. Oxalat of zinc. It is hardly soluble in water.

It is composed of 75 parts of oxyd and 25 of acid.

12. Oxalat of manganese. It is composed of oxalic acid, and white oxyd of manganese. It appears capable of crystallizing¶.

¶ Ibid.

13. Oxalat of cobalt. This is a rose-coloured powder, insoluble in water, but soluble in oxalic acid; and capable, by that means, of crystallizing‡.

‡ Ibid.

14. Oxalat of nickel. This is a green coloured powder, hardly soluble in water. It is composed of two parts of acid, and one of oxyd¶.

¶ Ibid.

15. Oxalat of lead. It forms small crystalline grains. They are insoluble in alcohol, and nearly insoluble in water. They contain 55 parts of oxyd and 45 of acid‖.

‖ Ibid.

16. Oxalat of tin. This salt forms prismatic crystals. It has an austere taste. If the solution of this salt be quickly evaporated, it affords a mass resembling horn, and soluble in water‡.

‡ Ibid.

17. Oxalat of copper. This salt is uncrystallizable. It is a bluish powder, insoluble in water, except with excess of acid. It is composed of 21 parts of copper, and 29 of acid‖.

‖ Ibid.

18. Oxalat of bismuth. This salt may be formed by dropping oxalic acid into a solution of nitrat of bismuth. It forms pellucid polygonous crystals. When oxyd of bismuth is dissolved by oxalic acid, the result is a white powder, scarcely soluble in water*.

* Ibid.

19. Oxalat of antimony. This salt forms crystalline grains, with difficulty soluble in water†.

† Ibid.

20. Oxalat of arsenic. This salt is composed of oxalic acid and white oxyd of arsenic. Its crystals are prisms very soluble in water and alcohol. It reddens turnsole.

Heat sublimes it; and by a strong heat it may be decomposed†.

† Ibid.

21. Oxalat of mercury. A white powder, hardly soluble in water, except with excess of acid‡.

‡ Ibid.

22. Oxalat of silver. This salt may be formed by pouring oxalic acid into a solution of nitrat of silver. It is a white powder, scarcely soluble in water, and not at all in alcohol; but soluble in nitric acid. It becomes black by being exposed to the air, owing to the reduction of the oxyd‖.

‖ Ibid.

23. Oxalat of platinum. This salt affords yellow crystals.

Sect. XIII. *Of Tartrites.*

The salts into which tartarous acid enters as an ingredient are known by the name of *tartrites*. 809

Tartar. 1. Acidulous oxalat of potass or tartar. This salt, which is composed of potass and an excess of tartarous acid, or rather of tartrite of potass and tartarous acid, has

Tartrites.

has been long known. It is obtained in a ſtate of impurity at the bottom, and adhering to the ſides of caſks in which wine has fermented. It is called tartar, ſays Paracelſus, becauſe it produces the oil, water, limeſtone, and ſalt, which burn the patient as *Hell* does. According to him, it was the principle of every diſeaſe and every remedy, and all things contain the germ of it.

Margraf and Rouelle firſt demonſtrated that it contained potaſs ready formed: and Scheele firſt obtained tartarous acid from it in a ſtate of purity.

Its cryſtals are very ſmall and irregular. According to Montet, they are priſms, ſomewhat flat, and moſtly with ſix ſides. It has a ſtrong acid taſte. It is ſoluble in about 30 times its weight of boiling water ¶. According to Bergman, it contains 23 parts of alkali and 77 of acid.

¶ Wenzel.

It is not altered by expoſure to the air. Heat decompoſes it, and at the ſame time deſtroys the acid. It is capable of forming a great many compounds.

810
Tartrite of potaſs.

2. Tartrite of potaſs. This ſalt may be formed by ſaturating the laſt deſcribed ſalt with potaſs. It was formerly called *ſoluble tartar*, becauſe it is much more ſoluble in water than the acidulous tartrite of potaſs. It cryſtallizes moſt readily when there is a ſmall exceſs of alkali in the ſolution. Its cryſtals are ſmall oblongs.

It has an unpleaſant bitter taſte. It is ſoluble in 4 parts of water, at the temperature of 40°.

3. Tartrite of ſoda. This ſalt has never been accurately examined.

811
Tartrite of potaſs and ſoda.

4. Tartrite of potaſs and ſoda. This triple ſalt, formerly known by the name of ſalt of Seignette, becauſe firſt formed by Mr Seignette apothecary at Rochelle, is made by ſaturating tartar with ſoda.

Its cryſtals are priſms of eight or ten unequal ſides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes, and the baſe on which they ſtand is marked with two diagonal lines, ſo as to divide it into four triangles.

It has a bitter taſte. It is almoſt as ſoluble as tartrite of potaſs.

It effloreſces when expoſed to the air. Heat decompoſes it.

812
Tartrite of ammonia.

4. Tartrite of ammonia. The cryſtals of this ſalt are polygonous priſms, not unlike thoſe of the laſt deſcribed ſalt.

It has a cooling bitter taſte like that of nitre. It is eaſily ſoluble in water. Heat decompoſes it.

5. Acidulous tartrite of ammonia. This ſalt may be formed by pouring tartarous acid into a ſolution of tartrite of ammonia. Like acidulous tartrite of potaſs it is very inſoluble in water.

6. Tartrite of potaſs and ammonia. This triple ſalt may be formed by pouring ammonia into acidulous tartrite of potaſs.

Its cryſtals, according to Macquer, are priſms with four, five, or ſix ſides: according to the Dijon academicians, parallelopipeds, with two alternate ſloping ſides.

It has a cooling taſte. It is ſoluble enough in water. It effloreſces in the air. Heat decompoſes it.

813
Earthy tartrites.

7. Tartrite of barytes. Unknown.

8. Tartrite of lime. This ſalt, firſt formed by Scheele, is a taſteleſs and almoſt inſoluble powder. By heat the acid is decompoſed, and the pure lime remains behind.

9. Tartrite of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are ſmall regular triangular tables, having the edges and angles ſharp and well defined. It is inſipid. It diſſolves in 320 parts of boiling water.

Tartrites.

It is not altered by expoſure to the air. Heat decompoſes it by deſtroying the acid.*

* Hope, Edin. Tranſ. iv. 15.

10. Tartrite of magneſia. This ſalt is inſoluble in water except there be an exceſs of acid preſent. It then affords by evaporation ſmall cryſtals in the form of hexangular truncated priſms†.

† Bergman, ii. 288.

It has a more ſaline taſte, and is more fuſible than tartrite of lime‡.

‡ Von Packen de Sale eſſent. acid. Tartar.

Heat firſt melts and afterwards decompoſes it.

11. Tartrite of alumina. This ſalt does not cryſtallize, but forms by evaporation a clear tranſparent gummy maſs. Its taſte is aſtringent. It is ſoluble in water. It does not deliqueſce in the air.*

* Von Packen.

12. Tartrite of potaſs and alumina. This triple ſalt is formed by ſaturating tartar with alumina. It bears a very ſtriking reſemblance to the laſt deſcribed ſalt.

814
Metallic tartrites.

13. Tartrite of iron. This is a grey powder. When tartarous acid is poured into a ſolution of ſulphat of iron, ſcaly cryſtals are formed by evaporation. Theſe cryſtals are doubtleſs compoſed of tartarous acid combined with ſulphat of iron. This triple ſalt might be called *tartro-ſulphat of iron.*

14. Tartrite of potaſs and iron. This triple ſalt was formerly called *tartariſed tincture of Mars, chalybeated tartar*, and *tartariſed iron.* It may be formed by boiling two parts of tartar and one of iron filings, previouſly made up into a paſte, in a proper quantity of water. The liquor by evaporation depoſits cryſtals, which form the ſalt wanted.

15. Tartrite of zinc. This ſalt is not eaſily ſoluble in water.

16. Tartrite of potaſs and zinc. This triple ſalt, formed by combining tartar and oxyd of zinc, is very ſoluble in water‡.

‡ Elemens de Chim. Dijon.

17. Tartrite of lead. This ſalt, which is compoſed of tartarous acid and white oxyd of lead, is almoſt inſoluble in water. Nitric acid diſſolves it.

18. Tartrite of potaſs and lead. This ſalt, formed by combining white oxyd of lead with tartar, is very ſoluble in water.*

* Wenzel.

19. Tartrite of tin. Unknown. The tartrite of potaſs and tin, compoſed of tartar and oxyd of tin, is capable of cryſtallizing.

20. Tartrite of copper. This ſalt is beſt formed by pouring tartarous acid into the ſolutions of muriat or ſulphat of copper; it precipitates in the form of blue cryſtals ¶.

¶ Bergman.

This ſalt forms the beſt kind of the pigment called *Brunſwick green*‡.

‡ Leonhardi.

21. Tartrite of potaſs and copper. This triple ſalt is alſo in the form of blue cryſtals.

22. Tartrite of biſmuth. Small cryſtalline grains‖.

‖ Bergman.

23. Tartrite of antimony. This ſalt has never been examined with attention.

24. Tartrite of potaſs and antimony, or tartar emetic. To this ſalt, which is perhaps the moſt powerful emetic known, a great deal of attention has been paid, and a vaſt number of methods have been tried to prepare it. Theſe methods have been already deſcribed in the Encyclopædia. It appears from the experiments of Mr Bindheim, that if this ſalt be carefully prepared, the difference that reſults from the uſe of different oxyds is not ſo great as might have been expected†.

† Ann. de Chim. xiii. 218.

It was firſt made known by Adrian in 1631. It is a triple

Citrats. triple ſalt, compoſed of tartar and white oxyd of antimony.

It is of a white colour and tranſparent. Its cryſtals are trihedral pyramids.

It diſſolves in 60 parts of cold water, and in a ſmaller proportion of hot water. It is decompoſed by lime and alkalies, iron, &c. Care ought therefore to be taken to uſe only diſtilled water when it is adminiſtered as a medicine.

25. Tartrite of arſenic. This ſalt forms priſmatic cryſtals very like thoſe of oxalt of arſenic ¶.

26. Tartrite of mercury. A yellow powder.

27. Tartrite of potaſs and mercury. This triple ſalt cryſtallizes†.

¶ Bergman, ii. 295.
† Monnet.

Sect. XIV. *Of Citrats.*

The compounds into which the citric acid enters have been denominated *citrats*.

Theſe ſalts are at preſent very imperfectly known. Mr Dizé has promiſed ſoon to ſupply this defect.*

815 Alkaline citrats. 1. Citrat of potaſs. This ſalt does not cryſtallize. It has a cooling ſaline taſte, and deliqueſces when expoſed to the air.

2 Citrat of ſoda. This ſalt does not deliqueſce. It has a mild, pleaſant, cooling taſte ¶. According to Scheele it does not cryſtallize.

3. Citrat of ammonia. This ſalt cryſtallizes in thin needles. It has a cooling and moderately ſaline taſte‡. The ammonia is ſeparated by the application of heat.*

816 Earthy citrats. 4 Citrat of barytes. This ſalt is ſcarcely ſoluble in water. It aſſumes the form of a white powder†. It is ſoluble in citric acid.

5. Citrat of lime. This is a white powder, ſcarcely ſoluble in water||.

6. Citrat of magneſia. Does not cryſtallize. It forms a gummy ſaline maſs very ſoluble in water‡.

7. Citrat of alumina. This ſalt is ſcarcely ſoluble in water.

817 Metallic citrats. 8. Citrat of iron. A ſolution of a brown colour.

9. Citrat of copper. A green gummy maſs.

10. Citrat of mercury. This ſalt may be formed by pouring citric acid into nitrat or acetite of mercury. It is a flaky ſalt, of a brick-duſt colour, more or leſs red†.

* Jour. de Phyſ. 1794. Supplement.
¶ Dr Donald Monro, Phil. Tranſ. 57.
‡ Dobſon.
* Scheele.
† Id.
|| Id.
‡ Id.
† Dizé.

Sect. XV. *Of Malats.*

The compounds into which the malic acid enters are called *malats*. This claſs of ſalts was firſt diſcovered by Scheele. They are no better known than the citrats.

818 Malats.

1. Malat of potaſs.
2. Malat of ſoda.
3. Malat of ammonia.

} Theſe ſalts are deliqueſcent‡.

4. Malat of lime. Small irregular cryſtals. They require a large quantity of boiling water for their ſolution. With exceſs of acid they are readily ſoluble in cold water§. They are inſoluble in alcohol||.

5. Malat of barytes. The properties of this ſalt reſemble pretty much thoſe of malat of lime¶.

6. Malat of magneſia. Deliqueſcent‡.

7. Malat of iron. A brown ſolution, not cryſtallizable†.

8. Malat of zinc. This ſalt forms beautiful cryſtals¶.

‡ Scheele.
§ Id.
|| Id.
¶ Id.
‡ Id.
† Id.
¶ Id.

Sect. XVI. *Of Lactats.*

The neutral ſalts formed by the combination of the lactic acid with various baſes are called *lactats*. They were firſt diſcovered by Scheele. 819 Lactats.

1. Lactat of potaſs. A deliqueſcent ſalt, ſoluble in alcohol§.

2. Lactat of ſoda. This ſalt does not cryſtallize. It is ſoluble in alcohol†.

3. Lactat of ammonia. Cryſtals which deliqueſce. Heat ſeparates a great part of the ammonia before deſtroying the acid.

4. Lactat of barytes.
5. Lactat of lime.
6. Lactat of alumina.

} Theſe ſalts deliqueſce§. The lactat of lime is ſoluble in alcohol‡.

7. Lactat of magneſia. Small deliqueſcent cryſtals||.

8. Lactat of iron. A brown ſolution.

9. Lactat of zinc. Cryſtals.*

Theſe ſalts have a very ſtrong reſemblance to malats. The only difference which Scheele obſerved was, that the malat of lime was inſoluble in alcohol, while alcohol diſſolved lactat of lime.

§ Scheele on Milk.
† Ibid.
§ Ibid.
‡ Ibid.
|| Ibid.
* Ibid.

Sect. XVII. *Of Saccholats.*

The compounds into which the saccholactic acid enters are called *saccholats*. They alſo were firſt diſcovered by Scheele. 820 Saccholats.

1. Saccholat of potaſs. Small cryſtals, ſoluble in eight times their weight of boiling water.*

2. Saccholat of ſoda. The ſame; ſoluble in five times their weight of boiling water§.

3. Saccholat of ammonia. A ſalt which has a ſouriſh taſte. Heat ſeparates the ammonia†.

4. Saccholat of barytes.
5. Saccholat of lime.
6. Saccholat of magneſia.
7. Saccholat of alumina.

} Theſe ſalts are inſoluble in water¶.

* Scheele on Sugar of Milk.
§ Ibid.
† Ibid.
¶ Ibid.

Sect. XVIII. *Of Gallats.*

The compounds into which the gallic acid enters are denominated *gallats*. They were firſt attended to by the Dijon academicians and by Scheele. 821 Gallats.

1. Gallat of potaſs.
2. Gallat of ſoda.
3. Gallat of ammonia.

} We only know that theſe compoſitions are poſſible, and that their properties are different from thoſe of all other ſalts.

4. Gallat of barytes.
5. Gallat of lime.

} Theſe ſalts are ſoluble in water, eſpecially when there is exceſs of acid.

6. Gallat of magneſia. This ſalt is a yellow powder, ſoluble in water and in alcohol||.

7. Gallat of alumina. This ſalt, according to Bartholdi, exiſts ready formed in nut galls. It is very ſoluble in water.

8. Gallat of iron. This ſalt, which Mr Prouſt has diſcovered to be formed of gallic acid and brown oxyd of iron, is of a black colour, and does not ſeem capable of cryſtallizing. It is ſoluble in the three mineral acids, and by that means is deprived of its black colour. It is to this ſalt that ink partly owes its black colour. Gallat of iron is decompoſed by alkalies.

We ſhall not attempt any farther account of this claſs of ſalts. Scarcely any addition has yet been made to the

|| Bartholdi, Ann. de Chim. xii. 305.

Benzoats.

the experiments of Scheele which have been given already in the article Chemistry, *Encycl.*

Sect. XIX. *Of Benzoats.*

822
Alkaline benzoats.

The compounds into which the benzoic acid enters have been called *benzoats*.

1. Benzoat of potaſs. This ſalt forms pointed feathery cryſtals. It has a ſaline ſharp taſte. It is very ſoluble in water. It deliqueſces when expoſed to the air¶.

¶ *Keir's Dictionary.*

2. Benzoat of ſoda. The cryſtals of this ſalt are larger, but its taſte is the ſame with that of benzoat of potaſs. It is alſo very ſoluble in water. It effloreſces in the air†.

† *Ibid.*

3. Benzoat of ammonia. This ſalt cryſtallizes with difficulty. Its cryſtals are feather-ſhaped. It deliqueſces‡.

‡ *Ibid.*

823
Earthy benzoats.

4. Benzoat of lime. This ſalt forms white, ſhining, pointed cryſtals, of a ſweetiſh taſte, and not eaſily ſoluble in water§.

§ *Ibid.*

5. Benzoat of magneſia. Feather-ſhaped cryſtals, of a ſharp bitter taſte, and eaſily ſoluble in water‖.

‖ *Ibid.*

824
Metalline benzoats.

6. Benzoat of alumina. An aſtringent ſalt.

7. Benzoat of iron. This ſalt forms yellow cryſtals. It has a ſweet taſte. It is ſoluble in water and alcohol. It effloreſces in the air. Heat diſengages the acid†.

† *Tromſdorf, Ann. de Chim.* xi. 314.

8. Benzoat of zinc. This ſalt forms arboreſcent cryſtals. It is ſoluble in water and alcohol. When expoſed to the air it is diſſipated. Heat decompoſes it‡.

‡ *Id. ibid.*

9. Benzoat of mangan eſe. This ſalt, which is formed of benzoic acid and white oxyd of manganeſe, cryſtallizes in ſmall ſcales. It diſſolves readily in water, with difficulty in alcohol. It is not altered by expoſure to the air¶.

¶ *Id. ibid.*

10. Benzoat of cobalt. Flat cryſtals‡.

‡ *Id. ibid.*

11. Benzoat of lead. Very white cryſtals, ſoluble in water and alcohol. They are not altered by expoſure to the air. Heat diſengages the acid‖.

‖ *Id. ibid.*

12. Benzoat of tin. This ſalt may be formed by pouring benzoat of potaſs into a ſolution of tin in the nitro-muriatic acid. The benzoat of tin is precipitated. It is ſoluble in hot water, but inſoluble in alcohol. Heat decompoſes it§.

§ *Id. ibid.*

13. Benzoat of copper. Small cryſtals of a deep green colour. They are with difficulty ſoluble in water, and not at all in alcohol†.

† *Id. ibid.*

14. Benzoat of biſmuth. This ſalt forms white needle-ſhaped cryſtals. They are ſoluble in water and in a very ſmall proportion in alcohol. They are not altered by expoſure to the air. Heat decompoſes them¶.

¶ *Id. ibid.*

15. Benzoat of antimony. Cryſtals which effloreſce in the air, and are decompoſed by heat‖.

‖ *Id. ibid.*

16. Benzoat of arſenic. Small feather-ſhaped cryſtals. It is ſoluble in hot water, but cryſtallizes in the cooling. A moderate heat ſublimes it; a ſtrong heat decompoſes it. Sulphur decompoſes it. It is not decompoſed by alkalies‡.

‡ *Id. ibid.*

17. Benzoat of mercury. A white powder. It is inſoluble in water, but diſſolves in a ſmall quantity in alcohol. It is not altered by expoſure to the air. A ſmall heat ſublimes it; a greater decompoſes it. It is decompoſed by ſulphur†.

† *Id. ibid.*

18. Benzoat of ſilver. This ſalt is ſoluble in water and alſo in a very ſmall proportion in alcohol. It is not altered by expoſure to the air, but the rays of the ſun render it brown. Heat diſengages its acid‖.

Camphorats.

‖ *Id. ibid.*

19. Benzoat of gold. Small irregular cryſtals, not eaſily ſoluble in water; inſoluble in alcohol. It is not altered by expoſure to the air. Heat decompoſes it¶.

¶ *Id. ibid.*

20. Benzoat of platinum. This ſalt forms ſmall browniſh cryſtals, with difficulty ſoluble in water; not ſoluble in alcohol. When expoſed to heat, it is decompoſed, and there remains behind a brown powder§.

§ *Id. ibid.*

Sect. XX. *Of Succinats.*

The neutral ſalts, formed by the combination of the ſuccinic acid with various baſes, have been called *ſuccinats*.

We ſhall not deſcribe theſe ſalts, as we could not add much to the account given in the Appendix to the article Chemistry in the Encyclopædia. That account was taken from Mr Keir's Chemical Dictionary, and that gentleman borrowed it from Leonhardi.

Sect. XXI. *Of Camphorats.*

The neutral ſalts into the compoſition of which camphoric acid enters, have been denominated *camphorats*. The only chemiſt who has hitherto examined them is Bouillon la Grange: his experiments have been publiſhed in the 27th volume of the *Annales de Chimie.*

825
Camphorat of potaſs.

1. Camphorat of potaſs. To prepare this ſalt carbonat of potaſs is to be diſſolved in water, and the ſolution ſaturated with camphoric acid. When the efferveſcence is over, the liquor is to be evaporated by a gentle heat to the proper conſiſtence, and cryſtals of camphorat of potaſs will be depoſited when the liquor cools.

Camphorat of potaſs is white and tranſparent; its cryſtals are regular hexagons. Its taſte is bitteriſh and ſlightly aromatic.

Water at the temperature of 60° diſſolves $\frac{1}{100}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{4}$th part of its weight.

It is ſoluble in alcohol, and the ſolution burns with a deep blue flame.

When expoſed to moiſt air, it loſes a little of its tranſparency, but in dry air it ſuffers no change.

When expoſed to heat it melts, ſwells, and the acid is volatilized in a thick ſmoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potaſs remains behind in a ſtate of purity.

By compound affinity this ſalt is decompoſed by

Nitrat of barytes,
All the ſalts whoſe baſe is lime,
Nitrat of ſilver,
Sulphat of iron,
Muriat of tin,
——— lead*.

* *Bouillon La Grange, Ann. de Chim.* xxvii. 24.

2. Camphorat of ſoda. This ſalt may be formed preciſely in the ſame manner with the camphorat of potaſs.

826
Camphorat of ſoda.

It is white and tranſparent; its taſte is ſomewhat bitter; its cryſtals are irregular.

Water at the temperature of 60° diſſolves leſs than $\frac{1}{200}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{8}$th of its weight.

It is alſo ſoluble in alcohol.

When expoſed to the air it loſes its tranſparency, and

Camphorats.

effloresces slightly, but is never completely reduced to powder.

Heat produces the same effect upon it as on camphorat of potass: the acid burns with a blue flame, which becomes reddish towards the end.

By compound affinity it is decomposed by

Nitrat of lime,	Muriat of lime,
——— silver,	——— iron,
Muriat of magnesia,	Sulphat of alumina,
——— barytes,	——— iron; and ma-
——— alumina,	ny other salts with me-

tallic bases*.

* Bouillon La Grange, Ann. de Chim. xxvii. 26.

827 Camphorat of ammonia.

3. Camphorat of ammonia. This salt may be prepared by dissolving carbonat of ammonia in hot water, and adding camphoric acid slowly till the alkali is saturated. It must then be evaporated with a very moderate heat, to prevent the disengaging of ammonia.

It is very difficult to obtain this salt in regular crystals. When evaporated to dryness, there is obtained a solid opaque mass of a sharp and bitterish taste.

Water at the temperature of about 60° dissolves nearly $\frac{1}{100}$th part of its weight of this salt; boiling water dissolves $\frac{1}{3}$d of its weight: But this and the two salts above described are a good deal more soluble when there is excess of base.

It is entirely soluble in alcohol.

When exposed to the air it attracts moisture, but not in sufficient quantity to enable it to assume a liquid form.

When exposed to heat it swells, melts and is converted into vapour; before the blow-pipe it burns with a blue and red flame, and is entirely volatilized.

Most of the calcareous salts form triple salts with camphorat of ammonia.

It decomposes in part all the aluminous salts except the sulphat of alumina†.

† Ibid.

828 Camphorat of barytes.

4. Camphorat of barytes. In order to prepare this salt, barytes is to be dissolved in water, and camphoric acid added to the solution; the mixture is then to be boiled, and afterwards filtered and evaporated to dryness.

Camphorat of barytes does not crystallize; when the evaporation is conducted slowly, the salt is deposited in thin plates one above another, which appear transparent while immersed in the liquor, but become opaque whenever they come into contact with the air.

It has very little taste, though it leaves at last upon the tongue a slight impression of acidity mixed with bitterness.

Water dissolves only a very small quantity of this salt: boiling water being capable of taking up only $\frac{1}{600}$th part of it.

It is not altered by exposure to the air.

When exposed to heat it melts easily, and the acid is volatilized. When the heat is considerable, the acid burns with a lively blue flame, which becomes red and at last white.

It is decomposed by

Nitrat of potass, soda, lime, ammonia, and magnesia.
Muriat of lime, potass, alumina, and magnesia.
All the sulphats.
Carbonat of potass and soda.
Phosphat of potass, soda, and ammonia*.

* Bouillon La Grange, ibid. p. 28.

829 Camphorat of lime.

5. Camphorat of lime. This salt may be prepared by dropping into lime-water crystallized camphoric acid. The mixture is then to be made boiling hot, passed through a filter, and evaporated to about $\frac{1}{4}$ths of its volume. On cooling camphorat of lime is deposited.

It has no regular shape; but if the evaporation has been properly conducted, it is in plates lying one above another. It is of a white colour, and has a taste slightly bitter.

Water at the temperature of 60° dissolves very little of this salt; boiling water is capable of dissolving about $\frac{1}{200}$th part of its weight of it. It is insoluble in alcohol.

It is composed of 43 parts of lime, 50 of acid, and 7 of water.

When exposed to the air it dries and falls into powder.

When exposed to a moderate heat it melts and swells up: when placed on burning coals, or when heated in close vessels, the acid is decomposed and volatilized, and the lime remains pure.

When sulphuric acid is poured into a solution of this salt, it produces an insoluble precipitate; nitric and muriatic acids precipitate the camphoric acid.

It is decomposed by compound affinity by

Carbonat of potass,
Nitrat of barytes,
Muriat of alumina,
Sulphat of alumina,
Phosphat of soda*.

* Bouillon La Grange, Ann. de Chim. xxvii. 21.

830 Camphorat of magnesia.

6. Camphorat of magnesia. This salt may be prepared by pouring water on carbonat of magnesia, and then adding crystallized camphoric acid: heat is then applied, the solution is filtrated, and evaporated to dryness. The salt obtained is dissolved in hot water, passed through a filter, and evaporated by means of a moderate heat till a pellicle forms on the surface of the solution. On cooling the salt is deposited in thin plates. The second solution is to remove any excess of magnesia that may happen to be present.

This salt does not crystallize. It is white, opaque, and has a bitter taste.

It is scarcely more soluble in water than camphorat of lime.

Alcohol has no action on it while cold, but when hot it dissolves the acid and leaves the magnesia; and the acid precipitates again as the alcohol cools.

When exposed to the air it dries and becomes covered with a little powder; but this effect is produced slowly, and only in a warm place.

When this salt is placed on burning coals, the acid is volatilized, and the magnesia remains pure. Before the blow-pipe it burns like the other camphorats with a blue flame.

The nitrats, muriats, and sulphats, do not completely decompose this salt, if we except the nitrat of lime and muriat of alumina*.

* Id. ibid.

831 Camphorat of alumina.

7. Camphorat of alumina. To prepare this salt, alumina, precipitated by means of ammonia, and well washed, is to be mixed with water, and crystals of camphoric acid added. The mixture is then to be heated, filtered, and concentrated by evaporation.

This salt is a white powder, of an acid bitterish taste, leaving to the tongue, like most of the aluminous salts, a sensation of astringency.

Water at the temperature of 60° dissolves about $\frac{1}{100}$th part of its weight of this salt. Boiling water dissolves it

Suberats. it in considerable quantities; but it precipitates again as the solution cools.

Alcohol, while cold, dissolves it very sparingly; but when hot it dissolves a considerable quantity of it, which precipitates also as the solution cools.

This salt undergoes very little alteration in the air; but it rather parts with than attracts moisture.

Heat volatilizes the acid; and when the salt is thrown on burning coals it burns with a blue flame.

It is decomposed by the nitrats of lime and barytes.*

* Bouillon La Grange, Ann. de Chim. xxvii. 34.

Sect. XXII. *Of Suberats.*

The salts formed by the suberic acid have obtained the appellation of *suberats*. They have hitherto been examined only by Bouillon la Grange.

832 Suberat of potass.

1. Suberat of potass. This salt ought to be formed by means of crystallized carbonat of potass.

It crystallizes in prisms, having four unequal sides. It has a bitter saltish taste, and it reddens vegetable blues. It is very soluble in water. Caloric melts it, and at last volatilizes the acid.

It is decomposed by most of the metallic salts, and by sulphat of alumina, muriat of alumina, and of lime; nitrat of alumina and of lime; and phosphat of alumina †.

† Id. ibid. xxiii. 52.

833 Suberat of soda.

2. Suberat of soda. This salt does not crystallize. It reddens the tincture of turnsole. Its taste is slightly bitter. It is very soluble in water and in alcohol. It attracts moisture from the air. Caloric produces the same effect on it that it does on suberat of potass.

It is decomposed by the calcareous, aluminous, and magnesian salts ‡.

‡ Id. ibid. p. 53.

834 Suberat of ammonia.

3. Suberat of ammonia. This salt crystallizes in parallelopipeds. Its taste is saltish, and it leaves an impression of bitterness: It reddens vegetable blues.

It is very soluble in water. It attracts moisture from the air. When placed upon burning coals, it loses its water of crystallization, and swells up; and before the blow-pipe it evaporates entirely.

It is decomposed by the aluminous and magnesian salts §.

§ Id. ibid. p. 55.

835 Suberat of barytes.

4. Suberat of barytes. This salt does not crystallize. Heat makes it swell up, and melts it. It is scarcely soluble in water except there be an excess of acid.

It is decomposed by most of the neutral salts except the barytic salts and the fluat of lime ‖.

‖ Id. ibid. p. 52.

836 Suberat of lime.

5. Suberat of lime. This salt does not crystallize. It is perfectly white: it has a saltish taste: it does not redden the tincture of turnsole.

It is very sparingly soluble in water except when hot; and as the solution cools most of the salt precipitates again.

When placed upon burning coals it swells up, the acid is decomposed, and there remains only the lime in the state of powder.

It is decomposed by

- The muriat of alumina,
- The carbonats of potass and soda,
- The fluat of magnesia,
- The phosphats of alumina and soda,
- The borat of potass,
- All the metallic solutions ¶.

¶ Id. ibid. p. 54.

837 Suberat of magnesia.

6. Suberat of magnesia. This salt is in the form of a powder: it reddens the tincture of turnsole. It has a bitter taste: it is soluble in water, and attracts some moisture when exposed to the air.

When heated it swells up and melts: before the blow-pipe the acid is decomposed, and the magnesia remains in a state of purity.

It is decomposed by

- Muriat of alumina,
- Nitrat of lime and alumina,
- Borat of potass,
- Fluat of soda,
- Phosphat of alumina.*

* Bouillon La Grange, Ann. de Chim. xxiii. 55.

838 Suberat of alumina.

7. Suberat of alumina. This salt does not crystallize. When its solution is evaporated by a moderate heat in a wide vessel, the salt obtained is of a yellow colour, transparent, having a styptic taste, and leaving an impression of bitterness on the tongue. When too much heat is employed it melts and blackens. It reddens the tincture of turnsole, and attracts moisture from the air. Before the blow-pipe it swells up, the acid is volatilized and decomposed, and nothing remains but the alumina.

It is decomposed by

- The carbonats of potass and soda,
- The sulphat of iron,
- The muriat of iron,
- The nitrats of silver, mercury, and lead.†

† Id. ibid.

Suberic acid forms also compounds with the oxyds of silver, mercury, lead, copper, tin, iron, bismuth, arsenic, cobalt, zinc, antimony, manganese, and molybdenum; most of which are incrystallizable, and have an excess of acid ‡.

‡ Id. ibid. p. 57.

Sect. XXIII. *Of Prussiats.*

The compounds into which the prussic acid enters are called *Prussiats*.

These substances, the most important of which are triple salts, have something very peculiar in their affinities. The prussic acid appears to have a stronger affinity for alkalies and earths than for metals, at least these substances are capable of decomposing metallic prussiats; yet acids scarcely decompose the metallic prussiats, while the weakest acid known decomposes the prussiats of alkalies and earths. These phenomena have not yet been satisfactorily accounted for.

839 Alkaline prussiats.

1. Prussiat of potass. } These salts were first ob-
2. Prussiat of soda. }

tained pure by Mr Scheele. They are soluble in water; but they are of little use, as mere exposure to the air decomposes them.

3. Prussiat of ammonia. This salt has the smell of ammonia. It is very volatile and as easily decomposed as the other two.

840 Earthy prussiats.

4. Prussiat of lime. This salt is soluble in water. It is also decomposed by exposure to the air.

5. Prussiat of barytes. } These salts are also so-
6. Prussiat of magnesia. }

luble in water, and decomposed by all acids.

Prussic acid does not combine with alumina.

841 Prussian blue.

7. Prussiat of iron, or Prussian blue. This substance is composed, as Mr Proust has shewn, of the prussic acid and brown oxyd of iron. With the green oxyd the prussic acid forms a white compound, which, however, becomes gradually blue when exposed to the atmosphere, because the oxyd absorbs oxygen and is converted into brown oxyd ‖.

‖ Nicholson's Journal, i. 453.

Prussiat of iron is a deep blue coloured powder. It is is infoluble in water, and fcarcely foluble in acids. It is compofed, according to the moft accurate experiments hitherto made, of equal parts of oxyd of iron and pruffic acid. It is not affected by expofure to the air. Heat decompofes it by deftroying the acid, and the oxyd of iron remains behind.

The Pruffian blue of commerce, befides other impurities, contains mixed with it a great quantity of alumina. Its ufe as a pigment, and the attempts which have been made to introduce it as a dye, are well known.

Pruffiat of iron may alfo exift in another ftate: It may have a fuperabundance of oxyd; its colour is then more or lefs yellow. To this ftate it may be reduced by digefting it with alkalies or any of the alkaline earths. Thefe fubftances deprive it of part of its acid, but not of the whole.

842 This yellow pruffiat is foluble in acids.

Affinities of the pruffic acid explained.

Were we to attempt an explanation of this, and the other phenomena which the pruffic acid difplays in its combinations, we would conjecture, that this yellow pruffiat is the fubftance formed by the direct combination of brown oxyd of iron and pruffic acid, and that the blue pruffiat is formed of the yellow pruffiat combined as an integrant with pruffic acid: That the affinity between the pruffic acid and oxyd of iron is much ftronger than that between yellow pruffiat of iron and pruffic acid: that therefore alkalies and earths have a ftronger affinity for pruffic acid than the yellow pruffiat has, but a much weaker affinity than oxyd of iron, and perhaps every other oxyd;—hence the apparent fuperiority of alkalies and earths in fome cafes, while in others they appear very inferior. We would fuppofe, then, that the pruffic acid has a much ftronger affinity for oxyd of iron, and perhaps for all other oxyds, than for other bodies; that the pruffiats, thus formed, are capable of combining with pruffic acid; but that their affinity for it is much lefs than that of the alkalies and earths. This conjecture is fupported by all the phenomena at prefent known; it would remove all the apparent anomalies which the combinations of this fingular acid prefent, and reduce the whole of them under the known laws of affinity.

843

Properties of Pruffian alkali,

8. Pruffiat of potafs and iron, commonly called *Pruffian alkali*, or *Pruffian teft*. This fubftance is a triple falt, compofed of pruffic acid, potafs, and oxyd of iron combined together. To chemifts and mineralogifts it is one of the moft important inftruments ever invented; as, when properly prepared, it is capable of indicating whether any metallic fubftance (platinum excepted) be prefent in any folution whatever, and even of pointing out the particular metal, and of afcertaining its quantity: This it does by means of a compound affinity, which, after what has been faid above, may be eafily underftood. The Pruffian alkali may be conceived to be a combination of two fubftances, pruffiat of potafs and blue pruffiat of iron. Now every metallic oxyd has a ftronger affinity for pruffic acid than potafs has (and, in fact, feems to have a ftronger affinity for it than for any other fubftance). If, therefore, there happen to be any oxyd in the folution, it immediately feizes the pruffic acid with which the potafs is combined, and by that means decompofes the triple falt. A pruffiat of the particular metal is formed, and, as moft pruffiats of metals are infoluble, it is precipitated; and it indicates by its colour the particular metal, and by its weight the quantity of metal that happens to be prefent. At the fame time, the blue pruffiat of iron is alfo precipitated, and its weight muft be deducted from the quantity of the precipitate.

In order to be certain of the accuracy of thefe refults, it is neceffary to have a Pruffian alkali perfectly pure, and to be certain before hand of the quantity, or rather of the proportions of its ingredients. To obtain a teft of this kind has been the object of chemifts ever fince the difcoveries of Macquer pointed out its importance. It is to the ufe of impure tefts that a great part of the contradictory refults of mineralogical analyfes by different chemifts is to be afcribed.

There are two ‡ ways in which this teft may be rendered impure, befides the introduction of foreign ingredients, which we do not mention, becaufe it is obvious that it muft be guarded againft. 1. There may be a fuperabundance of alkali prefent, or, which is the fame thing, there may be mixed with the Pruffian teft a quantity of pure alkali; or, 2. There may be contained in it a quantity of yellow pruffiat of iron, for which pruffiat of potafs has alfo a confiderable affinity.

‡ See *Kirwan's Min.* i. 487.

844

Liable to impurities.

If the Pruffian teft contain a fuperabundance of alkali, two inconveniences follow. This fuperabundant quantity will precipitate thofe earthy falts which are liable to contain an excefs of acid, and which are only foluble by that excefs: Hence alumina and barytes will be precipitated. It is to the ufe of impure tefts of this kind that we owe the opinion, that barytes and alumina are precipitated by the Pruffian alkali, and the confequent theories of the metallic nature of thefe earths. This miftake was firft corrected, we believe, by Mr Klaproth.

Another inconvenience arifing from the fuperabundance of alkali in the Pruffian teft is, that it gradually decompofes the blue pruffiat which the teft contains, and converts it into yellow pruffiat. In what manner it does this will be underftood, after what has been faid, without any explanation.

On the other hand, when the Pruffian alkali contains a quantity of yellow pruffiat of iron, as great inconveniences follow. This yellow pruffiat has an affinity for pruffic acid, which, though inferior to that of the potafs, is ftill confiderable; and, on the other hand, the potafs has a ftronger affinity for every other acid than for the pruffic. When, therefore, the teft is expofed to the air, the carbonic acid, which the atmofphere always contains, affifted by the affinity between the yellow pruffiat and the pruffic acid, decompofes the pruffiat of potafs in the teft; and the yellow pruffiat is precipitated in the form of Pruffian blue: And every other acid produces the fame effect. A teft of this kind, therefore, would indicate the prefence of iron in every mixture which contains an acid (for a precipitation of Pruffian blue would appear); and could not, therefore, be trufted to with any confidence.

845

Klaproth's method of forming it.

We will not attempt to defcribe the various methods which different chemifts have adopted of preparing this teft; but fhall fatisfy ourfelves with defcribing the method of Klaproth, which anfwers the purpofe completely. This we fhall do nearly in the words of Mr Kirwan.

Prepare a pure potafs, by gradually projecting into a large crucible heated to whitenefs a mixture of equal parts of purified nitre and cryftals of tartar; when the whole

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Pruſſiats. is injected, let it be kept at a white heat for half an hour, to burn off the coal.

Detach the alkali thus obtained from the crucible, reduce it to powder, ſpread it on a muffle, and expoſe it to a white heat for half an hour.

Diſſolve it in ſix times its weight of water, and filter the ſolution while warm.

Pour this ſolution into a glaſs receiver placed in a ſand furnace, heated to 170° or 180°, and then gradually add the beſt Pruſſian blue in powder, injecting new portions according as the former becomes grey, and ſupplying water as faſt as it evaporates; continue until the added portions are no longer diſcoloured, then increaſe the heat to 212° for half an hour.

Filter the ley thus obtained, and ſaturate it with ſulphuric acid moderately diluted; a precipitate will appear; when this ceaſes, filter off the whole, and waſh the precipitate.

Evaporate the filtered liquor to about one quarter, and ſet it by to cryſtallize: after a few days, yellowiſh cryſtals of a cubic or quadrangular form will be found mixed with ſome ſulphat of potaſs and oxyd of iron; pick out the yellowiſh cryſtals, lay them on blotting paper, and rediſſolve them in four times their weight of cold water, to exclude the ſulphat of potaſs.

7. Eſſay a few drops of this ſolution with barytic water, to ſee whether it contains any ſulphuric acid, and add ſome barytic water to the remainder if neceſſary: filter off the ſolution from the ſulphat of barytes, which will have precipitated, and ſet it by to cryſtallize for a few days; that the barytes, if any ſhould remain, may be precipitated. If the cryſtals now obtained be of a pale yellow colour, and diſcover no bluiſh ſtreaks when ſprinkled over with muriatic acid, they are fit for uſe; but if they ſtill diſcover bluiſh or green ſtreaks, the ſolutions and cryſtallizations muſt be repeated.

Theſe cryſtals muſt be kept in a well ſtopped bottle, which to preſerve them from the air ſhould be filled with alcohol, as they are inſoluble in it.

Before they are uſed, the quantity of iron they contain ſhould be aſcertained, by heating 100 grains to redneſs for half an hour in an *open* crucible: the pruſſic acid will be conſumed, and the iron will remain in the ſtate of a reddiſh brown magnetic oxyd, which ſhould be weighed and noted: This oxyd is half the weight of the Pruſſian blue afforded by the Pruſſian alkali; its weight muſt therefore be ſubtracted from that of metallic precipitates formed by this teſt. Hence the weight of the cryſtals in a given quantity of the ſolution, ſhould be noted, that the quantity employed in precipitation may be known. Care muſt be taken to continue the calcination till the oxyd of iron becomes brown; for while it is black, it weighs conſiderably more than it ſhould‡.

9. Pruſſiat of ſoda and iron. The only diſcernible difference between this ſalt and the laſt is, that it cryſtallizes differently‖.

846 Pruſſiat of ammonia and iron. 10. Pruſſiat of ammonia and iron. This triple ſalt has alſo been employed as a teſt; but it is not ſo eaſy to obtain it in a ſtate of purity as the other two. It was diſcovered by Macquer, and firſt recommended by Meyer.

It forms flat hexangular cryſtals, ſoluble in water, and deliqueſces in the air. Heat decompoſes it like the other Pruſſiats*.

We ſhall not give any deſcription of the triple ſalts formed by digeſting the alkaline earths on pruſſiat of iron; they are ſufficiently known, and are not of any uſe except as teſts; and in that reſpect they are inferior to that above deſcribed. They are all ſoluble in water, and are moſt of them capable of cryſtallizing. Sebats.

847 Pruſſiat of mercury. 11. Pruſſiat of mercury. This ſalt, which was firſt formed by Scheele, is compoſed of the pruſſic acid combined with the red oxyd of mercury. It may be formed by boiling the red oxyd of mercury with Pruſſian blue. It cryſtallizes in tetrahedral priſms, terminated by quadrangular pyramids, the ſides of which correſpond with the angles of the priſm.

This ſalt is capable of combining with ſulphuric and muriatic acids, and forming triple ſalts, which have not yet been examined§.

‡ Kirwan's Mineral. 494.

‖ Berthollet.

* Woulfe, Journ. de Phyſ. xxxiv. 91.

§ Berthollet.

Sect. XXIV. *Of Formats.*

The compounds into which the formic acid enters are called *formats*. We ſhall not deſcribe them, as little has been added to the account already given in the Appendix to the article Chemistry in the Encyclopædia.

Sect. XXV. *Of Sebats.*

The compounds into which the ſebacic acid enters are called *ſebats*. For our knowledge of this claſs of ſalts we are chiefly indebted to the celebrated Crell, who publiſhed a diſſertation on the ſebacic acid and its combinations in the Philoſophical Tranſactions for 1780 and 1782.

848 Alkaline ſebats. 1. Sebat of potaſs. This ſalt is of a white colour. Its cryſtals are quadrangular pyramids, of which two oppoſite ſides are narrower than the others. It has a ſharp ſaline taſte like muriat of ammonia, but milder. It is ſoluble in water, inſoluble in alcohol, and does not deliqueſce when expoſed to the air. Heat decompoſes it.

2. Sebat of ſoda. This ſalt is white. Its cryſtals are pyramids, with three or four ſides: a very moderate heat melts them.

3. Sebat of ammonia. This ſalt in taſte and ſolubility reſembles muriat of ammonia, but it differs from it in not being capable of ſubliming iron.

849 Earthy ſebats. 4. Sebat of lime. The cryſtals of this ſalt are hexagons, terminated by a plane ſurface: they have a ſharp acrid taſte: are very ſoluble in water, but not in alcohol: they do not deliqueſce.

5. Sebat of magneſia. A gummy, ſaline, uncryſtallizable maſs.

6. Sebat of alumina. A gummy, ſaline maſs, which does not cryſtallize, and has an auſtere aſtringent taſte.

850 Metallic ſebats. 7. Sebat of iron. Needle-ſhaped cryſtals which deliqueſce.

8. Sebat of lead. Needle-ſhaped cryſtals, very ſoluble in water.

9. Sebat of tin. A white deliqueſcent ſalt.

10. Sebat of copper. This ſalt is capable of cryſtallizing, but is very deliqueſcent.

11. Sebat of antimony. A cryſtallizable ſalt, which does not deliqueſce.

12. Sebat of arſenic. Small cryſtals.

13. Sebat of mercury. A white powder, very difficultly ſoluble in water.

14. Sebat of gold. Yellow cryſtals.

15. Sebat of platinum. Browniſh yellow cryſtals.

The bombats or compounds which the bombic acid forms are ſtill unknown.

Metallic Acid Salts.

Sect. XXVI. *Of Arſeniats.*

The compounds formed by the combination of the arſenic acid with baſes are called *arſeniats*. This claſs of ſalts was firſt diſcovered by Macquer; but little accurate was known concerning it till Scheele made known the arſenic acid.

An abſtract of Scheele's experiments has been given in the article Chemistry, *Encycl.*

To his deſcription of arſeniats ſeveral additions might be made, but not of ſufficient conſequence to warrant a repetition of what has been given in that article; and without ſuch a repetition theſe additions would ſcarcely be intelligible.

Sect. XXVII. *Of Metallic Acid Salts.*

It has been conjectured that all metals may be converted into acids by combining them with a ſufficient quantity of oxygen. This conjecture has been verified in a conſiderable number of inſtances. We have ſeen the arſenic acid, the tungſtic acid, the molybdic acid, and the new metallic acid of Vauquelin. Berthollet has diſcovered that platinum becomes an acid; and the ſame thing has been aſcertained with regard to tin. Even thoſe metallic oxyds which do not poſſeſs many of the characters of acids are capable of combining with alkalies and earths, and of forming peculiar neutral ſalts. Theſe oxyds, therefore, perform the office of acids; and conſequently muſt be conſidered as partaking of their nature, or rather as a kind of intermediate ſubſtances between acids and thoſe bodies which unite only with acids.

Some of theſe neutral ſalts we ſhall proceed to enumerate.

851 Fulminating gold. 1. Aurat of ammonia, or fulminating gold. This ſalt is compoſed of the oxyd of gold and ammonia. This compound may be formed by precipitating gold from nitro-muriatic acid by ammonia. The precipitate is fulminating gold. Bergman was the firſt who clearly demonſtrated that this powder is compoſed of oxyd of gold and ammonia. When heated a little above the boiling temperature it explodes with aſtoniſhing violence. Chemiſts had made many attempts to explain the cauſe of this phenomenon, but without ſucceſs, till Mr Berthollet diſcovered the compoſition of ammonia. After making that diſcovery, he proved, by a number of delicate and hazardous experiments, that during the fulmination the ammonia is decompoſed, that its hydrogen combines with the oxygen of the oxyd, and forms water, while the azot flies off in a gaſeous form, and occaſions the exploſion.

852 Fulminating ſilver. 2. Argentat of ammonia, or fulminating ſilver. This ſubſtance was diſcovered by Mr Berthollet. It may be formed by diſſolving oxyd of ſilver in ammonia. It is a black powder. It poſſeſſes the fulminating property much more powerfully than the laſt deſcribed ſubſtance. The ſlighteſt friction makes it explode with violence. This property, as Mr Berthollet has proved¶, is owing to the ſame decompoſition of ammonia and formation of water that cauſes the exploſion of fulminating gold.

¶ Berthollet, Ann. de Chim. i.

If a ſmall retort be filled with the liquor from which the fulminating ſilver has been precipitated, and be made to boil, ſome azot is diſengaged, and ſmall opaque cryſtals are formed, conſiſting of the ſame ſubſtance; which explode when touched, though they be covered with water. Nitrat and muriat of barytes precipitate ſilver from this ſalt.

Hydroſulphurets.

853 Mercuriat of lime and of ammonia. 3. Mercuriat of lime. Oxyd of mercury boiled with lime-water, forms, by evaporation, ſmall, tranſparent yellow cryſtals‡.

4. Mercuriat of ammonia. Oxyd of mercury diſſolves in ammonia in large quantity, and by evaporation furniſhes a white ſalt†.

‡ Id. ibid.

† Lavoiſier, ibid.

854 Cuprat of ammonia. 5. Cuprat of ammonia. Oxyd of copper diſſolves in ammonia. Mr Sage has deſcribed its cryſtallization. It is decompoſed by lime and potaſs, and cuprat of lime and potaſs are formed.

855 Stannat of gold. 6. Stannat of gold. When gold is precipitated by tin it unites with it. Vogel and Beaumé firſt obſerved that the precipitate, which is purple, contained tin.

856 Plumbat of lime. 7. Plumbat of lime. Lime-water boiled on the red oxyd of lead diſſolved it. This ſolution evaporated in a retort, gave very ſmall tranſparent cryſtals, forming priſmatic colours, and not more ſoluble in water than lime. It is decompoſed by all the ſulphats of alkalies and by ſulphurated hydrogen gas. The ſulphuric and muriatic acids precipitate the lead. It blackens wool, the nails, hair, the white of eggs; but it does not affect the colour of ſilk, the ſkin, the yoke of egg, nor animal oil. It is the lead which is precipitated on theſe coloured ſubſtances in the ſtate of oxyd; for all acids can diſſolve it. The ſimple mixture of lime and oxyd of lead blackens theſe ſubſtances; a proof that the ſalt is eaſily formed*.

* Berthollet, Ann. de Chim. i. 37.

857 Zincat of ammonia. 8. Zincat of ammonia. De Caſſone has publiſhed a great number of experiments on the property which ammonia has of diſſolving oxyd of zinc. Lime water and potaſs alſo diſſolve it†.

† Id. Ibid. p. 42.

858 Antimoniat of potaſs. 9. Antimoniat of potaſs. When antimony is detonated with nitre in a crucible, part of its oxyd unites with the potaſs of the nitre‡.

‡ Id. ibid.

Chap. III. *Of* Hydrosulphurets.

859 Properties of ſulphurated hydrogen gas. Sulphurated hydrogen gas, which has been deſcribed in the firſt part of this article, poſſeſſes almoſt all the properties of acids. It combines with water, and the ſolution gives a red colour to vegetable blues. It decompoſes ſoaps and ſulphurets, and is capable of combining with alkalies, earths and metallic oxyds, and of forming compounds, to which Mr Berthollet, to whom we are indebted for diſcovering them, has given the name of *hydroſulphurets**.

* Ann. de Chim. xxv. 233.

Before giving any account of theſe compounds, which we ſhall do from the paper of Berthollet juſt quoted, we beg leave to make a few previous obſervations, in order to rectify ſome inaccuracies into which we have fallen from not being acquainted with the experiments of that philoſopher.

860 Remarks on ſulphurets. Sulphur is capable of combining with alkalies, earths, metals, and metallic oxyds, and forming the compounds known by the name of *ſulphurets*. The alkaline, earthy, and even ſome of the metallic ſulphurets, can only exiſt in a ſtate of dryneſs: the inſtant they are moiſtened with water, a quantity of ſulphurated hydrogen gas is formed, which combines with the ſulphuret, and forms a new compound. To theſe triple compounds Mr Berthollet has given the name of *hydrogenous ſulphurets*. All ſolutions of ſulphurets in water are in fact hydrogenous ſulphurets. Were it not for the formation and combination of ſulphurated hydrogen, the alkaline ſulphurets would

Hydrosulphurets.

would be completely decomposed by water, and their sulphur precipitated; for water has a stronger affinity for the alkalies than sulphur has. This Berthollet proved by the following experiment: To a solution of sulphuret of potass in water (that is, to hydrogenous sulphuret of potass) a quantity of oxy-muriatic acid supersaturated with potass was added, and the sulphur was immediately precipitated. In this experiment the sulphurated hydrogen was destroyed by the oxygen of the oxy-muriatic acid; and the precipitation of the sulphur shews that its affinity for potass was not sufficient to keep it dissolved, or, which is the same thing, that its affinity for potass was inferior to that of water.

861 Hydrogenous sulphuret of mercury.

The substance which we described in Part I, chap. iii. sect. 4. of this article, under the name of *Black Sulphuret of Mercury*, is a hydrogenous sulphuret of mercury, and therefore differs from the red sulphuret of mercury or cinnabar, by containing a quantity of sulphurated hydrogen. Potass has a stronger affinity for this last substance than the sulphuret; potass therefore, by the assistance of heat, deprives the black or hydrogenous sulphuret of its sulphurated hydrogen, and reduces it to the state of red sulphuret. This explains the method of forming cinnabar described in the section above referred to, and points out a much easier process for obtaining that useful pigment.

862 Method of forming hydrosulphurets.

We shall now proceed to the method of forming the hydrosulphurets. Berthollet obtained sulphurated hydrogen gas from sulphuret of iron in the usual manner, by means of sulphuric acid. It was made to pass thro' a vessel filled with water before it entered that in which the combination was to take place. By this method a solution of potass was impregnated with sulphurated hydrogen; and in order to be certain of saturating the alkali completely, the gas was added in excess, and the excess was afterwards driven off by means of heat. By this method hydrosulphurets of potass, soda, and ammonia, may be formed.

In order to form hydrosulphuret of lime, that earth was mixed with distilled water, and sulphurated hydrogen gas passed into this mixture till a sufficient quantity of hydrosulphuret was judged to be formed; the liquid, which contained it in solution, was poured off the undissolved lime, and saturated to excess with sulphurated hydrogen, and this excess was afterwards driven off by means of heat.

Hydrosulphuret of magnesia may be formed by dissolving magnesia in water impregnated with sulphurated hydrogen gas.

If a solution of sulphuret of barytes in water, or, more properly, if hydrogenous sulphuret of barytes be evaporated, a great number of confused crystals are formed; if these be separated quickly by filtration, and placed upon blotting paper to dry, a white crystalline substance is obtained, which is hydrosulphuret of barytes.

863 Affinities of sulphurated hydrogen.

The affinities of the alkalies and earths for sulphurated hydrogen appear from the experiments of Berthollet to be as follows:

Barytes,
Potass,
Soda,
Lime,
Ammonia,
Magnesia,
Jargonia.

Almost all the metallic oxyds have a stronger affinity for sulphurated hydrogen than the earths have.

864 Properties of hydrosulphurets.

When the hydrosulphurets are prepared with the necessary precautions to prevent the contact of atmospherical air, they are colourless, but the action of the air renders them yellow.

If they be decomposed while they are colourless, by pouring upon them sulphuric acid, muriatic acid, or any other acid which does not act upon hydrogen, the sulphurated hydrogen gas exhales without the deposition of a single particle of sulphur; but if the hydrosulphuret has become yellow, some sulphur is always deposited during its decomposition, and the quantity of sulphur is proportional to the deepness of the colour.

The yellow colour, therefore, which hydrosulphurets acquire by exposure to the atmosphere is owing to a commencement of decomposition. Part of the hydrogen of the sulphurated hydrogen abandons the sulphur, combines with the oxygen of the atmosphere, and forms water. By degrees, however, a portion of the sulphur is also converted into an acid; and when the proportion of sulphurated hydrogen is diminished, and that of the sulphur increased to a certain point, the sulphur and the hydrogen combine equally with oxygen.

If sulphuric or muriatic acids be poured upon a hydrosulphuret after it has been for some time exposed to the air, a quantity of sulphurated hydrogen gas exhales, sulphur is deposited, and after an interval of time sulphurous acid is disengaged. It is therefore sulphurous, and not sulphuric acid, which is formed while the hydrosulphuret spontaneously absorbs oxygen. This acid, however, is not perceptible till after a certain interval of time when separated from the hydrosulphuret by means of an acid; because as long as it meets with sulphurated hydrogen a reciprocal decomposition takes place. The oxygen of the acid combines with the hydrogen of the gas, and the sulphur of both is precipitated.

865 Metalline hydrosulphurets.

Sulphurated hydrogen is capable of combining with several of the metals, mercury, for instance, and silver: it combines with the greater number of the metallic oxyds, and forms hydrosulphurets, on which the alkalies have no action at the temperature of the atmosphere: But concentrated acids combine with the oxyds of these hydrosulphurets, and separate the sulphurated hydrogen in the form of gas.

In the greater number of these metallic oxyd hydrosulphurets, the tendency which oxygen and hydrogen have to combine occasions a partial decomposition of the sulphurated hydrogen, and brings the oxyds nearer to the metallic state. In some of these hydrosulphurets part of the sulphur also combines with oxygen, and forms sulphuric acid.

The alkaline hydrosulphurets precipitate all the metals from their combination with acids; they are therefore very valuable tests of the presence of metals in any solution, as they do not precipitate any of the earths except alumina and jargonia. The following table exhibits a view of the effect of hydrosulphuret of potass, hydrogenous sulphuret of potass, and water impregnated with sulphurated hydrogen gas, upon various metallic solutions.

Hydrosulphurets.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potafs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrofulphuret of Potafs.
Green fulphat of iron.	A black precipitate, which becomes yellow by the contact of the air.		A black precipitate. The potafs feparated.
Red oxyd of iron.		Becomes black. The liquor remains very deep coloured if there be an excefs of fulphurated hydrogen.	Becomes black.
Sulphat of zinc.	A white precipitate.	A white precipitate.	A white precipitate.
Acetite of lead.	A white precipitate, which by an addition becomes black.	A black precipitate.	A black precipitate.
Red oxyd of lead.		Becomes black.	The potafs feparated.
Nitrat of bifmuth.		A black precipitate.	A black precipitate.
Oxyd of bifmuth.		Becomes black.	
Nitrat of filver.	A black precipitate.	A black precipitate.	A black precipitate.
Sulphat of copper.	A brown precipitate.	A black precipitate.	A black precipitate.
Green oxyd of copper.		Becomes black.	Separation of the potafs.
Nitrat of mercury.	In a great deal of water, a brown colour.	A brownifh black precipitate.	A brownifh black precipitate.
Oxy-muriat of mercury.	A white precipitate, which becomes black by addition.	A white precipitate, becoming black by an addition.	White becomes black by addition.
Red oxyd of mercury.		Blackifh.	A heat produced which caufed the hydrofulphuret to boil. The alkali feparated (A).
Muriat of tin.			A black precipitate.
Oxy-muriat of tin.	A precipitation of fulphur, and of the oxyd.	No change.	A precipitate of white oxyd of tin, and a difengagement of fulphurated hydrogen gas.
White oxyd of tin.		No change.	Difengagement of fulphurated hydrogen gas.
Sulphat of manganefe.		No change.	A white precipitate.
Black oxyd of manganefe.		The odour difappears. An excefs of the water diffolves the oxyd.	Ammonia difengaged. Heat. The liquor boils (A).
Nitrat of antimony.			A reddifh orange precipitate.
Tartrite of antimony.	A yellow orange precipitate.	An orange colour, but no precipitate.	An orange red precipitate, rediffolved by an excefs of hydrofulphuret.
White oxyd of antimony.		Becomes yellow after fome feconds.	The liquor lofes its colour (A).

Metallic

(A) In thefe, hydrofulphuret of ammonia was ufed inftead of hydrofulphuret of potafs.

Table continued.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrofulphuret of Potaſs.
Oxyd of antimony ſublimed.		Scarcely changes colour.	
Solution of oxyd of arſenic.	Sulphuret decompoſed as by an acid.	Becomes ſomewhat muddy, and of a yellow colour.	A yellow colour, but no precipitate.
Sulphat of titanium.			A precipitate of a deep green.
Molybdic acid.		A brown precipitate.	A brown precipitate.

CHAP. IV. *Of* CRYSTALLIZATION.

866 Cryſtals

THE word *Cryſtal* in its ſtrict and proper ſenſe ſignifies a tranſparent body poſſeſſed of a regular figure. But it is now uſed to denote a body which has aſſumed a regular figure whether it be tranſparent or not. *Cryſtallization* is the *act* by which this regular figure is formed.

As the greater number of cryſtals belong to the claſs of neutral ſalts, it may not be improper before we conclude this part of the article to make a few obſervations on the phenomena of cryſtallization.

As cryſtallization is confeſſedly nothing elſe than the regular arrangement of the particles of bodies, it is evident that before it can take place the particles of the body to be cryſtallized muſt be at ſome diſtance from each other, and that they muſt be at liberty to obey the laws of attraction. They may be put into this ſituation
867 by three methods, ſolution, ſuſpenſion and fuſion.

Formed by ſolution,

1. Solution is the common method of cryſtallizing ſalts. They are diſſolved in water: The water is ſlowly evaporated, the ſaline particles gradually approach each other, combine together, and form ſmall cryſtals; which become conſtantly larger by the addition of other particles till at laſt they fall by their gravity to the bottom of the veſſel. It ought to be remarked, however, that there are two kinds of ſolution, each of which preſents different phenomena of cryſtallization. Some ſalts diſſolve in very ſmall proportions in cold water, but are very ſoluble in hot water; that is to ſay, water at the common temperature has little effect upon them, but water combined with caloric diſſolves them readily. When hot water ſaturated with any of theſe ſalts cools, it becomes incapable of holding them in ſolution: the conſequence of which is, that the ſaline particles gradually approach each other and cryſtallize. Sulphat of ſoda is a ſalt of this kind. To cryſtallize ſuch ſalts nothing more is neceſſary than to ſaturate hot water with them, and ſet it by to cool. But were we to attempt to cryſtallize them by evaporating the hot water, we ſhould not ſucceed; nothing would procured but a ſhapeleſs maſs. Many of the ſalts which follow this law of cryſtallization combine with a great deal of water; or, which is the ſame thing, many cryſtals formed in this manner contain a great deal of water of cryſtallization.

There are other ſalts again which are nearly equally ſoluble in hot and cold water; common ſalt for inſtance. It is evident that ſuch ſalts cannot be cryſtallized by cooling; but they cryſtallize very well by evaporating their ſolution while hot. Theſe ſalts generally contain but little water of cryſtallization. 868

Suſpenſion,

2. It appears, too, that ſome ſubſtances are capable of aſſuming a cryſtalline form merely by having their particles ſuſpended in water, without any regular ſolution; at leaſt it is not eaſy, on any other ſuppoſition, to explain the cryſtallizations of carbonat of lime ſometimes depoſited by waters that run over quantities of that mineral. 869

And fuſion.

3. There are many ſubſtances, however, neither ſoluble in water, nor capable of being ſo minutely divided as to continue long ſuſpended in that fluid; and which, notwithſtanding, are capable of aſſuming a cryſtalline form. This is the caſe with the metals, with glaſs, and ſome other bodies. The method employed to cryſtallize them is *fuſion*, which is a ſolution by means of caloric. By this method the particles are ſeparated from one another; and if the cooling goes on gradually, they are at liberty to arrange themſelves in regular cryſtals. There are many ſubſtances, however, which it has been hitherto impoſſible to reduce to a cryſtalline form, either by theſe or any other method. Whether this be owing to the nature of theſe bodies themſelves, or to our ignorance of the laws by which cryſtals are formed as is much more likely, cannot be determined. 870

Cryſtallization explained.

The phenomena of cryſtallization ſeem to have attracted but little of the attention of the ancient philoſophers. Their theory indeed, that the elements of bodies poſſeſs certain regular geometrical figures, may have been ſuggeſted by theſe phenomena; but we are ignorant of their having made any regular attempt to explain them. The ſchoolmen aſcribed the regular figure of cryſtals to their ſubſtantial forms, without giving themſelves much trouble about explaining the meaning of the term. This notion was attacked by Boyle; who proved, that cryſtals were formed by the mere aggregation of particles†. But it ſtill remained to explain, why that aggregation took place? and why the particles united in ſuch a manner as to form regular figures? Theſe queſtions were anſwered by Newton. According to him, the aggregation is produced by the attraction which he had proved to exiſt between the particles of all bodies, and which acts as ſoon as theſe particles are brought within a certain diſtance of each other by the evaporation of the liquid in which they are diſſolved. The regularity of their figures he explained by ſuppoſing, that while in a ſtate of ſolution, they were arranged in the liquid in regular rank and file; the conſequence

† Treatiſe on the Origin of Forms and Qualities.

ſequence of which, as they are acted upon by a power which at equal diſtances is equal, at unequal diſtances unequal, will be cryſtals of determinate figures ‡.

‡ Optics, p. 362.

This explanation, which is worthy of Newton, is now univerſally admitted as the true one, and has contributed much towards elucidating this important part of chemiſtry.

Still, however, there remain various phenomena relating to cryſtallization which it is no eaſy matter to explain.

871 Salts do not eaſily cryſtallize in cloſe veſſels,

It has been obſerved, that thoſe ſalts which cryſtallize upon cooling, do not aſſume a cryſtalline form ſo readily if they are allowed to cool in cloſe veſſels. If a ſaturated ſolution of ſulphat of ſoda, for inſtance, in hot water be put into a phial, corked up cloſely, and allowed to cool without being moved, no cryſtals are formed at all; but the moment the glaſs is opened, the ſalt cryſtallizes with ſuch rapidity that the whole of the ſolution in a manner becomes ſolid. This phenomenon has been explained by ſuppoſing, that there is an affinity between the ſalt and caloric, and that while the caloric continues combined with it the ſalt does not cryſtallize; that the caloric does not leave the ſalt ſo readily when external air is not admitted, as glaſs receives it very ſlowly, and parts with it very ſlowly. In ſhort, the atmoſpherical air ſeems to be the agent employed to carry off the caloric; a taſk for which it is remarkably well fitted, on account of the change of denſity which it undergoes by every addition of caloric. This is confirmed by the quantity of caloric which always makes its appearance during theſe ſudden cryſtallizations. This explanation might be put to the teſt of experiment, by putting two ſolutions of ſulphat of ſoda in hot water in two ſimilar veſſels; one of glaſs, the other of metal, and both cloſed in the ſame manner. If the ſalt contained in the metallic veſſel cryſtallized, which ought to be the caſe on account of the great conducting power of metals, while that in the glaſs veſſel remained liquid, this would be a confirmation of the theory, amounting almoſt to demonſtration. On the contrary, if both ſolutions remained liquid, it would be a proof that the phenomenon was ſtill incompletely underſtood.

872 And why.

Not only ſalts but water itſelf, which commonly cryſtallizes at 32°, may be made to exhibit the ſame phenomenon: it may be cooled much lower than 32 without freezing. This, as Dr Black has completely proved, depends entirely upon the retention of caloric.

873 Variety of forms in cryſtals accounted for.

If the regular form of cryſtals depends upon the aggregation of particles, and if during all cryſtallizations this aggregation goes on in the ſame manner, why have not all cryſtals the ſame form? Some have aſcribed theſe differences to a certain polarity which the particles of bodies are ſuppoſed to poſſeſs, and which diſpoſes each kind of particles to arrange themſelves according to a certain law. Sir Iſaac Newton appears rather to have aſcribed it to the forms of the particles themſelves‡; and this ſeems to be the real ſolution of the problem. For ſuppoſing that all particles have the ſame form, they muſt of courſe poſſeſs the ſame polarity; and therefore every cryſtal muſt have the ſame form. It is impoſſible, then, to account for the different forms of cryſtals without ſuppoſing that the particles which compoſe them have alſo different forms. And if the particles of bodies have different forms, their regular aggregation muſt produce cryſtals of various ſhapes; and therefore their polarity, which is merely a ſuppoſition founded on this difference in the appearance of cryſtals, cannot be admitted. Suppoſe, for inſtance, that eight cubic particles were regularly arranged in water, and that by the gradual evaporation of the liquid were to approach, and at laſt to combine, it is evident that the cryſtal which they would produce would be a cube. Eight ſix-ſided priſms would alſo produce a ſix-ſided priſm: and eight tetrahedrons would form a very different figure.

‡ Optics, p. 375.

But it will be aſked, if the figure of cryſtals depends entirely upon the form of the particles that compoſe them, how comes it that the ſame ſubſtance does not always cryſtallize in the ſame way, but preſents often ſuch a variety of forms that it is ſcarcely poſſible to reckon them? We anſwer, that theſe various forms are ſometimes owing to variations in the ingredients which compoſe the integrant particles of any particular body. Alum, for inſtance, cryſtallizes in octahedrons; but when a quantity of alumina is added, it cryſtallizes in cubes; and when there is an exceſs of alumina it does not cryſtallize at all. If the proportion of alumina varies between that which produces octahedrons and what produces cubic cryſtals, the cryſtals become figures with fourteen ſides; ſix of which are parallel to thoſe of the cube and eight to thoſe of the octahedron; and according as the proportions approach nearer to thoſe which form cubes or octahedrons, the cryſtals aſſume more or leſs of the form of cubes or octahedrons. What is ſtill more, if a cubic cryſtal of alum be put into a ſolution that would afford octahedral cryſtals, it paſſes into an octahedron: and on the other hand, an octahedral cryſtal put into a ſolution that would afford cubic cryſtals, becomes itſelf a cube¶. Now, how difficult a matter it is to proportion the different ingredients with abſolute exactneſs, muſt appear evident to all.

¶ *Le Blanc, Ann. de Chim.* xiv. 149.

Another circumſtance which contributes much to vary the form of cryſtals, is the different degree of concentration to which their ſolution has been reduced, and the rapidity or ſlowneſs with which they are formed. For it is too evident to require illuſtration, that when cryſtals are depoſited very rapidly they muſt obſtruct one another, and mix together ſo as very much to obſcure the natural regularity of their form.

Even the nature of the veſſel in which the cryſtallization is performed, is not without ſome influence.

874 Hauy's theory of cryſtals.

But, independent of theſe accidental circumſtances, Mr Hauy has ſhewn that every particular ſpecies of cryſtals has a primitive figure, and that the variations are owing to the different ways in which the particles arrange themſelves. Of this theory, which is certainly exceedingly ingenious, and even ſatisfactory, we ſhall attempt to give a ſhort view.

Happening to take up a hexangular priſm of calcareous ſpar, or carbonat of lime, which had been detached from a group of the ſame kind of cryſtals, he obſerved that a ſmall portion of the cryſtal was wanting, and that the fracture preſented a very ſmooth ſurface. Let *a b c d e f g h* (fig. 8.) be the cryſtal; the fracture lay obliquely as the trapezium *p s u t*, and made an angle of 135°, both with the remainder of the baſe *abcsph* and with *tuef*, the remainder of the ſide *i n e f*. Obſerving that the ſegment *ps ut in* thus cut off had for its vertex *i n*, one of the edges of the baſe *a b c n i h* of the priſm, he attempted to detach a ſimilar a fimilar fegment in the part to which the next edge $c\,n$ belonged, employed for that purpofe the blade of a knife directed in the fame degree of obliquity as the trapezium *p s u t*, and affifted by the ftrokes of a hammer. He could not fucceed: But upon making the attempt upon the next edge *b c*, he detached another fegment precifely fimilar to the firft, and which had for its vertex the edge *b c*. He could produce no effect on the next edge *a b*; but from the next following, *a h*, he cut a fegment fimilar to the other two. The fixth edge likewife proved refractory. He then went to the other bafe of the prifm *d e f g h r*, and found, that the edges which admitted fections, fimilar to the preceding ones were not the edges *e f*, *d r*, *g k*, correfponding with thofe which had been found divifible at the oppofite bafe, but the intermediate edges *d e*, *k r*, *g f*. The trapezium *l q y v* reprefents the fection of the fegment, which had *k r* for its vertex. This fection was evidently parallel to the fection *p s u t*; and the other four fections were alfo parallel two and two. Thefe fections were, without doubt, the natural joinings of the layers of the cryftal. And he eafily fucceeded in making others parallel to them, without its being poffible for him to divide the cryftal in any other direction. In this manner he detached layer after layer, approaching always nearer and nearer the axis of the prifm, till at laft the bafes difappeared altogether, and the prifm was converted into a folid OX (fig. 9.) terminated by twelve pentagons, parallel two and two; of which thofe at the extremities, that is to fay, ASRIO, IGEDO, BAODC at one end, and FKNPQ, MNPXU, ZQPXY at the other, were the refults of mechanical divifion, and had their common vertices O, P fituated at the centre of the bafes of the original prifm. The fix lateral pentagons RSUXY, ZYRIG, &c. were the remains of the fix fides of the original prifm.

By continuing fections parallel to the former ones, the lateral pentagons diminifhed in length; and at laft the points R, G coinciding with the points Y, Z, the points S, R with the points U, Y, &c. there remained nothing of the lateral pentagons but the triangles YIZ, UXY, &c. (fig. 10.). By continuing the fame fections, thefe triangles at laft difappeared, and the prifm was converted into the rhomboid *a e* (fig. 11.).

So unexpected a refult induced him to make the fame attempt upon more of thefe cryftals; and he found that all of them could be reduced to fimilar rhomboids. He found alfo, that the cryftals of other fubftances could be reduced in the fame manner to certain primitive forms; always the fame in the fame fubftances, but every fubftance having its own peculiar form. The primitive form of fluat of lime, for inftance, was an octahedron; of fulphat of barytes, a prifm with rhomboidal bafes; of field fpath, an oblique angled parallelopiped, but not rhomboidal; of adamantine fpar, a rhomboid, fomewhat acute; of blende, a dodecahedron, with rhomboidal fides, and fo on.

Thefe muft be confidered as the real *primitive forms* of the cryftals; the other forms which they often affume may be called *fecondary forms*.

The primitive cryftals obtained by the above procefs may be divided by fections parallel to their different fides: all the matter which furrounded this primitive cryftal may alfo be divided by fections parallel to the fides of the primitive cryftal. It follows from this, that the parts detached by means of thefe fections are fimilar, and differ from one another only in fize, which diminifhes in proportion to the length that the divifion is carried. But the divifion of the cryftals into fimilar folids has a term, beyond which we fhould come to the fmalleft particles of the body, which could not be divided without chemical decompofition. It is probable, therefore, that the form of the integrant particles of a body is the fame with the primitive form of its cryftals. Here, then, we have a method of difcovering the form of the particles of bodies; and if this method could be applied to all fubftances whatever, it would enable us to afcertain the affinity of all bodies for each other by accurate calculation. It muft be allowed, that feveral objections might be made to the conclufions of Mr Hauy; but his theory is, on the whole, fo plaufible, that it would certainly be worth while to extend it, and apply it to the calculation of affinities as far as it is fufceptible of the application. If the cryftals obtained by the above procefs be the primitive forms, it becomes a queftion of fome confequence to determine in what manner the fecondary forms are produced.

According to Hauy, all the parts fuperadded to the primitive cryftals, in order to form the fecondary cryftal, confift of plates, which decreafe regularly by the fubtraction of one or more rows of integrant particles, in fuch a manner, that the number of thefe ranks, and confequently the form of the fecondary cryftal, may be determined by theory (c).

To explain this, let us fuppofe that EP (fig. 12.) reprefents a dodecahedron, terminated by equal and fimilar rhombs; that this dodecahedron is a fecondary cryftal, the primitive form of which is a cube: the fituation of this cube in the dodecahedron may be conceived from fig. 13. The fmaller diagonals DC, CG, GF, FD, of four fides of the dodecahedron, united round the fame folid angle L, form the fquare CDFG. Now there are fix folid angles, compofed of four plains, to-wit, the angles L, O, E, N, R, P (fig. 12.); and confequently, by making fections through the fmaller diagonals of the fides that form thefe angles, fix fquares will be made apparent, which are the fix fides of the primitive cube, three of which are reprefented in fig. 13. CDFG, ABCD, BCGH.

This cube being compofed of cubic integrant particles, each of the pyramids, LCDFG for inftance (fig. 13.) which repofe upon its fides, muft alfo, according to the theory, be compofed of fimilar cubic particles. To make this appear, let us fuppofe that ABFG (fig. 14.) is a cube compofed of 729 fmall cubes: Each of its fides will confift of 81 fquares, being the external fides of as many cubic particles, which together conftitute the cube. Upon ABCD, one of the fides of this cube, let us apply a fquare lamina, compofed of cubes equal to thofe of which the primitive cryftal confifts, but which has on each fide a row of cubes lefs than the outermoft layer of the primitive cube. It will of courfe be compofed of 49 cubes, 7 on each fide; fo that its lower bafe *o n f g* (fig. 15.) will fall exactly on the fquare marked with the fame letters in fig. 14.

Above this lamina let us apply a fecond *l m p u* (fig. 16.),

(c) The explanation of Bergman is not very different. See his *Opufc.* vol. ii. diff. 1.

16.), compoſed of 25 cubes; it will be ſituated exactly above the ſquare marked with the ſame letters (fig. 14). Upon this ſecond let us apply a third lamina *v x y z* (fig. 17.) conſiſting only of 9 cubes: ſo that its baſe ſhall reſt upon the letters *v x y z* (fig. 14.). Laſtly, on the middle ſquare *r* let us place the ſmall cube *r* (fig. 18.) which will repreſent the laſt lamina.

It is evident, that by this proceſs a quadrangular pyramid has been formed upon the face ABCD (fig. 14.), the baſe of which is this face, and the vertex the cube *r* (fig. 18.). By continuing the ſame operation on the other five ſides of the cube, as many ſimilar pyramids will be formed; which will envelope the cube on every ſide.

It is evident, however, that the ſides of theſe pyramids will not form continued planes, but that, owing to the gradual diminution of the laminæ of the cubes which compoſe them, theſe ſides will reſemble the ſteps of a ſtair. We can ſuppoſe, however (what muſt certainly be the caſe), that the cubes of which the nucleus is formed are exceedingly ſmall, almoſt imperceptible; that therefore a vaſt number of laminæ are required to form the pyramids, and conſequently that the channels which they form are imperceptible. Now DCBE (fig. 19.) being the pyramid reſting upon the face ABCD (fig. 14.), and CBOG (fig. 19.) the pyramid applied to the next face BCGH (fig. 14.) if we conſider that every thing is uniform from E to O (fig. 19.) in the manner in which the edges of the *laminæ of ſuperpoſition* (as the Abbé Hauy calls the laminæ which compoſe the pyramids) mutually project beyond each other, it will readily be conceived, that the face CEB of the firſt pyramid ought to be exactly in the ſame plane with the face COB of the adjacent pyramid; and that therefore the two faces together will form one rhomb ECOB. But all the ſides of the ſix pyramids amount to 24 triangles ſimilar to CEB; conſequently they will form 12 rhombs, and the figure of the whole cryſtal will be a dodecahedron, ſimilar to that repreſented in fig. 12 and 13.

If the decreaſe of the laminæ of ſuperpoſition took place according to a more rapid law, if each lamina had on its circumference, two, three or four rows of cubes leſs than the inferior lamina—in that caſe, the pyramids produced being lower, their adjacent faces would no longer form one plane; and therefore the ſurface of the ſecondary cryſtal would conſiſt of 24 iſoſceles triangles, all inclined towards each other.

In this manner Mr Hauy has ſhewn, that a variety of ſecondary cryſtals are formed, and that their forms vary by means of ſlight variations in the ratio of the *decrement*. Dodecahedral ſulphuret of iron, for inſtance, is formed from a cubic nucleus, by the addition of laminæ, decreaſing, as in the example given above, with this difference, that from every lamina laid upon the face ABCD (fig. 14.) only one row of cubes are ſubtracted at the ſides AD and BC reſpectively; whereas two rows are ſubtracted at each of the ſides AB and CD. The conſequence of this more rapid decrement on two parallel ſides than on the other two will be, that the pyramid raiſed on the face ABCD (fig. 14), inſtead of terminating in a ſingle cube as in the example given above, will terminate in a range of cubes *y* or (ſuppoſing the cubes infinitely ſmall) inſtead of terminating in a point, it will terminate in a ridge. The pyramid will therefore have for its two ſides, contiguous to AB and DC, two trapeziums, and for its ſides, contiguous to AD and BC, two triangles. Let us ſuppoſe alſo, that with regard to the laminæ of ſuperpoſition which ariſe on the face BCGH (fig. 14), the decrements follow the ſame law, and that each lamina decreaſes by two rows of cubes towards the lines BC and HG, and only by one row towards the lines CG, BH: The pyramid, in that caſe, will be placed in a direction oppoſite to the pyramid on ABCD, the ridge at the vertex of it running parallel to BC: the vertex of the pyramid raiſed upon CDFG muſt be parallel to CG: the pyramids on the three other ſides of the cube ought to ſtand each like that which ariſes on the oppoſite face.

The ſides of all the ſix pyramids thus formed amount to twelve trapeziums and twelve triangles. Every triangle is evidently contiguous and in the ſame plane with a trapezium of the neareſt pyramid; conſequently the ſecondary cryſtal thus formed conſiſts of twelve ſides, each of which is a pentagon.

Several other examples have been given by Mr Hauy; but theſe are ſufficient to ſhew in what manner the various ſecondary forms of cryſtals are conſtructed, according to the theory of that ingenious philoſopher.

In his reſearches on this ſubject, Mr Hauy perceived, that ſome cryſtals aſſumed ſecondary forms which could not be accounted for by any decrement whatever along the edges. Thus, for inſtance, ſome bodies, the primary form of which is cubic, are ſometimes found cryſtallized in regular octagons. Mr Hauy explains the formation of theſe ſecondary cryſtals, by ſuppoſing that the decrement took place parallel, not to the edges, but to the diagonals of the faces of the primary cubes.

In order to comprehend this, let us ſuppoſe ABCD (fig. 20.) to be the ſurface of a lamina compoſed of ſmall cubes, the baſes of which are repreſented by the little ſquares in the figure. It is evident, that the cubes *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, are in the direction of the diagonal of the ſquare ABCD; that the row of cubes *q*, *v*, *k*, *u*, *x*, *y*, *z*, is parallel to the diagonal; as alſo the row *n*, *t*, *l*, *m*, *p*, *o*, *r*, *s*; and that the whole figure might be divided into rows of ſquares, each of which would be parallel either to the diagonal AC or DB.

Now we may conceive that the laminæ of ſuperpoſition, inſtead of decreaſing by rows of cubes parallel to the edges AB, AD, decreaſe by rows parallel to the diagonals.

Let it be propoſed to conſtruct around the cube AB GF (fig. 21.), conſidered as a nucleus, a ſecondary ſolid, in which the laminæ of ſuperpoſition ſhall decreaſe on all ſides by ſingle rows of cubes, but in a direction parallel to the diagonals. Let ABCD (fig. 22.), the ſuperior baſe of the nucleus, be divided into 81 ſquares, repreſenting the faces of the ſmall cubes of which it is compoſed. Figure 23. repreſents the ſuperior ſurface of the firſt laminæ of ſuperpoſition; which muſt be placed above ABCD (fig. 22.), in ſuch a manner that the points *a*,′ *b*′, *c*′, *d*′, (fig. 23.) anſwer to the points *a*, *b*, *c*, *d*, (fig. 22.). By this diſpoſition the ſquares A *a*, B *b*, C *c*, D *d* (fig. 22.) which compoſe the four outermoſt rows of ſquares parallel to the diagonals AC, BD, remain uncovered. It is evident alſo, that the borders QV, ON, IL, GF (fig. 23.), project by one range beyond the borders AB, AD, CD, BC (fig. 22.), which is neceſſary, that the nucleus may be enveloped towards theſe edges: For if this were not the caſe, Cryftallization.

cafe, re-entering angles would be formed towards the parts AB, BC, CD, DA, of the cryftal ; which angles appear to be excluded by the laws which determine the formation of fimple cryftals, or, which comes to the fame thing, no fuch angles are ever obferved in any cryftal. The folid muft increafe, then, in thofe parts to which the decrement does not extend. But as this decrement is alone fufficient to determine the form of the fecondary cryftal, we may fet afide all the other variations which intervene only in a fubfidiary manner, except when it is wifhed, as in the prefent cafe, to conftruct artificially a folid reprefentation of a cryftal, and to exhibit all the details which relate to its ftructure.

The fuperior face of the fecond lamina will be A′ G′ L′ K′ (fig. 24.). It muft be placed fo that the points a'', b'', c'', d'', correfpond to the points a' b' c' d' (fig. 23.), which will leave uncovered a fecond row of cubes at each angle, parallel to the diagonals AC and BD. The folid ftill increafes towards the fides. The large faces of the laminæ of fuperpofition, which in fig. 23. were octagons, in fig. 24. arrive at that of a fquare; and when they pafs that term they decreafe on all fides ; fo that the next lamina has for its fuperior face the fquare B′M′L′S′ (fig. 25.) lefs by one range in every direction than the preceding lamina (fig. 24.). This fquare muft be placed fo that the points e', f', g', h', (fig. 25.) correfpond to the points e, f, g, h (fig. 24.). Figures 26, 27, 28, and 29, reprefent the four laminæ which ought to rife fucceffively above the preceding ; the manner of placing them being pointed out by correfponding letters, as was done with refpect to the three firft laminæ. The laft laminæ z' (fig. 30.) is a fingle cube which ought to be placed upon the fquare z (fig. 29.).

The laminæ of fuperpofition, thus applied upon the fide ABCD (fig. 22.) evidently produce four faces, which correfpond to the points A, B, C, D, and form a pyramid. Thefe faces, having been formed by laminæ, which began by increafing, and afterwards decreafed, muft be quadrilaterals of the figure reprefented in fig. 31.; in which the inferior angle C is the fame point with the angle C of the nucleus (fig. 21 and 22.); and the diagonal LQ reprefents L′G′ of the lamina A′G′L′K′ (fig. 24.). And as the number of laminæ compofing the triangle L Q C (fig. 31.) is much fmaller than that of the laminæ forming the triangle ZLQ, it is evident that the latter triangle will have a much greater height than the former.

The furface, then, of the fecondary cryftal thus produced, muft evidently confift of 24 quadrilaterals (for pyramids are raifed on the other 5 fides of the primary cube exactly in the fame manner), difpofed 3 and 3 around each folid angle of the nucleus. But in confequence of the decrement by one range, the three quadrilaterals which belong to each folid angle, as C (fig. 21.) will be in the fame plane, and will form an equilateral triangle ZIN (fig. 32.). The 24 quadrilaterals, then, will produce 8 equilateral triangles ; and confequently the fecondary cryftal will be a regular octagon. This is the ftructure of the octahedral fulphuret of lead and of muriat of foda.

Decrements which take place in this manner have been called by Mr Hauy *decrements on the angles*.

There are certain cryftals in which the decrements on the angles do not take place in lines parallel to the diagonals, but parallel to lines fituated between the diagonals and the edges. This is the cafe when the fubtractions are made by ranges of double, triple, &c. moleculæ. Fig. 33. exhibits an inftance of the fubtractions in queftion; and it is feen that the moleculæ which compofe the range reprefented by that figure are afforted in fuch a manner, as if of two there were formed only one ; fo that we need only to conceive the cryftal compofed of parallelopipedons having their bafes equal to the fmall rectangles $a\ b\ c\ d$, $e\ d\ f\ g$, $h\ g\ i\ l$, &c. to reduce this cafe under that of the common decrements on the angles. To this particular kind of decrement Mr Hauy has given the name of *intermediate*.

In other cryftals, the decrements, either on the edges or on the angles, vary according to laws, the proportion of which cannot be expreffed but by the fraction $\frac{2}{3}$ or $\frac{3}{4}$. It may happen, for example, that each lamina exceeds the following by two ranges parallel to the edges, and that it may at the fame time have an altitude triple that of a fimple molecule. Figure 34 reprefents a vertical geometrical fection of one of the kinds of pyramids which would refult from this decrement ; the effect of which may be readily conceived, by confidering that AB is a horizontal line taken on the upper bafe of the nucleus, $b\ a\ z\ r$ the fection of the firft lamina of fuperpofition, $g\ f\ e\ n$ that of the fecond, &c. Thefe decrements Mr Hauy has called *mixed*.

Thefe two laft fpecies of decrements occur but rarely ; Mr Hauy found them only in certain metallic fubftances.

All the metamorphofes to which cryftals are fubjected depend, according to Mr Hauy, on the laws of ftructure juft explained, and others of the like kind. Sometimes the decrements take place at the fame time on all the edges ; as in the dodecahedron having rhombufes for its planes, as before mentioned ; or on all the angles, as in the octahedron originating from a cube. Sometimes they take place only on certain edges or certain angles. Sometimes there is an uniformity between them ; fo that it is one fingle law by one, two, three ranges, &c. which acts on the different edges, or the different angles. Sometimes the law varies from one edge to the other, or from one angle to the other ; and this happens above all when the nucleus has not a fymmetrical form ; for example, when it is a parallelopipedon, the faces of which differ by their refpective inclinations, or by the meafure of their angles. In certain cafes the decrements on the edges concur with the decrements on the angles to produce the fame cryftalline form. It happens alfo fometimes that the fame edge, or the fame angle, is fubjected to feveral laws of decrement that fucceed each other. In fhort, there are cafes where the fecondary cryftal has faces parallel to thofe of the primitive form, and which combine with the faces produced by the decrements to modify the figure of the cryftal.

The cryftals arifing from a fingle law of decrement have been called by Mr Hauy *fimple fecondary forms* ; thofe which arife from feveral fimultaneous laws of decrement he has called *compound fecondary forms*.

" If amidft this diverfity of laws (he obferves), fometimes infulated, fometimes united by combinations more or lefs complex, the number of the ranges fubtracted were itfelf extremely variable ; for example, were thefe decrements by twelve, twenty, thirty or forty ranges, or more, as might abfolutely be poffible, the multitude of

Cryftalli-zation.

of the forms which might exift in each kind of mineral would be immenfe, and exceed what could be imagined. But the power which effects the fubtractions feems to have a very limited action. These fubtractions, for the moft part, take place by one or two ranges of molecules. I have found none which exceeded four ranges, except in a variety of calcareous fpar, forming part of the collection of C. Gillet Laumont, the ftructure of which depends on a decrement by fix ranges; fo that if there exift laws which exceed the decrements by four ranges, there is reafon to believe that they rarely take place in nature. Yet, notwithftanding thefe narrow limits by which the laws of cryftallization are circumfcribed, I have found, by confining myfelf to two of the fimpleft laws, that is to fay, thofe which produce fubtractions by one or two ranges, that calcareous fpar is fufceptible of two thoufand and forty-four different forms: a number which exceeds more than fifty times that of the forms already known; and if we admit into the combination decrements by three and four ranges, calculation will give 8,388,604 poffible forms in regard to the fame fubftance. This number may be ftill very much augmented in confequence of decrements either mixed or intermediary.

"The ftriæ remarked on the furface of a multitude of cryftals afford a new proof in favour of theory, as they always have directions parallel to the projecting edges of the laminæ of fuperpofition, which mutually go beyond each other, unlefs they arife from fome particular want of regularity. Not that the inequalities refulting from the decrements muft be always fenfible, fuppofing the form of the cryftals had always that degree of finifhing of which it is fufceptible; for, on account of the extreme minutenefs of the molecules, the furface would appear of a beautiful polifh, and the ftriæ would elude our fenfes. There are therefore fecondary cryftals where they are not at all obferved, while they are very vifible in other cryftals of the fame nature and form. In the latter cafe, the action of the caufes which produce cryftallization not having fully enjoyed all the conditions neceffary for perfecting that fo delicate operation of nature, there have been ftarts and interruptions in their progrefs, fo that, the law of continuity not having been exactly obferved, there have remained on the furface of the cryftal vacancies apparent to our eyes. Thefe fmall deviations are attended with this advantage, that they point out the direction according to which the ftriæ are arranged in lines on the perfect forms where they efcape our organs, and thus contribute to unfold to us the real mechanifm of the ftructure.

"The fmall vacuities which the edges of the laminæ of fuperpofition leave on the furface of even the moft perfect fecondary cryftals, by their re-entering and falient angles, thus afford a fatisfactory folution of the difficulty a little before mentioned; which is, that the fragments obtained by divifion, the external fides of which form part of the faces of the fecondary cryftal, are not like thofe drawn from the interior part. For this diverfity, which is only apparent, arifes from the fides in queftion being compofed of a multitude of fmall planes, really inclined to one another, but which, on account of their fmallnefs, prefent the appearance of one plane; fo that if the divifion could reach its utmoft bounds, all thefe fragments would be refolved into molecules fimilar to each other, and to thofe fituated towards the centre.

"The fecundity of the laws on which the variations of cryftalline forms depend, is not confined to the producing of a multitude of very different forms with the fame molecules. It often happens alfo, that molecules of different figures arrange themfelves in fuch a manner as gives rife to like polyhedra in different kinds of minerals. Thus the dodecahedron with rhombufes for its planes, which we obtained by combining cubic molecules, exifts in the granite with a ftructure compofed of fmall tetrahedra, having ifofceles triangular faces, and I have found it in fparry fluor *(fluat of lime)*, where there is alfo an affemblage of tetrahedra, but regular: that is to fay, the faces of which are equilateral triangles. Nay more, it is poffible that fimilar molecules may produce the fame cryftalline form by different laws of decrement. In fhort, calculation has conducted me to another refult, which appeared to me ftill more remarkable, which is, that, in confequence of a fimple law of decrement, there may exift a cryftal which externally has a perfect refemblance to the nucleus, that is to fay, to a folid that does not arife from any law of decrement*."

* *Ann. de Chim.* xvii. 225.

Such is a fhort view of the theory by which Mr Hauy explains the various cryftalline forms of the fame fubftance. We would with pleafure have entered more into detail, had not moft of his examples been deduced from fubftances which belong rather to mineralogy than to the elements of chemiftry. This theory, to fay no more of it, is, in point of ingenuity, inferior to few; and the mathematical fkill and induftry of its author are intitled to the greateft applaufe.

But what we confider as the moft important part of that philofopher's labours, is the method which they point out of difcovering the figure of the integrant particles of cryftals; becaufe it may pave the way for calculating the affinities of bodies, which is certainly by far the moft important part of chemiftry. This part of the fubject, therefore, deferves to be inveftigated with the greateft care.

Mr Hauy has found, that the primitive form of all the cryftals which he has examined may be reduced to fix; 1. The parallelopipedon in general, comprehending the cube, the rhomboid, and all folids terminated by fix fides parallel two and two: 2. The regular tetrahedron; 3. The octahedron with triangular fides; 4. The hexagonal prifm; 5. The dodecahedron bounded by rhombs; 6. The dodecahedron bounded by ifofceles triangles. Were we to fuppofe that thefe primitive forms are exactly fimilar to the form of the integrant particles which compofe them, it would follow, that the integrant particles of all the cryftals hitherto formed have only fix different forms. This fuppofition, however, is not probable; becaufe the fame nucleus has been difcovered in different fpecies of minerals, and becaufe we can eafily conceive integrant particles of different forms combining in fuch a manner as to compofe nuclei of the fame figure, juft as we have feen that different primitive forms are capable of producing the fame fecondary form. Still, therefore, in endeavouring to difcover the integrant particles of bodies, there are difficulties to remove, which hitherto, at leaft, have been unfurmountable. But the theory of Mr Hauy may be confidered as a firft ftep towards the difcovery, and a *ftep* in refearches of fo difficult a nature is of very great confequence.

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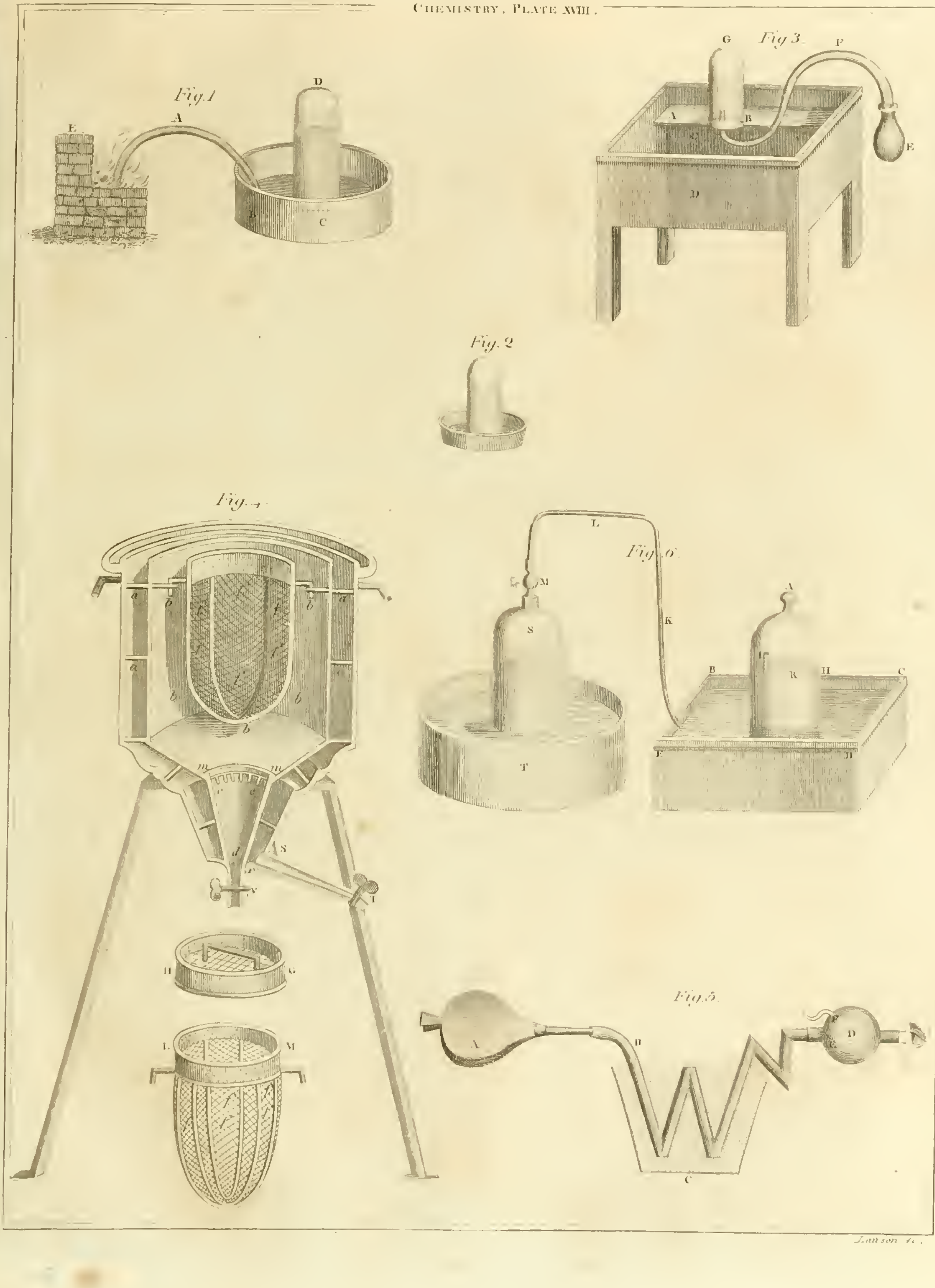
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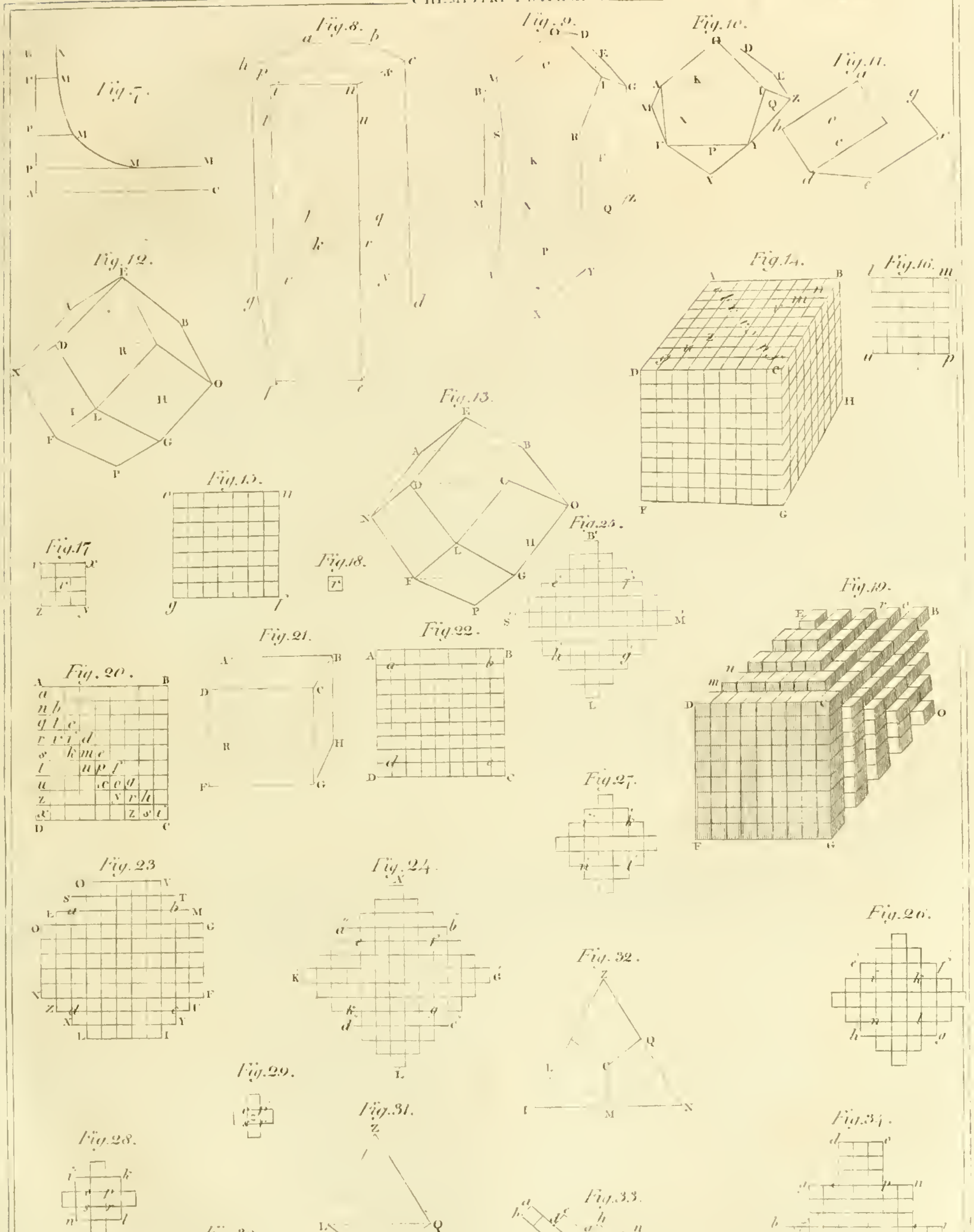
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Fig.33.
Fig.34.

Conclusion.

We have now finished the three first parts of this article, which comprehend all the elementary part of chemistry. We ought now to proceed to the fourth part, which was to consist of a chemical examination of substances as they exist in nature in the mineral, vegetable, and animal kingdoms; but this, for various reasons we shall defer till we come to the words MINERALOGY, and *Animal and Vegetable* SUBSTANCES.

We shall finish this article with a few remarks upon the chemical nomenclature, which for some time past has been an object of serious attention.

875 Remarks on the chemical nomenclature

Chemistry was unfortunately first cultivated by a set of ignorant men, filled with the highest notions of their own importance, and buoyed up with the mighty feats which they were to perform by their art. The little which they did know they were anxious to conceal; and their anxiety was no less to inspire the world with high ideas of their knowledge and power. The consequence of this was, that they loaded chemistry with the most ridiculous and whimsical names that can well be conceived. *Liver of sulphur, mercury of life, horned moon, butter of antimony, the double secret, the corraline secret, the secret of vitriol, the wonderful salt, the secret salt, the salt with many virtues, the salt of two ingredients, the foliated earth of tartar*, were the names by which they distinguished some of the most familiar preparations; and, were it worth while, a great many more names of the same stamp might easily be added.

As soon as chemistry had attracted the attention of men of science, the absurdity of its nomenclature was felt, and several partial improvements were at different times made in it. Macquer, in particular, discarded many of the ancient names, and substituted others less exceptionable in their place.

But soon after the publication of the first edition of his Dictionary, an evil began to be felt severely, which never could have occurred to the earlier chemists. Hitherto the number of objects which had engaged the attention of those who cultivated the science had been very limited; the acids amounted only to five; the earths to four, the metals to 12 or 14, and the neutral salts scarcely exceeded 20 or 30. To remember names for so small a number of bodies, however ridiculous they happened to be, was no very difficult matter. But about that time, in consequence chiefly of the discovery of fixed air by Dr Black, which laid the foundation of pneumatic chemistry, the science began to extend itself, and to enlarge its boundaries with inconceivable rapidity. The number of bodies connected with it, and which it had to describe, soon became immense; and if every one of them received names not dependant upon one another, the most retentive memory could not have remembered the thousandth part of them.

The difficulty of studying chemistry from that time till the year 1782 must have been very great: it was even perceived and complained of by the masters of the science. In 1782 Mr de Morveau, who had undertaken the chemical part of the *Encyclopedie Methodique*, published in the *Journal de Physique* a new chemical nomenclature, and at the same time invited all those persons who were fond of chemistry, and interested in its progress, to propose objections and improvements.

This new nomenclature was formed agreeably to the five following rules:

1. Every substance ought to have a name, and not to be denoted by a phrase.

2. Names ought to be as much as possible conformable to the nature of the things signified by them.

3. When the character of a substance is not well enough known to determine the denomination, a name which has no meaning is preferable to one which conveys a false idea.

4. In the choice of new words, those ought to be preferred which have their roots in the dead languages most generally known, that the word may be easily suggested by the sense, and the sense by the word.

5. The new words ought to be as suitable as possible to the genius of the languages for which they are formed.

This nomenclature was approved of by Macquer, and by Bergman, who had himself proposed one upon a plan not very different (D). He wrote to Morveau, and exhorted him to prosecute his undertaking with courage. "Do not spare (says he) a single improper denomination; those that are already learned will be always so, and those that are not will learn the sooner*."

* Encycl. Method. Chim. Preface.

This nomenclature was adopted by several chemists, and it was used in the greatest part of the first volume of the chemical part of the *Encyclopedie Methodique*; but the new discoveries in chemistry had produced a more accurate method of reasoning, and had enabled Lavoisier to explain the phenomena of the science without the assistance of the hypothetical principle of phlogiston, which had hitherto been necessary. As the language, even in its improved state, was accommodated to this principle, and presupposed its existence, new changes became evidently necessary, in order that, according to Morveau's rule, the words might denote the most essential properties of the things intended to be signified. Accordingly, when Morveau was in Paris in 1787, Lavoisier, Berthollet, and Fourcroy, agreed to labour in concert with him to bring the chemical nomenclature still nearer to perfection. These philosophers, assisted by the mathematicians of the Royal Academy and by several chemists, formed a new nomenclature, which they made public in 1787.

For some time little attention was paid to this nomenclature by foreign chemists, and it seemed generally to be disapproved. The adherents of the phlogistic system in France, who were exceedingly numerous, viewed it as an engine artfully formed to undermine and destroy their favourite theory. They resolved, therefore, unanimously, to crush, if possible, this new instrument, which they considered as

> ——— *in nostros fabricata machina muros,*
> *Inspectura domos, venturaque desuper urbi.*

And for this purpose they exerted themselves with a vigour, which was only equalled by the zeal and indefatigable exertions of their antagonists. A kind of civil war was thus kindled in the republic of letters, which was carried on with great animosity: And posterity will see, with regret, men of undoubted genius at times divesting themselves of the armour of truth and of candour, and endeavouring to serve their party, and stab their adversaries with darts steeped in the poison of calumny and falsehood*. This contest, however, which was not confined to France, was productive of good effects, which infinitely surpassed all the bad ones. It occa-

* See the Jour. de Phys. for 1788, 89, 90, 91, *passim*.

(D) See his thoughts on a natural history of fossils in the 4th vol. of his *Opusc.*

Conclusion.

occasioned an accumulation of facts, produced a rigid examination of the theories and opinions, introduced an accuracy into chemical experiments which has been of the most essential service, and gave that tone and vigour to the cultivators of chemistry which have brought to light the most sublime and unlooked for truths. It deserves attention, and the fact is no inconsiderable evidence in favour of the antiphlogistic theory, that almost all the illustrious chemists who at present adhere to it declared originally against it. Berthollet, Morveau, Black, Kirwan, and many other chemists, who are now its ablest defenders, were at first its most powerful opponents. "This system had hardly been published in France (says Dr Priestley, who still continues to adhere to the doctrine of phlogiston) before the principal philosophers and chemists of England, notwithstanding the rivalship which has long subsisted between the two countries, eagerly adopted it. Dr Black, in Edinburgh, and as far as I hear, all the Scots, have declared themselves converts, and, what is more, the same has been done by Mr Kirwan, who wrote a pretty large treatise in opposition to it. The English reviewers of books, I perceive, universally favour the new doctrine. In America, also, I hear of nothing else. It is taught, I believe, in all the schools on this continent, and the old system is entirely exploded. And now that Dr Crawford is dead, I hardly know of any person except my friends of the Lunar Society at Birmingham, who adhere to the doctrine of phlogiston; and what may now be the case with *them* in this age of revolutions, philosophical as well as civil, I will not at this distance answer for.

"It is no doubt *time*, and of course opportunity of examination and discussion, that gives stability to any principles. But this new theory has not only kept its ground, but has been constantly and uniformly advancing in reputation more than *ten years*, which, as the attention of so many persons, the best judges of every thing relating to the subject, has been unremittingly given to it, is no inconsiderable period. Every year of the last twenty or thirty has been of more importance to science, and especially to chemistry, than any ten in the preceding century†."

† *Considerations on the doctrine of phlogiston*, Introduction.

We have endeavoured in the preceding article to state the different theories which have successively made their appearance in *chemistry* with as much fairness as possible. If we have succeeded, the reader will be enabled to judge for himself which of these theories is the most consistent with truth; or rather, if we have succeeded, he will join with us in thinking that the theory of Lavoisier is in most points an accurate account of what takes place in nature.

This we consider as a sufficient reason for having adopted the new nomenclature; for as Morveau long ago observed, most of the objections that were made to it were rather levelled at the doctrine of those who formed it, than at the nomenclature itself. Its superiority to every other nomenclature cannot be disputed for an instant; and the vast facility which it has added to the acquisition of chemistry, must be acknowledged by every one who knows any thing about the science. The table of the new nomenclature will not be expected here, as it has been already given in the Appendix to the article Chemistry in the *Encyclopædia*. At any rate, it would have been unnecessary, as we have used the new names all along; and therefore our readers must by this time be well acquainted with them.

Upon the almost infinite number of criticisms which have been made on the new nomenclature, and the many new terms which since its publication have been successively proposed, we do not mean to enter. Few of these terms can bear a comparison with the French nomenclature, and still fewer have any claim to be preferred to it; and the philosophers who persist in these useless innovations, are more probably actuated by the desire of appearing to have a share in the great revolution which chemistry has undergone, than by any hopes of being able to improve the accuracy or the elegance of its language. How few have displayed the magnanimity of an illustrious philosopher of our own country, who, though he had invented a new nomenclature himself, exhorted his pupils not to use it, but to adopt that of the French chemists, which was likely soon to come into universal use.

Even the etymological remarks which have been made on the new nomenclature, we consider as either of little consequence or as ill-founded. The philosophers who formed it have displayed a sagacity and a moderation which could not be excelled, and have, upon the whole, formed a language much more systematic, and much more perfect, than could have been expected; and whoever compares it with the nomenclature proposed in 1782 by Morveau, will see how great a share of it is due to that illustrious and candid philosopher.

Notwithstanding what we have here said, we would not be understood to consider the new nomenclature as already arrived at a state of such absolute perfection, that no alteration whatever can be made in it except for the worse. Such perfection belongs not to the works of man; nor if it did, could it be expected in this case, if we consider for a moment the present state of chemistry. New discoveries must occasion additions and alterations in the nomenclature; but the authors of the new nomenclature have given us the rules by which changes and additions are to be made; and if they are adhered to, we may expect with confidence that the language of chemistry will in its advancement to perfection keep pace with the science. We have in the preceding article ventured in an instance or two to adopt little improvements that have been suggested by later writers. We have taken the liberty, too, of choosing, from the variety which the British chemists have proposed, that mode of spelling each of the terms which appeared to us most agreeable to the English idiom, and most conformable to analogy: Whether or not we have made a proper choice must be left for others to determine.

Erratum in the article Chemistry.

In page 305. *dele* the whole account of *Adamanta*, the existence of which as a peculiar earth has been destroyed by the subsequent experiment of *Klaproth*. It may be proper to mention, that in that section, n° 239. line 2. *infusible* ought to be *fusible*.

INDEX.

INDEX.

CHEMUNG, is a townfhip in Tioga co. New-York. By the ftate cenfus of 1796, 81 of its inhabitants were electors. It has Newton W. and Ofwego E. about 160 miles N. W. from New-York city, meafuring in a ftraight line.

Between this place and Newton, Gen. Sullivan, in his victorious expedition againft the Indians, in 1779, had a defperate engagement with the Six Nations, whom he defeated. The Indians were ftrongly intrenched, and it required the utmoft exertions of the American army, with field pieces, to diflodge them; although the former, including 250 tories, amounted only to 800 men, while the Americans were 5000 in number, and well appointed in every refpect.—*Morse*.

CHENENGO, is a northern branch of Sufquehanna River. Many of the military townfhips are watered by the N. W. branch of this river. The towns of Fayette, Jerico, Greene, Clinton, and Chenengo, in Tioga co. lie between this river and the E. waters of Sufquehanna.—*ib.*

CHENENGO, a poft town, and one of the chief in Tioga co. New-York. The fettled part of the town lies about 40 miles N. E. from Tioga point, between Chenengo River and Sufquehanna; has the town of Jerico on the northward. By the ftate cenfus of 1796, 169 of its inhabitants are electors. It was taken off from Montgomery co. and in 1791, it had only 45 inhabitants. It is 375 miles N. N. W. of Philadelphia.—*ib.*

CHENESSEE, or *Geneffee River* rifes in Pennfylvania, near the fpot which is the higheft ground in that

ftate, where the eafternmoft water of Alleghany river, and Pine creek, a water of Sufquehannah, and Tioga river rife. Fifty miles from its fource there are falls of 40 feet, and 5 from its mouth of 75 feet, and a little above that of 96 feet. Thefe falls furnifh excellent mill-feats, which are improved by the inhabitants. After a courfe of about 100 miles, moftly N. E. by N. it empties into lake Ontario, 4½ miles E. of Irondequat or Rundagut bay, and 80 E. from Niagara falls.

The fettlements on Cheneffee river from its mouth upwards, are, Hartford, Ontario, Wadfworth and Williamfburgh. The laft mentioned place, it is probable, will foon be the feat of extenfive commerce. There will not be a carrying place between New-York city and Williamfburgh, when the weftern canals and locks fhall be completed. The carrying places at prefent are as follows, viz. Albany to Schenectady 16 miles, from the head of the Mohawk to Wood creek 1, Ofwego falls 2, Cheneffee falls 2; fo that there are but 21 miles land carriage neceffary, in order to convey commodities from a tract of country capable of maintaining feveral millions of people. The famous Cheneffee flats lie on the borders of this river. They are about 20 miles long, and about 4 wide; the foil is remarkably rich, quite clear of trees, producing grafs near ten feet high. Thefe flats are eftimated to be worth £.200,000, as they now lie. They are moftly the property of the Indians.—*ib.*

CHEPAWAS, or *Chipeways*, an Indian nation inhabiting the coaft of lake Superior and the iflands in the lake. They

They could, according to Mr Hutchins, furnifh 1000 warriors 20 years ago. Other tribes of this nation inhabit the country round Saguinam or Sagana bay and lake Huron, bay Puan, and a part of lake Michigan. They were lately hoftile to the United States, but, by the treaty of Greenville, Auguft 3, 1795, they yielded to them the ifland de Bois Blanc.—*ib.*

CHEPAWYAN *Fort*, is fituated on a peninfula at the S. weftern end of Athapefcow lake, N. lat. 58. 45. W. long. 110. 18.; in the territory of the Hudfon bay company.—*ib.*

CHEPOOR, a fmall Spanifh town on the ifthmus of Darien and Terra Firma, in S. America, feated on a river of the fame name, 6 leagues from the fea. Lat. 10. 42. long. 77. 50.—*ib.*

CHEQUETAN, or *Seguataneio*, on the coaft of Mexico, or New-Spain, lies 7 miles weftward of the rocks of Seguataneio. Between this and Acapulco, to the eaftward, is a beach of fand of 18 leagues extent, againft which the fea breaks fo violently, that it is impoffible for boats to land on any part of it; but there is a good anchorage for fhipping at a mile or two from the fhore, during the fair feafon. The harbor of Chequetan is very hard to be traced, and of great importance to fuch veffels as cruife in thefe feas, being the moft fecure harbor to be met with in a vaft extent of coaft, yielding plenty of wood and water; and the ground near it is able to be defended by a few men. When Lord Anfon touched here, the place was uninhabited. —*ib.*

CHERA, a river near Colan, in the province of Quito, in Peru, running to Amotage: from whence Paita has its frefh water.

CHERAWS, a diftrict in the upper country of S. Carolina, having N. Carolina on the N. and N. E; Georgetown diftrict on the S. E. and Lynche's creek on the S. W. which feparates it from Camden diftrict. Its length is about 85 miles and its breadth 63; and is fubdivided into the counties of Darlington, Chefterfield and Marlborough. By the cenfus of 1791, there were 10,706 inhabitants, of which 7618 were white inhabitants, the reft flaves. It fends to the ftate legiflature 6 reprefentatives and 2 fenators; and in conjunction with Georgetown diftrict, one member to Congrefs. This diftrict is watered by Great Pedee River and a number of fmaller ftreams, on the banks of which the land is thickly fettled and well cultivated. The chief towns are Greenville and Chatham. The court-houfe in this diftrict is 52 miles from Camden, as far from Lumberton, and 90 from Georgetown. The mail ftops at this place.—*ib.*

CHERIPPE, an inconfiderable village on Terra Firma, from which the market of Panama is furnifhed with provifions weekly.—*ib.*

CHEROKEE, the ancient name of Tenneffee River. The name of Tenneffee was formerly confined to the fouthern branch which empties 15 miles above the mouth of Clinch River and 18 below Knoxville.—*ib.*

CHEROKEES, a celebrated Indian nation, now on the decline. They refide in the northern parts of Georgia, and the fouthern parts of the ftate of Tenneffee; having the Apalachian or Cherokee mountains on the E. which feparate them from N. and S. Carolina, and Tenneffee River on the N. and W. and the Creek Indians on the S. The country of the Cherokees, extending weftward to the Miffiffippi and northward to the Six Nations, was furrendered, by treaty at Weftminfter, 1729, to the crown of Great-Britain. The prefent line between them and the ftate of Tenneffee is not yet fettled. A line of experiment was drawn in 1792, from Clinch River acrofs Holfton to Chilhowee mountain; but the Cherokee commiffioners not appearing, it is called a line of experiment. The complection of the Cherokees is brighter than that of the neighboring Indians. They are robuft and well made, and taller than many of their neighbors; being generally 6 feet high, a few are more, and fome lefs. Their women are tall, flender, and delicate. The talents and morals of the Cherokees are held in great efteem. They were formerly a powerful nation; but by continual wars, in which it has been their deftiny to be engaged, with the northern Indian tribes, and with the whites, they are now reduced to about 1500 warriors; and they are becoming weak and pufillanimous. Some writers eftimate their numbers at 2500 warriors. They have 43 towns now inhabited.—*ib.*

CHERRY *Valley*, a poft town in Otfego co. New-York, at the head of the creek of the fame name, about 12 miles N. E. of Cooperftown, and 18 foutherly of Conajohary, 61 W. of Albany and 336 from Philadelphia. It contains about 30 houfes, and a Prefbyterian church. There is an academy here, which contained in 1796, 50 or 60 fcholars. It is a fpacious building, 60 feet by 40. The townfhip is very large, and lies along the E. fide of Otfego lake and its outlet to Adiquatangie creek. By the ftate cenfus of 1796, it appears that 629 of its inhabitants are electors. This fettlement fuffered feverely from the Indians in the late war.—*ib.*

CHERUBIM were emblematical figures: of which an account, a very vague one indeed, has been given in the *Encyclopædia*. We are far from thinking ourfelves qualified to improve that account, or to explain emblems in the Jewifh worfhip which even Jofephus did not underftand; and we certainly fhould not have refumed the fubject but to gratify a numerous clafs of our readers, and to comply with the requeft of fome highly refpected friends.

The followers of Mr Hutchinfon, who are firmly perfuaded that their mafter brought to light from the writings of the Old Teftament many important doctrines which had lain concealed, from all the piety, all the induftry, and all the learning of 1700 years, believe that, among other things, he and they have been able to afcertain the form and the import of the Hebrew Cherubim. Their difcoveries on this fubject, as we have been told by better judges than we pretend to be, are more clearly ftated by Mr Parkhurft in his Hebrew Lexicon, than by any other writer of that fchool. We fhall therefore lay before our readers his doctrine refpecting the form of the artificial cherubs, as well as of their emblematical meaning; and fubjoin a few remarks, which the nature of his reafoning has forced from us.

"*Firft*, then, as to the *form* of the artificial cherubs in the tabernacle and temple, Mofes (fays our author) was commanded (Exod. xxv. 18, 19.) 'Thou fhalt make two cherubs: of beaten gold fhalt thou make them at the two ends of the mercy feat. And thou fhalt make one cherub at the one end, and the other cherub

Cherubim. cherub at the other end : מן הכפרת out of the mercy-ſeat (Margin Eng. Tranſlat. of the matter of the mercy-ſeat) ſhall ye make the cherubs at the two ends thereof.' All which was accordingly performed (Exod. xxxvii. 7, 8.), and theſe cherubs were with the ark placed in the holy of holies of the tabernacle (Exod. xxvi. 33, 34. xl. 20.); as thoſe made by Solomon were afterwards in the holy of holies of the temple (1 Kings vii. 23, 27.)

We may obſerve that in Exodus Jehovah ſpeaks to Moſes of the cherubs as of figures well known; and no wonder, ſince they had always been among believers in the holy tabernacle from the beginning. (See Gen. iii. 24. Wiſd. ix. 8. And though mention is made of their faces (Exod. xxv. 20. 2 Chron. iii. 13.), and of their wings, (Exod. xxv. 20. 1 Kings, viii. 7. 2 Chron. iii. 11, 12.); yet neither in Exodus, Kings, nor Chronicles have we any particular deſcription of their form. This is however very exactly, and as it were, anxiouſly ſupplied by the prophet Ezekiel, ch. i. 5. 'Out of the midſt thereof (*i. e.* of the fire infolding itſelf, ver. 4.) דמות the likeneſs of four living creatures or animals; דמות אדם להנה the likeneſs of a man (being) with them.' This laſt Hebrew expreſſion cannot mean that they, *i. e.* the four animals, had the likeneſs of a man, which interpretation would indeed make the prophet contradict himſelf (comp. ver. 10.); but it imports that the likeneſs of a man in glory, called (verſe 26.) דמות כמראה אדם the likeneſs as the appearance of a man, and particularly deſcribed in that and the following verſes was with them. Ver. 6. 'And there were four faces to one (דמות or ſimilitude), and four wings to one, להם to them.' So there were at leaſt two compound figures. Ver 10. 'And the likeneſs of their faces; the face of a man, and the face of a lion, on the right ſide, to them four; and the face of an ox to them four; and the face of an eagle to them four.' Ezekiel knew (ch. x. 1—20.) that theſe were cherubs. Ver. 21. 'Four faces לאחד to one (cherub) and four wings to one.' This text alſo proves that the prophet ſaw more cherubs than one, and that each had four faces and four wings. And we may be certain that the cherubs placed in the holy of holies were of the form here deſcribed by the prieſt and prophet Ezekiel, becauſe we have already ſeen from Exodus, 1 Kings, and 2 Chronicles, that they likewiſe had faces and wings, and becauſe Ezekiel knew what he ſaw to be cherubs, and becauſe there were no four-faced cherubs any where elſe but in the holy of holies; for it is plain, from a compariſon of Exod. xxvi. 1, 31. 1 Kings vi, 29, 32, and 2 Chron. iii. 14. with Ezekiel xli. 18, 19, 20. that the artificial cherubs on the curtains and vail of the tabernacle, and on the walls, doors, and vail of the temple, had only two faces; namely, thoſe of a lion and of a man.

"For it muſt be obſerved further, that as the word כרוב is uſed for one compound figure with four faces, and כרובים in the plural for ſeveral ſuch compounds (ſee Exod. xxv. 18, 19. xxxvii. 8. 1 Kings vi. 23—26), ſo is כרוב applied to one of the cherubic animals, as to the ox, Ezek. x. 14; (compare ch. i. 10.) to the coupled cherub or lion-man, Ezek. xli. 18.; and כרובים to ſeveral of the cherubic animals as to ſeveral oxen, 1 Kings vii. 36, (compare ver. 29) to ſeveral coupled cherubs, Exod. xxvi. 1. 1 Kings vi. 32, 35. & al. I proceed to ſhew

"*Secondly*, of what the cherubs were emblems, and with what propriety. Cherubim.

"That the cherubic figures were emblems or repreſentatives of ſomething beyond themſelves is, I think, agreed by all, both Jews and Chriſtians. But the queſtion is, of what they were emblematical? To which I anſwer in a word, Thoſe in the holy of holies were emblematical of the ever bleſſed Trinity in covenant to redeem man, by uniting the human nature to the Second Perſon; which union was ſignified by the union of the faces of the lion and of the man in the cherubic exhibition, Ezek. i. 10. compare Ezek. xli. 18, 19. The cherubs in the holy of holies were certainly intended to repreſent ſome beings in heaven, becauſe St Paul has expreſly and infallibly determined that the holy of holies was a figure or type of heaven, even of that heaven where is the peculiar reſidence of God (Heb. ix. 24). And therefore theſe cherubs repreſented either the ever bleſſed Trinity with the man taken into the eſſence, or created ſpiritual angels. The following reaſons will, I hope, clearly prove them to be emblematical of the former, not of the latter:

"*1ſt*, Not of angels; becauſe (not now to inſiſt on other circumſtances in the cherubic form) no tolerable reaſon can be aſſigned why angels ſhould be exhibited with four faces apiece.

"*2dly*, Becauſe the cherubs in the holy of holies of the tabernacle were, by Jehovah's order, 'made out of the matter of the mercy-ſeat, or beaten out of the ſame piece of gold as that was' (Exod. xxv. 18, 19. xxxvii. 9.). Now the mercy-ſeat made of gold, and crowned, was an emblem of the divinity of Chriſt (See Rom. iii. 25.). The cherubs therefore repreſented not the angelic, but the Divine nature.

"*3dly*, The typical blood of Chriſt was ſprinkled before them on the great day of atonement (compare Exod. xxxviii. 9. Lev. xvi. 14. Heb. ix. 7, 12.): And this cannot in any ſenſe be referred to created angels, but muſt be referred to Jehovah only, becauſe,

"*4thly*, The high prieſt's entering into the holy of holies on that day, repreſented Chriſt's entering with his own blood into heaven, 'to appear in the preſence of God for us' (Heb. ix. 7, 24.). And,

"*5thly*, When God 'raiſed Chriſt (the humanity) from the dead, he ſet him at his own right hand in the heavenly places, far above, ΥΠΕΡΑΝΩ, all principality and power, and might, and dominion, and every name that is named, not only in this world, but alſo in that which is to come (Eph. i. 21.). Angels and authorities and powers being made ſubject unto him' (1 Peter iii. 22.)

"*6thly*, The prophet Ezekiel ſaith (ch. x. 20.), 'This is the living creature, החיה (which muſt mean one compound figure, comp. ver. 14.) that I ſaw' תחת (inſtead of, a ſubſtitute of 'the Aleim of Iſrael. תחת, it is granted, may refer either to ſituation or ſubſtitution, (ſee Gen. xxx. 2. l. 19.) as the ſenſe requires. Here, notwithſtanding what is ſaid ver. 19. the latter ſenſe is preferable, becauſe it was the glory of the God of Iſrael, *i. e.* the God-man in glory, (compare ch. i. 26.) not the Aleim (the Trinity) of Iſrael that were over the cherubim; and the text ſays not, *theſe* were the living *creatures*, but, *this* was the living *creature*, which I ſaw תחת אלהי ישראל. Now the glory was over both

Cherubim. both the cherubims, ver. 19. but one compound cherub only was a ſubſtitute of the Aleim.

" If it ſhould be here aſked, Why, then, were there two compound cherubs in the holy of holies? I anſwer, Had there not in this place been two compound cherubs, it would have been naturally impoſſible for them to repreſent what was there deſigned; for otherwiſe, all the faces could not have looked inwards toward each other, and down upon the mercy-ſeat, and on the interceding high prieſt ſprinkling the typical blood of Chriſt, (ſee Exod. xxxvii. 9.) and at the ſame time have looked outward toward the temple, לבית (Vulg. ad. domum exteriorem, to the outer houſe,) 2 Chron. iii. 13. Or, in other words, the Divine Perſons could not have been repreſented as witneſſing to each other's voluntary engagements for man's redemption, as beholding the ſacrifice of Chriſt's death, typified in the Jewiſh church, and at the ſame time as extending their gracious regards to the whole world. (See Iſa. liv. 5. and Spearman's Enquiry, p. 382. edit. Edinburgh.)

" The coupled cherub, or lion-man, on the vail, and curtains of the outer tabernacle, and on the vail, doors, and walls of the temple, accompanied with the emblematic palm tree, is ſuch a ſtriking emblem of the lion of the tribe of Judah (Rev. v. 5.) united to the man Chriſt Jeſus, as is eaſy to be perceived, but hard to be evaded. Theſe coupled cherubs appropriate the tabernacle or temple and their vails as emblems of Chriſt, and expreſs in viſible ſymbols what he and his apoſtles do in words. See John ii. 19, 21. Heb. viii. 2. ix. 11. x. 20. comp. Matt. xxvii. 51. And as the texts juſt cited from the New Teſtament afford us divine authority for aſſerting that the outer tabernacle or temple was a type of the body of Chriſt, ſo they furniſh us with an irrefragable argument to prove that the cherubs on their curtains or walls could not repreſent angels. For did angels dwell in Chriſt's body? No ſurely: But ' in him dwelt all the fulneſs of the Godhead bodily.' (Col. ii. 9.)

" I go on to conſider the propriety of the animals in the cherubic exhibition repreſenting the Three Perſons in the ever-bleſſed Trinity. And here to obviate any undue prejudice which may have been conceived againſt the Divine Perſons being ſymbolically repreſented under any animal forms whatever, let it be remarked that Jehovah appeared as three men to Abraham, (Gen. xviii.); that the ſerpent of braſs ſet up by God's command in the wilderneſs was a type or emblem of Chriſt, God-man, lifted up on the croſs (comp. Num. xxxi. 1—9. with John iii. 14. 15.); that at Jeſus' baptiſm the Holy Spirit deſcended in a bodily ſhape, like a dove, upon him (Luke iii. 21, 22); that Chriſt, as above intimated, is expreſsly called the lion of the tribe of Judah (Rev. v. 5.); and continually in that ſymbolical book ſet before us under the ſimilitude of a lamb. All theſe are plain ſcriptural repreſentations, each of them admirably ſuited, as the attentive reader will eaſily obſerve, to the particular circumſtances or ſpecific deſign of the exhibition. Why then ſhould it appear a thing incredible, yea why not highly probable, that Jehovah Aleim ſhould, under the typical ſtate, order his own Perſons and the union of the manhood with the eſſence to be repreſented by animal forms in the cherubim of glory? Eſpecially if it be conſidered that the three animal forms, excluſive of the man (who ſtood for the very human nature itſelf) are the chief of their reſpective genera: the ox or bull, of the tame or graminivorous; the lion of the wild or carnivorous; and the eagle, of the winged kind.—But this is by no means all: For as the great agents in nature, which carry on all its operations, certainly are the fluid of the heavens, or, in other words, the fire at the orb of the ſun, the light iſſuing from it, and the ſpirit or groſs air conſtantly ſupporting, and concurring to the actions and effects of the other two; ſo we are told (Pſal. xix. 1.) that השמים מספרים כבוד אל the heavens (are) the means of declaring, recounting, or particularly exhibiting the glory of God, even his eternal power and godhead, as St Paul ſpeaks, Rom. i. 20. And accordingly Jehovah himſelf is ſometimes, though rarely (I preſume for fear of miſtakes) called by the very name שמים or שמיא heavens in the Old Teſtament, ſee 2 Chron. xxxii. 20. (comp. 2 Kings xix. 14. Iſa. xxxvii. 15.) Dan. iv. 23. or 26.; as he is more frequently expreſſed by Ουρανος heaven in the New. (See Mat. xxi. 25. Mark xi. 30, 31. Luke xv. 18, 21. xx. 4, 5. John iii. 27.) Yea not only ſo, but we find in the Scriptures both of the Old and New Teſtament, that the Perſons of the eternal Three and their economical operations in the ſpiritual, are repreſented by the three conditions of the celeſtial fluid and their operations in the material world. Thus the peculiar emblem of the Word or Second Perſon is the שמש or light, and he is and does that to the ſouls or ſpirits of men, which the material or natural light is and does to their bodies. (See inter al. 2 Sam. xxiii. 4. Iſa. xlix. 6. lx. 1. Mal. iv. 2. or iii. 20. Luke i. 78. ii. 32. John i. 4—9. viii. 12. xii. 35, 36, 46.) The Third Perſon has no other diſtinctive name in ſcripture but רוח in Hebrew, and Πνευμα in Greek, (both which words in their primary ſenſe denote the material ſpirit or air in motion), to which appellation the epithet קדש, ἁγιον holy, or one of the names of God, is uſually added: and the actions of the Holy Spirit in the ſpiritual ſyſtem are deſcribed by thoſe of the air in the natural. (See John iii. 8. xx. 22. Acts ii. 2.) Thus, then, the Second and Third Perſons of the ever-bleſſed Trinity are plainly repreſented by ſcripture by the material light and air. But it is further written, Jehovah thy Aleim is a conſuming fire, Deut. iv. 24. (Comp. Deut. ix. 23. Heb. xii. 29. Pſal. xxi. 10. lxxviii. 21. Nah. i. 2.) And by fire, derived either immediately or mediately from heaven, were the typical ſacrifices conſumed under the old diſpenſation. Since, then, Jehovah is in ſcripture repreſented by the material heavens, and even called by their name, and eſpecially by that of fire, and ſince the Second and Third Perſons are exhibited reſpectively by the two conditions of light and ſpirit, and ſince fire is really a condition of the heavenly fluid as much diſtinct from the other two as they are from each other, it remains that the peculiar emblem of the Firſt Perſon (as we uſually ſpeak) of the eternal Trinity, conſidered with reſpect to the other two, be the fire.

" Bearing then in mind that the perſonality in Jehovah is in ſcripture repreſented by the material Trinity of nature; which alſo, like their divine antitype, are of one ſubſtance, that the primary ſcriptural type of the Father is fire; of the Word, light; and of the Holy Ghoſt, ſpirit, or air in motion; we ſhall eaſily perceive the propriety of the cherubic emblems. For the ox or bull, on account of his horns, the curling hair on

Cherubim. on his forehead, and his unrelenting fury when provoked (ſee Pſal. xxii. 13.) is a very proper animal emblem of fire; as the lion from his uſual tawny goldlike colour, his flowing mane, his ſhining eyes, his great vigilancy and prodigious ſtrength, is of light; and thus likewiſe the eagle is of the ſpirit or air in action, from his being chief among fowls, from his impetuous motion (ſee 2 Sam. i. 23. Job ix. 26. Jer. iv. 13. Lam. iv. 19.), and from his towering and ſurpriſing flights in the air (ſee Job xxxix. 27. Prov. xxiii. 5. xxx. 19. Iſa. xl. 31. and Bochart, vol. iii. page 173.) And the heathen uſed theſe emblematic animals, or the like, ſometimes ſeparate, ſometimes joined, in various manners, as repreſentatives of the material Trinity of nature, which they adored. Theſe particulars Mr Hutchinſon has proved with a variety of uſeful learning, vol. vii. p. 381. & ſeq. and any perſon who is tolerably acquainted with the heathen mythology will be able to increaſe his valuable collection with many inſtances of the ſame kind from modern as well as ancient accounts of the pagan religions.

"Thus, then, the faces of the ox, the lion, and the eagle, repreſenting at ſecond hand the Three Perſons of Jehovah, the Father, the Word, and the Holy Spirit; and the union of the divine light with man being plainly pointed out by the union of the faces of the lion and the man (ſee Ezek. i. 10. xli. 18.), we may ſafely aſſert, that the cherubim of glory (Heb. ix. 5.) in the holy of holies were divinely inſtituted and proper emblems of the Three Eternal Perſons in covenant to redeem man, and of the union of the divine and human natures in the perſon of Chriſt. And we find (Gen. iii. 24.) that immediately on Adam's expulſion from paradiſe, and the ceſſation of the firſt or paradiſiacal diſpenſation of religion, Jehovah Aleim himſelf ſet up theſe emblems, together with the burning flame המתהפכת rolling upon itſelf, to keep the way to the tree of life; undoubtedly, conſidering the ſervices performed before them, not to hinder, but to enable, man to paſs through it."

Thus far Mr Parkhurſt; and to his diſſertation where is the man who will deny the merit of erudition, combined with ingenuity? To the latter part of his reaſoning, however, objections obtrude themſelves upon us of ſuch force, that we know not how to anſwer them. The reader obſerves, that according to this account, the cherubim are only at *ſecond hand* emblematical of the Holy Trinity, and that the *primary* emblem is that fluid which the author conceives to fill the ſolar ſyſtem, and to be one ſubſtance under the different appearances or modifications of *fire*, *light*, and *groſs air*. But unfortunately for this reaſoning, we are as certain as we can be of any matter of fact, that *fire* and *air* are *not* one ſubſtance; that the *groſs air* itſelf is compounded of very *different* ſubſtances; and that even *light* is a different ſubſtance from that which cauſes in us the ſenſation of heat, and to which modern chemiſts have given the name of *caloric* (See CHEMISTRY-*Index* in this Supplement). We admit, that the *primary atoms* of all matter *may be* ſubſtances of the very ſame kind, though we do not *certainly know* that they are: but this makes nothing for our author's hypotheſis; becauſe the ſun and all the planets muſt, in that caſe, be added to his one ſubſtance, which would no longer appear under a triple form. Could it indeed be proved, that all men from Adam downwards, who made uſe of cherubic figures Cherubim. for the very ſame purpoſe with the ancient Jews, *believed* that fire, air, and light, are different modifications of the ſame ſubſtance, their belief, though erroneous, would be a ſufficient foundation for our author's reaſoning: but of this no proof is attempted, and certainly none that is ſatisfactory could be brought.

Our learned author, indeed, takes much for granted without proof. He has not proved, that anywhere the bull was the emblem or hieroglyphic of *fire*, the lion of *light*, or the eagle of *air*. We do not, it muſt be owned, know that ſuch hieroglyphics were *not* uſed in Egypt and other countries before the introduction of alphabetical characters; but unleſs they were ſo uſed by Adam, all that is here ſaid of the *propriety* of theſe emblems muſt go for nothing: Indeed we ſee not their peculiar propriety. The tawny colour, flowing mane, and fierceneſs of the lion, might, for any thing that we can perceive to the contrary, repreſent *fire* as fitly as the horns, curling hair, and fury of the bull; and if it be true, as is generally ſaid, that the eagle can look ſteadily on the ſun, he ſeems, of all the three, to be the fitteſt emblem of light.

But there are other objections to this interpretation of the word cherubim. The four animals in the Revelation, which were undoubtedly cherubim, as well as the four and twenty elders, fell down before the Lamb, and worſhipped God.* Now, ſays Dr Gregory Sharp, "it is ſcarce to be conceived, if theſe four beaſts were repreſentatives of the divine perſons, that they could with any propriety, or without the greateſt ſolecifm, be ſaid and deſcribed to fall down before and worſhip other emblematical repreſentations of the ſame divine nature and perfections: And therefore, whatever theſe beaſts were emblems of, they could not be cherubim in Mr Hutchinſon's ſenſe of that word; it being as contrary to the rational explanation of a viſion to ſay that one emblem of the divinity ſhould worſhip another emblem of it, as it is contrary to the reaſon of mankind, and to all our notions either of the Godhead or of worſhip, to ſay that the Trinity worſhipped the Trinity, or any one Perſon in the Trinity."

* Ch. v. 8. xix. 4.

This objection is admitted by our learned author to be a very plauſible one. To us it appears unanſwerable. He anſwers it, however, in the following words:

"Let it be carefully obſerved, that theſe repreſentations in Rev. ch. v. and xix. are not only viſional but hieroglyphical, and therefore muſt be explained according to the analogy of ſuch emblematical exhibitions; and as at ver. 6. 'the lamb, as it had been ſlain, having ſeven horns and ſeven eyes, ſtanding in the midſt of the throne, and of the four animals, and of the four-and-twenty elders,' is evidently ſymbolical of the Lamb of God now raiſed from the dead, and inveſted with all knowledge and power both in heaven and in earth; ſo 'the four animals falling down before him' (ver. 8.), and, as it is expreſſed (ch. xix. 4.) 'worſhipping God who ſat upon the throne,' muſt, in all reaſon, be explained ſymbolically likewiſe, not from any abſtract or metaphyſical notions we may have framed to ourſelves of worſhip in general, but from the ſpecific and peculiar circumſtances of the caſe before us. Thus likewiſe, when in 1 Chron. xxix. 20. 'All the congregation worſhipped Jehovah and the king, namely David, the worſhip to both is expreſſed by the ſame ſtrong

strong phrase—ל וישתחוו prostrated themselves to, LXX. προσεκυνησαν; yet surely no one will say that the people meant to worship David as God, but only to acknowledge him as king. So Adonijah, who had contested the crown with Solomon, came, וישתחו and worshipped King Solomon, (1 Kings 1, 53.) not as God doubtless, but as king, thereby surrendering his own claim to the throne. However "contrary therefore it may be to the reason of mankind, and to all our notions either of the Godhead or of worship, to say that the Trinity worshipped the Trinity, or any one Person of the Trinity," *i. e.* with divine worship as a creature worships his Creator; yet it is by no means contrary to the rational and scriptural explanation of an emblematic vision, to say that the hieroglyphical emblems of the whole ever-blessed Trinity fell down and worshipped the hieroglyphical emblem of the God-man, or God who sat upon the throne. Since such falling down, prostration, or worshipping, was the usual symbolical act, as it still is in the east, not only of divine worship, but of acknowledging the regal power to be in the person so worshipped; and these acts of the cherubic animals in Rev. v. 6, xix. 4. meant nothing more than either a cession of the administration of all divine power to Christ God-man, or a declaration of the divine Persons, by their hieroglyphical representatives, that He must reign till all his enemies were made his footstool. Comp. Mat. xxviii. 18. 1 Cor. xv. 25."

With every inclination to honour the memory of Mr Parkhurst, who was certainly a scholar, and, which is of more value, a pious and a good man, we cannot help considering this answer as mere trifling. In the 18th Psalm, the Lord is said to "ride upon a cherub;" and in Ezekiel, chap. i. there is said to have "been over the heads of the cherubim *a throne*, and upon that throne the likeness or appearance of *a man*," whom we take to be the Son of God incarnate. But is there any country in which the regal power of the sovereign is acknowledged by his riding, not upon his subjects, but upon other co-equal sovereigns? or, in which it is the custom for the sovereign to place his viceroy (for such our Saviour in his *human* nature certainly is) in his throne above himself?

We must therefore confess, that we know not of what the cherubic figures were emblematical, and that he who labours to establish the doctrine of the ever blessed Trinity by such criticisms and reasonings as those which we have examined, is either a secret enemy to that doctrine, or a very injudicious friend.

CHESAPEAK, is one of the largest and safest bays in the United States. Its entrance is nearly E. N. E. and S. S. W. between Cape Charles, lat. 37. 12. and Cape Henry, lat. 37. in Virginia, 12 miles wide, and it extends 270 miles to the northward, dividing Virginia and Maryland. It is from 7 to 18 miles broad, and generally as much as 9 fathoms deep; affording many commodious harbors, and a safe and easy navigation. It has many fertile islands, and these are generally along the E. side of the bay, except a few solitary ones near the western shore. A number of navigable rivers and other streams empty into it, the chief of which are Susquehanna, Patapsco, Patuxent, Potowmack, Rappahannock, and York, which are all large and navigable. Chesapeak bay affords many excellent fisheries of herring and shad. There are also excellent crabs and oysters. It is the resort of swans, but is more particularly remarkable for a species of wild duck, called *canvasback*, whose flesh is entirely free from any fishy taste, and is admired by epicures, for its richness and delicacy. In a commercial point of view, this bay is of immense advantage to the neighboring states, particularly to Virginia. Of that state it has been observed, with some little exaggeration, however, that "every planter has a river at his door." —*Morse.*

CHEESADAWD *Lake*, about 210 miles N. E. by E. of the Canadian house, on the E. end of Slave lake, in the Hudson bay company's territory; is about 35 miles in length and the same in breadth. Its western shore is mountainous and rocky.—*ib.*

CHESHIRE *Co.* in New-Hampshire, lies in the S. W. part of the state, on the E. bank of Connecticut river. It has the state of Massachusetts on the south, Grafton co. on the N. and Hillsborough co. E. It has 34 townships, of which Charlestown and Keene are the chief, and 28,772 inhabitants, including 16 slaves.—*ib.*

Cheshire, a township in Berkshire co. Massachusetts; famous for its good cheese; 140 miles N. westerly from Boston.—*ib.*

Cheshire, a township in New-Haven co. Connecticut, 15 miles N. of New-Haven city, and 26 S. W. of Hartford. It contains an Episcopal church and academy, and 3 Congregational churches.

CHESNUT *Hill*, a town in Northampton county Pennsylvania, ten miles from Philadelphia and two from Germantown, a fine elevated and healthy situation, commanding an extensive and delightful prospect of the capital and the surrounding country.

Chesnut *Hill*, a township in Northampton co. Pennsylvania.—*ib.*

Chesnut *Creek*, a branch of the Great Kanhaway, in Virginia, where it crosses the Carolina line. Here, it is said, are iron mines.—*ib.*

Chesnut *Ridge*. Part of the Alleghany mountains, in Pennsylvania, are thus called, S. eastward of Greensborough.—*ib.*

CHESS, the celebrated game, of which a copious account has been given in the Encyclopædia, is affirmed by Sir William Jones to have been invented by the Hindoos. If evidence were required to prove this fact (says he*), we may be satisfied with the testimony of the Persians, who, though as much inclined as other nations to appropriate the ingenious inventions of a foreign people, unanimously agree that the game was imported from the west of *India* in the sixth century of our era. It seems to have been immemorially known in *Hindostan* by the name of *Cheturanga*, i. e. the four *angá's*, or members of an army; which are these, *elephants*, *horses*, *chariots*, and *foot-soldiers*; and in this sense the word is frequently used by epic poets in their descriptions of real armies. By a natural corruption of the pure Sanscrit word, it was changed by the old Persians into *Chetrang*; but the Arabs, who soon after took possession of their country had neither the initial nor final letter of that word in their alphabet, and consequently altered it further into *Shetranj*, which found its way presently into the modern *Persian*, and at length into the dialects of India, where the true derivation of the name is known only to the learned. Thus has a very significant word in the sacred language of the

* *Asiatic Researches*, vol. ii. Mem. 9.

Brahmins

Chefs. Brahmins been transformed by fucceffive changes into *axedrez*, *fcacchi*, *échces*, *chefs*, and by a whimfical concurrence of circumftances, has given birth to the English word *check*, and even a name to the *exchequer* of Great Britain."

It is confidently afferted, that Sanfcrit books on *chefs* exift in Bengal; but Sir William had feen none of them when he wrote the memoir which we have quoted. He exhibits, however, a defcription of a very ancient *Indian* game of the fame kind, but more complex, and in his opinion, more modern than the fimple chefs of the *Perfians*. This game is alfo called *Chaturanga*, but more frequently *Chaturaji*, or the *four kings*, fince it is played by four perfons reprefenting as many princes, two allied armies combating on each fide. The defcription is taken from a book called *Bhawifhya Purán*; in which the form and principal rules of this factitious warfare are thus laid down: "Eight fquares being marked on all fides, the *red* army is to be placed to the eaft, the *green* to the fouth, the *yellow* to the weft, and the *black* to the north. Let the *elephant* (fays the author of the *Purán*) ftand on the left of the *king*; next to him the *horfe*; then the *boat*; and before them all four *foot-foldiers*; but the *boat* muft be placed in the angle of the board."

"From this paffage (fays the prefident) it clearly appears that an army with its four *angás* muft be placed on each fide of the board, fince an *elephant* could not ftand, in any other pofition, on the left hand of each *king*; and Radhacant (a pandit) informed me, that the board confifted, like ours, of 64 fquares, half of them occupied by the forces, and half vacant. He added, that this game is mentioned in the oldeft law books, and that it was invented by the wife of a king, to amufe him with an image of war, while his metropolis was befieged in the fecond age of the world. A *fhip* or *boat* is abfurdly fubftituted, we fee, in this complex game for the *rat'h*, or armed *chariot*, which the *Bengalefe* pronounce *rot'h*, and which the Perfians changed into *rokh*; whence came the *rook* of fome European nations; as the *vierge* and *fol* of the French are fuppofed to be corruptions of *ferz* and *fil*, the *prime minifter* and *elephant* of the Perfians and Arabs."

As fortune is fuppofed to have a great fhare in deciding the fate of a battle, the ufe of dice is introduced into this game to regulate its moves; for (fays the Purán) "if *cinque* be thrown, the *king* or a *pawn* muft be moved; if *quatre*, the *elephant*; if *trois*, the *horfe*; and if *deux*, the *boat*. The *king* paffes freely on all fides, but over *one* fquare only; and with the fame limitation the *pawn* moves, but he advances ftraight forward, and kills his enemy through an angle. The *elephant* marches in all directions as far as his driver pleafes; the *horfe* runs obliquely, traverfing the fquares; and the *fhip* goes over two fquares diagonally." The *elephant*, we find, has the powers of our *queen*, as we are pleafed to call the *general* or *minifter* of the Perfians; and the *fhip* has the motion of the piece, to which we give the unaccountable appellation of *bifhop*, but with a reftriction which muft greatly leffen its value.

In the *Purán* are next exhibited a few general rules and fuperficial directions for the conduct of the game. Thus, "the *pawns* and the *fhip* both kill and may be voluntarily killed; while the *king*, the *elephant*, and the *horfe* may flay the foe, but muft not expofe themfelves to be flain. Let each player preferve his own forces with extreme care, fecuring his *king* above all, and not facrificing a fuperior to keep an inferior piece." Here (fays the Prefident) the commentator on the *Purán* obferves, that the *horfe*, who has the choice of *eight* moves from any central pofition muft be preferred to the *fhip*, which has only the choice of *four*. But the argument would not hold in the common game, where the *bifhop* and *tower* command a whole line, and where a knight is always of lefs value than a tower in action, or the bifhop of that fide on which the attack is begun. "It is by the overbearing power of the *elephant*, (continues the *Purán*) that the king fights boldly; let the whole army, therefore, be abandoned, in order to fecure the *elephant*. The king muft never place one *elephant* before another, unlefs he be compelled by want of room, for he would commit a dangerous fault: and if he can flay one of two hoftile elephants, he muft deftroy that on his left hand."

All that remains of the paffage which was copied for Sir William Jones relates to the feveral modes in which a partial fuccefs or complete victory may be obtained by any one of the four players; for, as in a difpute between two allies, one of the kings may fometimes affume the command of all the forces, and aim at a feparate conqueft. Firft, "When any one king has placed himfelf on the fquare of another king (which advantage is called *finhafana* or the *throne*) he wins a ftake, which is doubled if he kill the adverfe monarch when he feizes his place; and if he can feat himfelf on the throne of his ally, he takes the command of the whole army." Secondly, "If he can occupy fucceffively the thrones of all the three princes, he obtains the victory, which is named *cheturaji*; and the ftake is doubled if he kill the laft of the three, juft before he takes poffeffion of his throne; but if he kill him on his throne, the ftake is quadrupled. Both in giving the *finhafana* and the *cheturaji* the king muft be fupported by the *elephants*, or by all the forces united." Thirdly, "When one player has his own king on the board, but the king of his partner has been taken, he may replace his captive ally, if he can feize both the adverfe kings; or, if he cannot effect their capture, he may exchange his king for one of them againft the general rule, and thus redeem the allied prince, who will fupply his place." This advantage has the name of *nripacrifhta* or *recovered by the king*. Fourthly, "If a *pawn* can march to any fquare, on the oppofite extremity of the board, except that of the king or that of the fhip, he affumes whatever power belonged to that fquare." Here we find the rule, with a flight exception, concerning the advancement of *pawns*, which often occafions a moft interefting ftruggle at our common chefs; but it appears that, in the opinion of one ancient writer on the Indian game, this privilege is not allowable when a player has three pawns on the board; but when only one pawn and one fhip remains, the pawn may advance even to the fquare of a king or a fhip, and affume the power of either. Fifthly, According to the people of *Lancá*, where the game was invented, "there could be neither victory or defeat, if a king were left on the plain without force; a fituation which they named *cacacafht' ha*." Sixthly, "If three fhips happen to meet, and the fourth fhip can be brought up to them in the remaining angle, this has the name of *vrihannauca*; and the player of the fourth feizes all the others."

The

The account of this game in the original Sanfcrit is in verfe, and there are two or three couplets ftill remaining, fo very dark, either from an error in the manufcript, or from the antiquity of the language, that Sir William Jones could not underftand the *Pandit's* explanation of them, and fufpects, that even to him, they gave very indiftinct ideas. It would be eafy, however, he thinks, if it be judged worth while, to play at the game by the preceding rules, and a little practice would perhaps make the whole intelligible.

CHESTER, a townfhip in Lunenburg co. Nova-Scotia, on Mahone bay, fettled originally by a few families from New-England. From hence to Windfor is a road, the diftance of 25 miles.—*Morse*.

Chester a fmall plantation in Lincoln co. Maine, 9 miles from Titcomb. It has 8 or 9 families.—*ib*.

Chester, a townfhip in Hampfhire co. Maffachufetts, adjoining Weftfield on the E. and about 20 miles N. W. of Springfield. It contains 177 houfes, and 1119 inhabitants.—*ib*.

Chester, a large, pleafant, and elevated townfhip in Rockingham co. New-Hampfhire. It is 21 miles in length; and on the W. fide is a pretty large lake, which fends its waters to Merrimack River. It was incorporated in 1722, and contains 1902 inhabitants, who are chiefly farmers. It is fituated on the E. fide of Merrimack River, 14 miles N. W. of Haverhill, as far W. of Exeter, 30 W. by S. of Portfmouth, 6 northerly of Londonderry, and 306 from Philadelphia. From the compact part of this town there is a gentle defcent to the fea, which, in a clear day, may be feen from thence. It is a poft town, and contains about 60 houfes and a Congregational church.

Rattlefnake hill, in this townfhip, is a great curiofity: it is half a mile in diameter, of a circular form, and 400 feet high. On the S. fide, 10 yards from its bafe, is the entrance of a cave, called the Devil's Den, which is a room 15 or 20 feet fquare, and 4 feet high, floored and circled by a regular rock, from the upper part of which are dependent many excrefcences, nearly in the form and fize of a pear, which, when approached by a torch, throw out a fparkling luftre of almoft every hue. It is a cold, dreary place, of which many frightful ftories are told by thofe who delight in the marvellous.—*ib*.

Chester, a townfhip in Windfor co. Vermont, W. of Springfield, and 11 miles W. by S. of Charleftown, in New-Hampfhire, and contains 981 inhabitants.—*ib*.

Chester, a borough and poft town in Pennfylvania, and the capital of Delaware co. pleafantly fituated on the W. fide of Delaware River near Marcus Hook, and 13 miles N. E. of Wilmington. It contains about 60 houfes, built on a regular plan, a court-houfe and a gaol. From Chefter to Philadelphia is 20 miles by water, and 15 N. E by land; here the river is narrowed by iflands of marfh, which are generally banked, and turned into rich and immenfely valuable meadows. The firft colonial affembly was convened here, the 4th of December, 1682. The place affords genteel inns and good entertainment, and is the refort of much company from the metropolis, during the fummer feafon. It was incorporated in December, 1795, and is governed by 2 burgeffes, a conftable, a town clerk, and 3 affiftants; whofe power is limited to preferve the peace and order of the place.—*ib*.

Chester *Co.* in Pennfylvania, W. of Delaware co. and S. W. of Philadelphia; about 45 miles in length, and 30 in breadth. It contains 33 townfhips, of which Weft-Chefter is the fhire-town, and 27,937 inhabitants, of whom 145 are flaves. Iron ore is found in the northern parts, which employs 6 forges. Thefe manufacture about 1000 tons of bar iron annually.—*ib*.

Chester *Court-Houfe*, in S. Carolina, 22 miles S. of Pinckney court-houfe, and 58 N. W. of Columbia. A poft-office is kept here.—*ib*.

Chester *River*, a navigable water of the eaftern fhore of Maryland, which rifes two miles within the line of Delaware ftate, by two fources, Cyprus and Andover creeks, which unite at Bridgetown; runs nearly S. weftward; after paffing Chefter it runs S. nearly 3 miles, when it receives S. E. creek, and 15 miles farther, in a S. W. direction, it empties into Chefapeak bay, at Love point. It forms an ifland at its mouth, and by a channel on the E. fide of Kent Ifland communicates with Eaftern bay. It is propofed to cut a canal, about 11 miles long, from Andover creek, a mile and an half from Bridgetown, to Salifbury, on Upper Duck creek, which falls into Delaware at Hook ifland.—*ib*.

Chester, a fmall town in Shannandoah co. Virginia, fituated on the point of land formed by the junction of Allen's or North River and South River which form the Shannandoah; 16 miles S. by W. of Winchefter. N. lat. 39. 2. W. long. 78. 22.—*ib*.

Chester *Co.* in Pinckney diftrict, S. Carolina, lies in the S. E. corner of the diftrict, on Wateree River and contains 6866 inhabitants; of whom 5866 are whites, and 938 flaves. It fends two reprefentatives, but no fenator, to the ftate legiflature.—*ib*.

Chester, a town in Cumberland co. Virginia, fituated on the S. W. bank of James River, 15 miles N. of Blandford, and 6 S. of Richmond.—*ib*.

CHESTERFIELD, a townfhip in Hampfhire co. Maffachufetts, 14 miles W. of Northampton. It contains 180 houfes, and 1183 inhabitants.

Chesterfield, a townfhip in Chefhire co. New-Hampfhire, on the E. bank of Connecticut River, having Weftmoreland N. and Hinfdale S. It was incorporated in 1752, and contains 1905 inhabitants. It lies about 25 miles S. by W. of Charleftown, and about 90 or 100 W. of Portfmouth. About the year 1730, the garrifon of fort Dummer was alarmed with frequent explofions and with columns of fire and fmoke emitted from Weft river mountain, in this townfhip, and 4 miles diftant from that fort. The like appearances have been obferved at various times fince; particularly one in 1752, was the moft fevere of any. There are two places, where the rocks bear marks of having been heated and calcined.—*ib*.

Chesterfield *Co.* in S. Carolina, is in Cheraws diftrict, on the N. Carolina line. It is about 30 miles long, and 29 broad.—*ib*.

Chesterfield *Co.* in Virginia, is between James and Appamatox rivers. It is about 30 miles long, and 25 broad; and contains 14,214 inhabitants, including 7487 flaves.—*ib*.

Chesterfield *Inlet*, on the W. fide of Hudfon bay, in New South Wales, upwards of 200 miles in length, and from 10 to 30 in breadth—full of iflands.—*ib*.

CHESTERTOWN, a poft town and the capital of

Kent co. Maryland, on the W. side of Chester River, 16 miles S. W. of Georgetown, 38 E. by S. from Baltimore, and 81 S. W. of Philadelphia. It contains about 140 houses, a church, college, court house, and gaol. The college was incorporated in 1782, by the name of *Washington.* It is under the direction of 24 trustees, who are empowered to supply vacancies and hold estates, whose yearly value shall not exceed £.6,000 currency. In 1787, it had a permanent fund of £.1,250 a year settled upon it by law. N. lat. 39. 12. W. long. 75 57.—*ib.*

CHETIMACHAS. The Chetimachas fork is an outlet of Mississippi River in Louisiana, about 30 leagues above New-Orleans, and after running in a southerly direction about 8 leagues from that river, divides into two branches, one of which runs S. westerly, and the other S. easterly, to the distance of 7 leagues, when they both empty their waters into the Mexican gulf. On the Chetimachas, 6 leagues from the Mississippi, there is a settlement of Indians of the same name; and thus far it is uniformly 100 yards broad, and from 2 to 4 fathoms deep, when the water is lowest. Some drifted logs have formed a shoal at its mouth on the Mississippi; but as the water is deep under them, they could be easily removed; and the Indians say there is nothing to impede navigation from their village to the gulf. The banks are more elevated than those of the Mississippi, and in some places are so high as never to be overflowed. The natural productions are the same as on the Mississippi, but the soil, from the extraordinary size and compactness of the canes, is superior. If measures were adopted and pursued with a view to improve this communication, there would soon be, on its banks, the most prosperous and important settlements in that colony.—*ib.*

CHETIMACHAS, GRAND LAKE OF, in Louisiana, near the mouth of the Mississippi, is 24 miles long, and 9 broad. Lake de Portage, which is 13 miles long, and 1½ broad, communicates with this lake at the northern end, by a strait a quarter of a mile wide. The country bordering on these lakes, is low and flat, timbered with cypress, live and other kinds of oak; and on the eastern side, the land between it and the Chafalaya River is divided by innumerable streams, which occasion as many islands. Some of these streams are navigable. A little distance from the S. eastern shore of the lake Chetimachas, is an island where persons passing that way generally halt as a resting place. Nearly opposite this island, there is an opening which leads to the sea. It is about 150 yards wide, and has 16 or 17 fathom water.—*ib.*

CHETTENHAM, a township in Montgomery co. Pennsylvania.—*ib.*

CHEVRETTE, in artillery, is an engine employed to raise guns or mortars into their carriage. It is formed of two pieces of wood about four feet long, standing upon a third, which is square. The uprights are about a foot asunder, and pierced with holes exactly opposite to one another, to receive a bolt of iron, which is put in, either higher or lower at pleasure, to serve as a support to a handspike, by which the gun is raised up. By the author of the Military Guide, this is said to be the most useful of all the inventions for raising guns into their carriages; and it seems these inventions have been many.

CHIAMETLAN, a maritime province of Mexico, in N. America, with a town of the same name, said to be 37 leagues either way, from N. to S. or from E. to W. It is very fertile, contains mines of silver, and produces a great deal of honey and wax. The native Indians are well made and warlike. The river St Jago empties into the sea here, N. W. from the point of St Blas. The chief town is St Sebastian.—*Morse.*

CHIAPA, a river and inland province of Mexico or New-Spain, in the audience of Mexico. This province is bounded by Tabasco on the N.; by Yucatan N. E.; by Soconusco S. E.; and by Vera Paz on the E. It is 85 leagues from E. to W. and about 30 where narrowest, but some parts are near 100. It abounds with great woods of pine, cypress, cedar, oak, walnut, wood-vines, aromatic gums, balsams, liquid amber, tacamahaca, copal, and others, that yield pure and sovereign balsams; also with corn, cocoa, cotton and wild cochineal; pears, apples, quinces, &c. Here they have achiotte, which the natives mix with their chocolate to give it a bright color. Chiapa abounds with cattle of all sorts; it is famous for a fine breed of horses, so valuable, that they send their colts to Mexico, though 500 miles off. Beasts of prey are here in abundance, with foxes, rabbits, and wild hogs. In this province there is variety of snakes, particularly in the hilly parts, some of which are said to be 20 feet long, others of a curious red color, and streaked with white and black, which the Indians tame, and even put them about their necks. Here are two principal towns called Chiapa. The Chiapese are of a fair complexion, courteous, great masters of music, painting and Mechanics, and obedient to their superior. The principal river is that of Chiapa, which, running from the N. through the country of the Quelenes, at last falls into the sea at Tabasco. It is well watered; and by means of Chiapa River, they carry on a pretty brisk trade with the neighboring provinces, which chiefly consists in cochineal and silk; in which last commodity the Indians employ their wives for making handkerchiefs of all colors, which are bought up by the Spaniards and sent to Europe. Though the Spaniards reckon this one of their poorest provinces in America, as having no mines or sand of gold, nor any harbor on the South Sea, yet in size it is inferior to none but Guatimala. Besides, it is a place of great importance to the Spaniards, because the strength of all their empire in America depends on it; and into it is an easy entrance by the river Tabasco, Puerto Real, and its vicinity to Yucatan.—*ib.*

CHIAPA, the name of two towns in the above province; the one is sometimes called *Cividad Real*, or the Royal city, and the other *Chiapa de los Indos*, inhabited by Spaniards. Cividad Real is a bishop's see, and the seat of the judicial courts. It is delightfully situated on a plain, surrounded with mountains, and almost equally distant from the N. and S. seas, and 100 leagues N. W. from Guatimala. The bishop's revenue is 8000 ducats a year. The place is neither populous nor rich; and the Spanish gentry here are become a proverb on account of their pride, ignorance, and poverty. It has several monasteries; and the cathedral is an elegant structure. This city is governed by magistrates chosen amongst the burgesses of the

the town by a particular privilege granted them by the king of Spain. N. lat. 17. W. long. 96. 40.

The other town, called *Chiapa de los Indos*, that is, as belonging to the Indians, is the largeft they have in this country, and lies in a valley near the river Tabafco, which abounds with fifh, and is about 12 leagues N. W. of Chiapa, or Cividad Real. The celebrated Bartholomew de las Cafas, the friend of mankind, was the firft bifhop of Chiapa; and having complained to the court of Madrid of the cruelties of the Spaniards here, procured the people great privileges, and an exemption from flavery. This is a very large and rich place, with many cloifters and churches in it, and no town has fo many *Dons* of Indian blood as this Chiapa. On the river they have feveral boats, in which they often exhibit fea-fights and fieges. In the environs are feveral farms well ftocked with cattle, and fome fugar plantations. Wheat is brought here from the Spanifh Chiapa, and of it they make hard bifcuit, which the poorer Spaniards and Indians carry about and exchange for cotton, wool, or fuch little things as they want. There are about 20,000 Indians in this town.—*ib.*

CHICAPEE, or *Chickabee*, a fmall river in Maffachufetts, which rifes from feveral ponds in Worcefter co. and running S. W. unites with Ware river, and 6 miles further empties into the Connecticut at Springfield, on the E. bank of that river.—*ib.*

CHICCAMOGGA, a large creek which runs N. wefterly into Tenneffee river. Its mouth is 6 miles above the Whirl and about 27 S. W. from the mouth of the Hiwaffee. N. lat. 35. 18. The Chiccamogga Indian towns lie on this creek, and on the bank of the Tenneffee.—*ib.*

CHICHA, the name given by the natives to the ifland of Jeffo, which lies to the fouth of Oku-Jeffo, or Segalian ifland. See SEGALIAN in this Supplement.

CHICHESTER, *Upper* and *Lower*, two townfhips in Delaware co. Pennfylvania.—*Morse.*

CHICHESTER, a fmall townfhip in Rockingham co. New-Hampfhire, about 35 miles N. W. of Exeter, and 45 from Portfmouth. It lies on Suncook River; was incorporated in 1727, and contains 491 inhabitants. —*ib.*

CHICKAHOMINY, a fmall navigable river in Virginia. At its mouth in James river, 37 miles from Point Comfort, in Chefapeak bay, is a bar, on which is only 12 feet water at common flood tide. Veffels paffing that, may go 8 miles up the river; thofe of 10 feet draught 12 miles; and veffels of 6 tons burden may go 32 miles up the river.—*ib.*

CHICKAMACOMICO *Creek*, in Dorchefter co. Maryland, runs foutherly between the towns of Middletown and Vienna, and empties into Fifhing bay.—*ib.*

CHICKASAW *Bluff*, is on the eaftern bank of the Miffiffippi, within the territories of the United States, in N. lat. 35. The Spaniards erected here a ftrong, ftockaded fort, with cannon, and furnifhed it with troops, all in the fpace of 24 hours, in the month of June, 1795. It has fince been given up according to the treaty of 1796.—*ib.*

CHICKASAW, a creek which falls into the Wabafh from the E. a little below Poft St Vincent.—*ib.*

CHIKASAW, a river which empties into the Miffiffippi, on the E. fide, 104 miles N. from the mouth of Margot, and 67 S. W. of Mine au fer. The lands here are of an excellent quality, and covered with a variety of ufeful timber, canes, &c. This river may be afcended during high floods upwards of 30 miles with boats of feveral tons burden.—*ib.*

CHIKASAWS, a famous nation of Indians, who inhabit the country on the E. fide of the Miffiffippi, on the head branches of the Tombigbee, Mobile and Yazoo rivers, in the N. W. corner of the ftate of Georgia, and N. of the country of the Chactaws. Their country is an extenfive plain, tolerably well watered from fprings, and of a pretty good foil. They have 7 towns, the central one of which is in N. lat. 34. 23. W. long. 89. 30. The number of fouls in this nation has been formerly reckoned at 1725, of which 575 were fighting men. There are fome negroes among the Chickafaws, who either were taken captive in war, or ran away from their mafters, and fought fafety among the Indians.

In 1539, Ferdinand de Soto, with 900 men, befides feamen, failed from Cuba with a defign to conquer Florida. He travelled northward to the Chickafaw country, about lat. 35. or 36.; and 3 years after died, and was buried on the bank of Miffiffippi river.—*ib.*

CHICOMUZELO, a town in the province of Chiapa, in New-Spain, having a cave very narrow at the entry, but fpacious within, with a ftagnant lake, which is, however, clear, and is 2 fathoms deep towards the banks.—*ib.*

CHIKAGO *River*, empties into the S. W. end of lake Michigan, where a fort formerly ftood. Here the Indians have ceded to the United States, by the treaty of Greenville, a tract of land 6 miles fquare.—*ib.*

CHIGNECTO *Channel*, the N. weftern arm of the bay of Fundy, into which Petitcodiac River falls. The fpring tides rife here 60 feet.—*ib.*

CHILAPAN, a town in New-Spain, in the country of the Cohuixcas. Between this and Tcoiltylan is an entire mountain of loadftone.—*ib.*

CHILCA, a town in the jurifdiction of Canette in Peru, S. America, celebrated for its excellent faltpetre, of which gun-powder is made in the metropolis. It abounds with plenty of fifh, fruits, pulfe, and poultry, in which it carries on a very confiderable trade with Lima, 10 leagues diftant. S. lat. 12. 31. W. long. 76. 5.—*ib.*

CHILHOWEE *Mountain*, in the fouth-eaftern part of the ftate of Tenneffee, and between it and the Cherokee country.—*ib.*

CHILISQUAQUE, a townfhip on Sufquehanna River in Pennfylvania.—*ib.*

CHILLAKOTHE, an Indian town on the Great Miami, which was deftroyed in 1782 by a body of militia from Kentucky. Gen. Harmar fuppofes this to be the "Englifh Tawixtwi," in Hutchins's map. Here are the ruins of an old fort, and on both fides of the river are extenfive meadows. This name is applied to many different places, in honor of an influential chief, who formerly headed the Shawanoes.—*ib.*

CHILLAKOTHE, OLD, is an Indian town deftroyed by the forces of the U. S. in 1780. It lies about 3 miles S. of Little Miami River. The country in its vicinity is of a rich foil, and is beautifully chequered with meadows.—*ib.*

CHILMARK,

CHILMARK, a townſhip on Martha's Vineyard Iſland, Duke's co. Maſſachuſetts, containing 771 inhabitants. It lies 99 miles S. by E. of Boſton.—*ib.*

CHILQUES, a juriſdiction of S. America, in Peru, ſubject to the biſhop of Cuſco, 8 leagues S. E. from that city. Its commerce conſiſts in woollen manufactures, grain of all kinds, cows, ſheep, &c.—*ib.*

CHIMBO, a juriſdiction in the province of Zinto, in S. America, in the torrid zone. The capital is alſo called by the ſame name.—*ib.*

CHIMBORAZO, in the province of Quito, is the higheſt point of the Andes, and the higheſt mountain as yet known in the world; being, according to Condamine, 19,200 feet; according to others, 20,608 feet, above the level of the ſea. It lies nearly under the line, being in 1. 41. 40. S. lat. yet its tops are covered with ice and ſnow, and the country adjacent is often pierced with intolerable cold from the winds which blow from the mountain.—*ib.*

CHIMERE, the upper robe worn by biſhops in church, and in the *Houſe* of Peers, to which the lawn ſleeves are generally ſewed. Before the Reformation, and even after it, till the reign of Queen Elizabeth, the chimere was always of *ſcarlet ſilk;* but biſhop Hooper, ſcrupling firſt at the robe itſelf, and then at the colour of it, as too light and gay for the epiſcopal gravity, the chimere was afterwards made of *black ſatin.* The archiepiſcopal chimere has a long train.

CHIMNEY, a particular part of a houſe well known, which Profeſſor Beckmann has, in our opinion, proved to be an invention comparatively modern. It would be very unfair dealing in us to give even a large abſtract of one of the moſt curious diſſertations of a curious book, which has been but lately publiſhed, and thereby injure the intereſt of him to whom the native of Britain is indebted for the pleaſure of peruſing it in his own tongue. No man, however, can blame us for here ſtating, in ſupport of our own opinion, the profeſſor's anſwer to the paſſage of Ferrari, which we have quoted under the word CHIMNEY in the Encyclopædia.

* *De bellis civil. lib.* iv. p. 962. edit. Tollii.

"When the triumviri, ſays Appian*, cauſed thoſe who had been proſcribed by them to be ſought for by the military, ſome of them, to avoid the bloody hands of their perſecutors, hid themſelves in wells, and others, as Ferrarius tranſlates the words, *in fumaria ſub tecto, qua ſcilicet fumus e tecto evolvitur* (A). The true tranſlation, however, (ſays Mr Beckmann) is *fumoſa cœnacula.* The principal perſons of Rome endeavoured to conceal themſelves in the ſmoky apartments of the upper ſtory under the roof, which, in general, were inhabited only by poor people; and this ſeems to be confirmed by what Juvenal† expreſsly ſays, *Rarus venit in cœnacula miles.*

† *Sat.* x. ver. 17.

"Thoſe paſſages of the ancients which ſpeak of ſmoke riſing up from houſes, have, with equal impropriety, been ſuppoſed to allude to chimneys, as if the ſmoke could not make its way through doors and windows. Seneca‡ writes, 'Laſt evening I had ſome friends with me, and on that account a ſtronger ſmoke was raiſed; not ſuch a ſmoke, however, as burſts forth from the kitchens of the great, and which alarms the watchmen, but ſuch a one as ſignifies that gueſts are arrived.'

‡ *Epiſt.* 64.

Thoſe whoſe judgments are not already warped by prejudice, will undoubtedly find the true ſenſe of theſe words to be, that the ſmoke forced its way through the kitchen windows. Had the houſes been built with chimney-funnels, one cannot conceive why the watchmen ſhould have been alarmed when they obſerved a ſtronger ſmoke than uſual ariſing from them; but as the kitchens had no conveniences of that nature, an apprehenſion of fire, when extraordinary entertainments were to be provided in the houſes of the rich for large companies, ſeems to have been well founded; and on ſuch occaſions people appointed for that purpoſe were ſtationed in the neighbourhood to be conſtantly on the watch, and to be ready to extinguiſh the flames in caſe a fire ſhould happen. There are many other paſſages to be found in Roman authors of the like kind, which it is hardly neceſſary to mention; ſuch as that of Virgil†.

† Eclog. i. ver. 83.

'Et jam ſumma procul villarum culmina fumant.'

and the following words of Plautus,* deſcriptive of a miſer:

* *Aulular.* act. ii. ſc. 4.

'Quin divum atque hominum clamat continuo fidem,
'Suam rem periiſſe, ſeque eradicarier,
'De ſuo tigillo fumus ſi qua exit foras.'

In the *Veſpæ* of Ariſtophanes, referred to in the Encyclopædia, old Philocleon wiſhes to eſcape through the kitchen. Some one aſks, "What is that which makes a noiſe in the chimney?" "I am the ſmoke (replies the old man), and am endeavouring to get out at the chimney." "This paſſage, however (ſays the profeſſor) which, according to the uſual tranſlation, ſeems to allude to a common chimney, can, in my opinion, eſpecially when we conſider the illuſtration of the ſcholiaſts, be explained alſo by a ſimple hole in the roof, as Reiſke has determined; and indeed this appears to be more probable, as we find mention made of a top or covering ‡ with which the hole was cloſed."

‡ Τηλια.

In the Encyclopædia we have ſaid, that the inſtances of chimneys remaining among the ruins of ancient buildings are few, and that the rules given by Vitruvius for building them are obſcure; but we are now ſatisfied that there are *no* remains of ancient chimneys, and that Vitruvius gives *no* rules, either obſcure or perſpicuous, for building what, in the modern acceptation of the word, deſerves the name of a chimney.

"The ancient maſon-work ſtill to be found in Italy does not determine the queſtion. Of the walls of towns, temples, amphitheatres, baths, aqueducts, and bridges, there are ſome though very imperfect remains, in which chimneys cannot be expected; but of common dwelling-houſes none are to be ſeen, except at Herculaneum, and there no traces of chimneys have been diſcovered. The paintings and pieces of ſculpture which are preſerved, afford us as little information; for nothing can be perceived in them that bears the ſmalleſt reſemblance to a modern chimney.

"If there were no funnels in the houſes of the ancients to carry off the ſmoke, the directions given by Columella, to make kitchens ſo high that the roof ſhould not catch fire, was of the utmoſt importance. An accident of the kind, which that author ſeems to have

 apprehended,

(A) Ες καπνωδεις υπωροφια, η των τεγων ταις κεραμισι βυομεναις.

Chimney.

apprehended, had almost happened at Beneventum, when the landlord who entertained Mæcenas and his company was making a strong fire in order to get some birds sooner roasted.

'——————— ubi sedulus hospes
'Pæne arsit, macros dum turdos versat in igne;
'Nam vaga per veterem dilapso flamma culinam
'Vulcano summum properabat lambere tectum †.'

† *Horat.* lib. i. sat. 5.

Had there been chimneys in the Roman houses, Vitruvius certainly would not have failed to describe their construction, which is sometimes attended with considerable difficulties, and which is intimately connected with the regulation of the plan of the whole edifice. He does not, however, say a word on this subject; neither does Julius Pollux, who has collected with great care the Greek names of every part of a dwelling-house; and Grapaldus, who in later times made a collection of the Latin terms, has not given a Latin word expressive of a modern chimney."*

* *Francisci Marii Grapaldi de partibus ædium libri.*

Our author admits the derivation of the word *chimney* to be as we have given it in the Encyclopædia; but (says he) "*Caminus* signified, as far as I have been able to learn, first a chemical or metallurgic furnace, in which a crucible was placed for melting and refining metals; secondly, a smith's forge; and thirdly, a hearth on which portable stoves or fire-pans were placed for warming the apartment. In all these, however, there appears no trace of a chimney." Herodotus relates (lib. viii. c. 137.), that a king of Libya, when one of his servants asked for his wages, offered him in jest the sun, which at that time shone into the house through an opening in the roof, under which the fire was perhaps made in the middle of the edifice. If such a hole must be called a chimney, our author admits that chimneys were in use among the ancients, especially in their kitchens; but it is obvious that such chimneys bore no resemblance to ours, through which the sun could not dart his rays upon the floor of any apartment.

"However imperfect may be the information which can be collected from the Greek and Roman authors respecting the manner in which the ancients warmed their apartments, it nevertheless shews that they commonly used for that purpose a large fire-pan or portable stove, in which they kindled wood, and, when the wood was well lighted, carried it into the room, or which they filled with burning coals. When Alexander the Great was entertained by a friend in winter, as the weather was cold and raw, a small fire bason was brought into the apartment to warm it. The prince observing the size of the vessel, and that it contained only a few coals, desired his host, in a jeering manner, to bring more wood or frankincense; giving him thus to understand that the fire was fitter for burning perfumes than to produce heat. Anacharsis, the Scythian philosopher, though displeased with many of the Grecian customs, praised the Greeks, however, because they shut out the smoke and brought only fire into their houses.* We are informed by Lampridius, that the extravagant Heliogabulus caused to be burned in these stoves, instead of wood, Indian spiceries and costly perfumes†. It is also worthy of notice, that coals were found in some of the apartments of Herculaneum, as we are told by Winklemann, but neither stoves nor chimneys."

* *Plutarch. Sympos.* lib. vi. 7. p. 692.
† *Æl. Lamprid. Vita Heliogab.* cap. 31.

It is well known to every scholar, that the useful arts of life were invented in the east, and that the customs, manners, and furniture of eastern nations, have remained from time immemorial almost unchanged. In Persia, which the late Sir William Jones seems to have considered as the original country of mankind, the methods employed by the inhabitants for warming themselves have a great resemblance to those employed by the ancient Greeks and Romans for the same purpose. According to De la Valle, the Persians make fires in their apartments, not in chimneys as we do, but in stoves in the earth, which they call *tennor*. "These stoves consist of a square or round hole, two spans or a little more in depth, and in shape not unlike an Italian cask. That this hole may throw out heat sooner, and with more strength, there is placed in it an iron vessel of the same size, which is either filled with burning coals, or a fire of wood and other inflammable substances is made in it. When this is done, they place over the hole or stove a wooden top, like a small low table, and spread above it a large coverlet quilted with cotton, which hangs down on all sides to the floor. This covering condenses the heat, and causes it to warm the whole apartment. The people who eat or converse there, and some who sleep in it, lie down on the floor above the carpet, and lean, with their shoulders against the wall, on square cushions, upon which they sometimes also sit; for the *tennor* is constructed in a place equally distant from the walls on both sides. Those who are not very cold only put their feet under the table or covering; but those who require more heat can put their hands under it, or creep under it altogether. By these means the stove diffuses over the whole body, without causing uneasiness to the head, so penetrating and agreeable a warmth, that I never in winter experienced any thing more pleasant. Those, however, who require less heat let the coverlet hang down on their side to the floor, and enjoy without any inconvenience from the stove the moderately heated air of the apartment. They have a method also of stirring up or blowing the fire when necessary, by means of a small pipe united with the tennor or stove under the earth, and made to project above the floor as high as one chooses; so that the wind, when a person blows into it, because it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occasion to use this stove, both holes are closed up, that is to say, the mouth of the stove and that of the pipe which conveys the air to it, by a flat stone made for that purpose. Scarcely any appearance of them is then to be perceived, nor do they occasion inconvenience, especially in a country where it is always customary to cover the floor with a carpet, and where the walls are plastered. In many parts these ovens are used to cook victuals, by placing kettles over them. They are employed also to bake bread; and for this purpose they are covered with a large broad metal plate, on which the cake is laid; but if the bread is thick and requires more heat, it is put into the stove itself."

Our learned author having proved, to our entire satisfaction, that chimneys, such as we have now in every comfortable room, were unknown to the most polished nations of antiquity, sets himself to inquire into the era of their invention; and the oldest account of them which he finds is an inscription at Venice, which relates, that in the year 1347 a great many chimneys were thrown

thrown down by an earthquake. It would appear, however, that in ſome places they had been in uſe for a conſiderable time before that period; for *De Gataris*, in his hiſtory of Padua, relates, that *Franceſco de Carraro*, lord of Padua, came to Rome in 1368, and finding no chimneys in the inn where he lodged, becauſe at that time fire was kindled in a hall in the middle of the floor, he cauſed two chimneys like thoſe which had *long* been uſed at Padua to be conſtructed by maſons and carpenters, whom he had brought along with him. Over theſe chimneys, the firſt ever ſeen at Rome, he affixed his arms, which were ſtill remaining in the time of De Gataris, who died of the plague in 1405.

Though chimneys have been thus long in uſe, they are yet far enough from being brought to perfection. There is hardly a modern houſe, eſpecially if highly finiſhed, in which there is not one room at leaſt liable to be filled with ſmoke when it is attempted to be heated by an open fire; and there are many houſes ſo infeſted with this plague, as to be almoſt uninhabitable during the winter months; not to mention other great defects in common chimneys, which not being ſo obvious have attracted leſs attention. Many ingenious methods have been propoſed to cure ſmokey chimneys in every ſituation (ſee Smoke, *Encycl.)*; but Count Rumford's Eſſay on this ſubject contains the moſt valuable directions that we have ſeen, not only for removing the inconveniency of ſmoke, but likewiſe for increaſing the heat of the room by a diminiſhed conſumption of fuel.

To thoſe who are at all acquainted with the nature and properties of elaſtic fluids, it muſt be obvious, that the whole myſtery of curing ſmokey chimneys conſiſts in finding out and removing the accidental cauſes which prevent the heated ſmoke from being forced up the chimney by the preſſure of the cool and therefore heavier air of the room. Though theſe cauſes are various, yet, ſays our author, that which will moſt commonly be found to operate, is the bad conſtruction of the chimney *in the neighbourhood of the fire-place.* "The great fault of all the open fire-places or chimneys for burning wood or coals in an open fire now in common uſe is, that they are much too large; or rather it is *the throat of the chimney*, or the lower part of its open canal, in the neighbourhood of the mantle, and immediately over the fire, which is too large."

To this fault, therefore, the attention ſhould be firſt turned in every attempt which is made to improve the conſtruction of chimneys; for however perfect a fire-place may be in other reſpects, if the opening left for the paſſage of the ſmoke is larger than is neceſſary for that purpoſe, nothing can prevent the warm air of the room from eſcaping through it; and whenever this happens, there is not only an unneceſſary loſs of heat, but the warm air which leaves the room to go up the chimney being replaced by cold air from without, draughts of cold air cannot fail to be produced in the room, to the great annoyance of thoſe who inhabit it. But although both theſe evils may be effectually remedied by reducing the throat of the chimney to a proper ſize, yet in doing this ſeveral precautions will be neceſſary. And firſt of all, the throat of the chimney ſhould be in its proper place; that is to ſay, in that place in which it ought to be, in order that the aſcent of the ſmoke may be moſt facilitated: now as the ſmoke and hot vapour which riſe from a fire naturally tend *upwards*, the proper place for the throat of the chimney is evidently perpendicularly *over the fire*.

But there is another circumſtance to be attended to in determining the proper place for the throat of a chimney, and that is, to aſcertain its diſtance from the fire, or *how far* above the burning fuel it ought to be placed. In determining this point there are many things to be conſidered, and ſeveral advantages and diſadvantages to be weighed and balanced.

As the ſmoke and vapour which aſcend from burning fuel riſe in conſequence of their being rarefied by heat, and made lighter than the air of the ſurrounding atmoſphere; and as the degree of their rarefaction, and conſequently their tendency to riſe, is in proportion to the intenſity of their heat; and further, as they are hotter near the fire than at a greater diſtance from it—it is clear that the nearer the throat of a chimney is to the fire, the ſtronger will be what is commonly called its *draught*, and the leſs danger there will be of its ſmoking. But, on the other hand, when the draught of a chimney is very ſtrong, and particularly when this ſtrong draught is occaſioned by the throat of the chimney being very near the fire, it may ſo happen that the draught of air into the fire may become ſo ſtrong as to cauſe the fuel to be conſumed too rapidly. There are likewiſe ſeveral other inconveniences which would attend the placing of the throat of a chimney *very near* the burning fuel.

The poſition of the throat of a chimney being once determined, the next points to be aſcertained are its ſize and form, and the manner in which it ought to be connected with the fire-place below, and with the open canal of the chimney above. But as theſe inveſtigations are intimately connected with thoſe which relate to the form proper to be given to the fire-place itſelf, we muſt conſider them all together.

Now the deſign of a chimney fire being ſimply to warm a room, it is neceſſary, firſt of all, to contrive matters ſo that the room ſhall be actually warmed; ſecondly, that it be warmed with the ſmalleſt expence of fuel poſſible; and, thirdly, that in warming it, the air of the room be preſerved perfectly pure, and fit for reſpiration, and free from ſmoke and all diſagreeable ſmells.

To determine in what manner a room is heated by an open chimney fire, it will be neceſſary firſt of all to find out *under what form* the heat generated in the combuſtion of the fuel exiſts, and then to ſee how it is communicated to thoſe bodies which are heated by it.

In regard to the firſt of theſe ſubjects of inquiry, it is quite certain that the heat which is generated in the combuſtion of the fuel exiſts under *two* perfectly diſtinct and very different forms. One part of it is *combined* with the ſmoke, vapour, and heated air which riſe from the burning fuel, and goes off with them into the upper regions of the atmoſphere; while the other part, which appears to be *uncombined*, or, as ſome ingenious philoſophers have ſuppoſed, combined only with light, and therefore called *radiant heat*, is ſent off from the fire in rays in all poſſible directions.

With reſpect to the ſecond ſubject of inquiry, namely, how this heat, exiſting under theſe two different forms, is communicated to other bodies, it is highly probable that the combined heat can only be communicated to other bodies by *actual contact* with the body with

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with which it is combined; and with regard to the rays which are sent off by burning fuel, it is certain that *they* communicate or generate heat only *when* and *where* they are stopped or absorbed. In passing through air, which is transparent, they certainly do not communicate any heat to it; and it seems highly probable that they do not communicate heat to solid bodies by which they are reflected.

As it is the radiant heat alone which can be employed in warming a room, when fuel is burnt for this purpose in an open fire-place, it becomes an object of much importance to determine how the greatest quantity of it may be generated in the combustion of the fuel, and how the greatest proportion possible of that generated may be brought into the room.

Now the quantity of radiant heat generated in the combustion of a given quantity of any kind of fuel depends very much upon the management of the fire, or upon the manner in which the fuel is consumed. When the fire burns bright, much radiant heat will be sent off from it; but when it is *smothered up*, very little will be generated, and indeed very little combined heat that can be employed to any useful purpose: most of the heat produced will be immediately *expended* in giving elasticity to a thick dense vapour or smoke, which will be seen rising from the fire; and the combustion being very incomplete, a great part of the inflammable matter of the fuel being merely rarefied and driven up the chimney without being inflamed, the fuel will be wasted to little purpose. And hence it appears of how much importance it is, whether it be considered with a view to economy, or to cleanliness, comfort, and elegance, to pay due attention to the management of a chimney fire.

Nothing can be more perfectly void of common sense, and wasteful and slovenly at the same time, than the manner in which chimney fires, and particularly where coals are burned, are commonly managed by servants. They throw on a load of coals at once, through which the flame is hours in making its way; and frequently it is not without much trouble that the fire is prevented from going quite out. During this time no heat is communicated to the room; and what is still worse, the throat of the chimney being occupied merely by a heavy dense vapour, not possessed of any considerable degree of heat, and consequently not having much elasticity, the warm air of the room finds less difficulty in forcing its way up the chimney and escaping than when the fire burns bright. And it happens not unfrequently, especially in chimneys and fire places ill-constructed, that this current of warm air from the room which presses into the chimney, crossing upon the current of heavy smoke which rises slowly from the fire obstructs it in its ascent, and beats it back into the room; hence it is that chimneys so often smoke when too large a quantity of fresh coals is put upon the fire. So many coals should never be put on the fire at once as to prevent the free passage of the flame between them. In short, a fire should never be smothered; and when proper attention is paid to the quantity of coals put on, there will be very little use for the poker; and this circumstance will contribute very much to cleanliness, and to the preservation of furniture.

As we have seen what is necessary to the *generation* of the greatest quantity of radiant heat, it remains to be determined how the greatest proportion of that which is generated and sent off from the fire in all directions may be made to *enter the room*, and assist in warming it. This must be done, first, by causing as many as possible of the rays, as they are sent off from the fire in straight lines, to come *directly* into the room; which can only be effected by bringing the fire as far forward as possible, and leaving the opening of the fire-place as wide and as high as can be done without inconvenience: and, secondly, by making the sides and back of the fire-place of such a form, and constructing them of such materials, as to cause the direct rays from the fire, which strike against them, to be sent into the room by reflection in the greatest abundance.

Now it will be found upon examination, that the best form for the vertical sides of a fire-place, or the *covings* (as they are called), is that of an upright plane, making an angle with the plane of the back of the fire-place of about 135 degrees.—According to the present construction of chimneys, this angle is sometimes only 90, and very seldom above 100 or 110 degrees; but it is obvious, that in all these cases the two sides or covings of the fire place are very ill-contrived for throwing into the room by reflection the rays from the fire which fall upon them.

With regard to the materials which should be employed in the construction of fire-places, particularly the backs and covings, it is obvious that those are to be preferred which *absorb* the *least*, and of course *reflect* the greatest quantity of radiant heat. Iron, therefore, and, in general, metals of all kinds, are the very worst materials which can possibly be employed for the backs and covings of chimneys; whilst fire stone white-washed, or common bricks and mortar, covered with a thin coating of plaster, and white-washed, answer the purpose extremely well. A white colour should, indeed, be always given to the inside of a chimney of whatever materials it be constructed; and black, which is at present so common, should be carefully avoided, because white reflects the most, and black, the least, radiant heat. The grate, however, cannot well be made of any thing else than iron; but there is no necessity whatever for that immense quantity of iron which surrounds grates as they are commonly fitted up, and which not only renders them very expensive, but essentially injures the fire-place.

To have only pointed out the faults of the chimneys in use, without shewing how these faults may be corrected, would have been a work of very little value; but the Count's Treatise is complete, and contains the plainest directions for the construction of fire-places. These directions are introduced by an explanation of some technical words and expressions. Thus, by the *throat* of a chimney, already mentioned, he means the lower extremity of its canal, where it unites with the upper part of its open fire-place. This throat is commonly found about a foot above the level of the lower part of the mantle, and it is sometimes contracted to a smaller size than the rest of the canal of the chimney, and sometimes not.

Plate XX.

Fig. 1. shews the section of a chimney, on the common construction, in which $d\,e$ is the throat.

Fig. 2. shews the section of the same chimney altered and improved, in which $d\,i$ is the reduced throat.

The *breast* of a chimney is that part of it which is immediately

immediately behind the mantle. It is the wall which forms the entrance from below into the throat of the chimney in front, or towards the room. It is oppofite to the upper extremity of the back of the open fire-place, and parallel to it: in fhort, it may be faid to be the back part of the mantle itfelf.—In the figures 1. and 2. it is marked by the letter *d*. The width of the throat of the chimney (*d e* fig. 1. and *d i* fig. 2.) is taken from the breaft of the chimney to the back, and its length is taken at right angles to its width, or in a line parallel to the mantle (*a* fig. 1. and 2.)

The bringing forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminifhing of the throat of the chimney, being two objects principally had in view in the alterations in fire-places propofed by the Count, it is evident that both thefe may be attained merely by bringing forward the back of the chimney. The only queftion therefore is, How far it fhould be brought forward? The anfwer is fhort, and eafy to be underftood; bring it forward as far as poffible, without diminifhing too much the paffage which muft be left for the fmoke. Now as this paffage, which in its narroweft part he calls *the throat of the chimney*, ought, for reafons which have been already explained, to be immediately, or perpendicularly over the fire, it is evident that the back of the chimney muft always be built perfectly upright. To determine, therefore, the place for the new back, or how far precifely it ought to be brought forward, nothing more is neceffary than to afcertain how wide the throat of the chimney ought to be left, or what fpace muft be left between the top of the breaft of the chimney where the upright canal of the chimney begins, and the new back of the fire-place carried up perpendicularly to that height.

Numerous experiments have convinced the Count, that, all circumftances being well confidered, and the advantages and difadvantages compared and balanced, *four inches* is the beft width that can be given to the throat of a chimney, whether the fire-place be deftined to burn wood, coals, turf, or any other fuel. In very large halls where great fires are kept up, it may fometimes, though very rarely, be proper to increafe this width to four inches and a half, or even to five inches.

The next thing to be confidered is the width which it will be proper to give to the back of the chimney; and, in moft cafes, this fhould be *one-third* of the width of the opening of the fire-place in front. It is not indeed abfolutely neceffary to conform with rigour to this decifion, nor is it always poffible; but it fhould invariably be conformed to as far as circumftances will permit. Where a chimney, fays the Count, is defigned for warming a room of a middling fize, and where the thicknefs of the wall of the chimney in front, meafured from the front of the mantle to the breaft of the chimney, is nine inches, I fhould fet off four inches more for the width of the throat of the chimney, which, fuppofing the back of the chimney to be built upright, as it always ought to be, will give thirteen inches for the depth of the fire-place, meafured upon the hearth, from the opening of the fire-place in front to the back. In this cafe, thirteen inches would be a good fize for the width of the back; and three times thirteen inches, or 39 inches, for the width of the opening of the fire-place in front; and the angle made by the back of the fire-place and the fides of it, or covings, would be juft 135 degrees, which is the beft pofition they can have for throwing heat into the room. This pofition, indeed, it may fometimes be impoffible to attain in altering chimneys already built; but a deviation from it of two or three degrees will be of no great confequence; for the points of by much the greateft importance in altering fire-places upon the principles here recommended, are the bringing forward the back to its proper place, and making it of the proper width.

Provifion, however, muft be made for the paffage of the chimney-fweeper up the chimney; and this may eafily be done in the following manner: In building up the new back of the fire-place; when this wall (which need never be more than the width of a fingle brick in thicknefs) is brought up fo high that there remains no more than about ten or eleven inches between what is then the top of it and the infide of the mantle, or lower extremity of the breaft of the chimney, an opening or door-way, eleven or twelve inches wide, muft be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be neceffary to carry up the back, will make the opening abundantly fufficient to let the chimney-fweeper pafs. When the fire place is finifhed, this door-way is to be clofed by a tile or fit piece of ftone placed in it without mortar, and by means of a rabbit made in the brick-work, confined in its place in fuch a manner as that it may be eafily removed when the chimney is to be fwept, and reftored to its place when that work is over. Of this contrivance the reader will be able to form a clear conception from fig. 2. which reprefents the fection of a chimney after it has been properly altered from what is exhibited in fig. 1. In this improved chimney *k l* is the new back of the fire place; *l i* the tile or ftone which clofes the door-way for the chimney-fweeper; *d i* the throat of the chimney narrowed to four inches; *a* the mantle, and *b* the ftone placed under the mantle, fuppofed to have been too high, in order to diminifh the height of the opening of the fire-place in front.

It has been obferved above, that the new back, which it will always be found neceffary to build in order to bring the fire fufficiently forward, in altering a chimney conftructed on the common principles, need never be thicker than the width of a common brick. The fame may be faid of the thicknefs neceffary to be given to the new fides or covings of the chimney; or if the new back and covings are conftructed of ftone, one inch and three quarters, or two inches in thicknefs, will be fufficient. Care fhould be taken in building up thefe new walls to unite the back to the covings in a folid manner.

Whether the new back and covings are conftructed of ftone or built of bricks, the fpace between them and the old back and covings of the chimney ought to be filled up to give greater folidity to the ftructure. This may be done with loofe rubbifh, or pieces of broken bricks or ftones, provided the work be ftrengthened by a few layers or courfes of bricks laid in mortar; but it will be indifpenfably neceffary to finifh the work where thefe new walls end, that is to fay, at the top of the throat of the chimney, where it ends abruptly in the open canal of the chimney, by a horizontal courfe of bricks well fecured with mortar. This courfe of bricks will

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will be upon a level with the top of the door-way left for the chimney-fweeper; and the void behind the doorway muft be covered with a horizontal ftone or tile, to be removed at the fame time the door is removed, and for the fame purpofe.

From thefe defcriptions it is clear, that where the throat of the chimney has an end, that is to fay, where it enters into the lower part of the open canal of the chimney, *there* the three walls which form the two covings and the back of the fire-place all end abruptly. It is of much importance that they fhould end in this manner; for were they to be floped outward, and raifed in fuch a manner as to fwell out the upper extremity of the throat of the chimney in the form of a trumpet, and increafe it by degrees to the fize of the canal of the chimney, this manner of uniting the lower extremity of the canal of the chimney with the throat would tend to affift the winds, which may attempt to blow down the chimney, in forcing their way through the throat, and throwing the fmoke backward into the room; but when the throat of the chimney ends abruptly, and the ends of the new walls form a flat horizontal furface, it will be much more difficult for any wind from above to find and force its way through the narrow paffage of the throat of the chimney.

As the two walls which form the new covings of the chimney are not parallel to each other, but inclined, prefenting an oblique furface towards the front of the chimney, and as they are built perfectly upright, and quite flat, from the hearth to the top of the throat, where they end, it is evident that an horizontal fection of the throat will not be an oblong fquare; but its deviation from that form is a matter of no confequence; and no attempts fhould ever be made, by twifting the covings above where they approach the breaft of the chimney, to bring it to that form. All twifts, bends, prominences, excavations, and other irregularities of form in the covings of a chimney, never fail to produce eddies in the current of air which is continually paffing into, and through, an open fire-place in which a fire is burning; and all fuch eddies difturb either the fire or the afcending current of fmoke, or both; and not unfrequently caufe the fmoke to be thrown back into the room. Hence it appears, that the covings of chimneys fhould never be made circular, or in the form of any other curve, but always quite flat.

For the fame reafon, that is to fay, to prevent eddies, the breaft of the chimney, which forms that fide of the throat that is in front or neareft to the room, fhould be neatly cleaned off, and its furface made quite regular and fmooth. This may be eafily done by covering it with a coat of plafter, which may be made thicker or thinner in different parts, as may be neceffary in order to bring the breaft of the chimney to be of the proper form.

With regard to the form of the breaft of a chimney, this is a matter of very great importance, and which ought always to be particularly attended to. The worft form it can have is that of a vertical plane or upright flat; and next to this the worft form is an inclined plane. Both thefe forms caufe the current of warm air from the room, which will, in fpite of every precaution, fometimes find its way into the chimney, to crofs upon the current of fmoke which rifes from the fire in a manner moft likely to embarrafs it in its afcent, and drive it back.

The current of air which paffing under the mantle, gets into the chimney, fhould be made *gradually to bend its courfe upwards*; by which means it will unite *quietly* with the afcending current of fmoke, and will be lefs likely to check it, or force it back into the room. Now this may be effected with the greateft eafe and certainty, merely by *rounding off* the breaft of the chimney or back part of the mantle, inftead of leaving it flat or full of holes and corners; and this of courfe ought always to be done.

Having thus afcertained the form and pofition of the new covings, the ingenious author next turns his attention to the height to which they fhould be carried. This will depend not only on the height of the mantle, but alfo, and more efpecially, on the height of the breaft of the chimney, or of that part of the chimney where the breaft ends and the upright canal begins.—The back and covings muft rife a few inches, five or fix for inftance, higher than this part, otherwife the throat of the chimney will not be properly formed; but no advantage would be gained by carrying them higher.

One important circumftance refpecting chimney fireplaces ftill remains to be confidered; and that is the grate. In placing the grate, the thing principally to be attended to is, to make the back of it coincide with the back of the fire-place. But as many of the grates now in common ufe will be found to be too large, when the fire-places are altered and improved, it will be neceffary to diminifh their capacities by filling them up at the back and fides with pieces of fire-ftone. When this is done, it is the front of the flat piece of fire-ftone which is made to form a new back to the grate, which muft be made to coincide with, and make part of the back of the fire-place.—But in diminifhing the capacities of grates with pieces of fire-ftone, care muft be taken not to make them *too narrow*.

The proper width for grates deftined for rooms of a middling fize will be from fix to eight inches, and their length may be diminifhed more or lefs according as the room is heated with more or lefs difficulty, or as the weather is more or lefs fevere.—But where the width of a grate is not more than five inches it will be very difficult to prevent the fire from going out.

It frequently happens that the iron backs of grates are not vertical, or upright, but inclined backwards — When thefe grates are fo much too wide as to render it neceffary to fill them up behind with fire-ftone, the inclination of the back will be of little confequence; for by making the piece of ftone with which the width of the grate is to be diminifhed in the form of a wedge, or thicker above than below, the front of this ftone, which in effect will become the back of the grate, may be made perfectly vertical; and the iron back of the grate being hid in the folid work of the back of the fireplace, will produce no effect whatever; but if the grate be already fo narrow as not to admit of any diminution of its width, in that cafe it will be beft to take away the iron back of the grate entirely, and fixing the grate firmly in the brick-work, caufe the back of the fireplace to ferve as a back to the grate.

Where grates, which are defigned for rooms of a middling fize, are longer than 14 or 15 inches, it will always be beft, not merely to diminifh their lengths, by filling them up at their two ends with fire-ftone, but,

forming

Chimney. forming the back of the chimney of a proper width, without paying any regard to the length of the grate, to carry the covings through the two ends of the grate in fuch a manner as to conceal them, or at leaft to conceal the back corners of them in the walls of the covings.

Had thefe directions been duly attended to by the mafons who in Scotland pretend to alter chimneys on the principles of Count Rumford, we fhould not have obferved fo many of the grates placed by them jutting out beyond the mantle of the chimney; nor of courfe heard fo many complaints of rooms being rendered more fmoky and the confumption of fuel increafed by thefe pretended improvements. But when the grate is not fet in its proper place, when its floping iron back is retained, when no pains have been taken to make its ends coincide with the covings of the fire place, when the mantle, inftead of having its back rounded off, is a vertical plane of iron cutting the column of fmoke which rifes beneath it, and, above all, when the throat of the chimney, inftead of four, is made, as we often fee, fourteen inches wide; let it be remembered, that not one of Count Rumford's directions has been followed, and that his principles have as little to do with the conftruction of fuch a chimney as with the building of the wall of China or the pyramids of Egypt.

To contribute our aid to prevent thefe blunders for the future, we fhall here fubjoin the Count's directions for laying out the work; not to inftruct mafons and bricklayers, to whom we earneftly recommend the ftudy of the effay itfelf (H), which contains much valuable information that we have omitted; but merely to give the country gentleman an opportunity of difcovering whether the workman whom he employs deviates far and needlefsly from the principles which he pretends to follow.

When a chimney is to be altered, after taking away the grate and removing the rubbifh, firft draw a ftrait line with chalk, or with a lead pencil, upon the hearth, from one jamb to the other,—even with the front of the jambs. The dotted line A B, fig. 3. may reprefent this line.

From the middle *c* of this line, (AB) another line *c d*, is to be drawn perpendicular to it, acrofs the hearth, to the middle *d*, of the back of the chimney.

A perfon muft now ftand upright in the chimney, with his back to the back of the chimney, and hold a plumb line to the middle of the upper part of the breaft of the chimney (*d*, fig. 1.), or where the canal of the chimney begins to rife perpendicularly;—taking care to place the line above in fuch a manner that the plumb may fall on the line *c d* (fig. 3.), drawn on the hearth from the middle of the opening of the chimney in front to the middle of the back, and an affiftant muft mark the precife place *e*, on that line where the plumb falls.

This being done, and the perfon in the chimney having quitted his ftation, four inches are to be fet off on the line *c d*, from *e*, towards *d*; and the point *f*, where thefe four inches end, (which muft be marked with chalk, or with a pencil), will fhow how far the new back is to be brought forward.

Through *f*, draw the line *g h* parallel to the line A B, and this line *g h* will fhow the direction of the new back, or the ground line upon which it is to be built. The line *c f* will fhow the depth of the new fire place; and if it fhould happen that *c f* is equal to about *one-third* of the line A B, and if the grate can be accommodated to the fire place inftead of its being neceffary to accommodate the fire-place to the grate; in that cafe, half the length of the line *c f* is to be fet off from *f* on the line *g f h*, on one fide to *k*, and on the other to *i*, and the line *i k* will fhow the ground line of the fore part of the back of the chimney.

In all cafes where the width of the opening of the fire-place in front (AB) happens to be not greater, or not more than two or three inches greater than *three times* the width of the new back of the chimney (*i k*), this opening may be left; and lines drawn from *i* to A, and from *k* to B, will fhow the width and pofition of the front of the new covings:—but when the opening of the fire-place in front is ftill wider, it muft be reduced; which is to be done in the following manner:

From *c*, the middle of the line A B, *c a* and *c b* muft be fet off equal to the width of the back (*i k*), added to half its width (*f i*); and lines drawn from *i* to *a*, and from *k* to *b*, will fhow the ground plan of the fronts of the new covings.

When this is done, nothing more will be neceffary than to build up the back and covings; and if the fire-place is defigned for burning coals, to fix the grate in its proper place, according to the directions already given.—When the width of the fire-place is reduced, the edges of the covings *a* A and *b* B are to make a finifh with the front of the jambs.—And in general it will be beft, not only for the fake of the appearance of the chimney, but for other reafons alfo, to lower the height of the opening of the fire place whenever its width in front is diminifhed.

A front view of the chimney, after it has been thus altered, is exhibited in fig. 4. where the under part of the door-way is reprefented, as clofed by the white dotted lines.

When the wall of the chimney in front, meafured from the upper part of the breaft of the chimney to the front of the mantle, is very thin, it may happen, and efpecially in chimneys defigned for burning wood upon the hearth, or upon dogs, that the depth of the chimney, determining according to the directions here given, may be too fmall.

Thus, for example, fuppofing the wall of the chimney in front, from the upper part of the breaft of the chimney to the front of the mantle, to be only four inches, (which is fometimes the cafe, particularly in rooms fituated near the top of a houfe), in this cafe, if we take four inches for the width of the throat, this will give eight inches only for the depth of the fire-place, which would be too little, even were coals to be burnt inftead of wood.—In this cafe (fays the Count) I fhould increafe the depth of the fire-place at the hearth to 12 or 13 inches, and fhould build the back perpendicular to the height of the top of the burning fuel (whether it be wood burnt upon the hearth or coals in a grate); and then, floping the back by a gentle inclination forward, bring it to its proper place, that

(H) It cofts but two fhillings; and he muft be a poor bricklayer indeed who cannot afford to pay that fum for inftruction in the moft important, as well as moft difficult, part of his bufinefs.

Chimney. that is to ſay, *perpendicularly under the back part of the throat of the chimney*. This ſlope, (which will bring the back forward four or five inches, or juſt as much as the depth of the fire-place is increaſed), though it ought not to be too abrupt, yet it ought to be quite finiſhed at the height of eight or ten inches above the fire, otherwiſe it may perhaps cauſe the chimney to ſmoke; but when it is very near the fire, the heat of the fire will enable the current of riſing ſmoke to overcome the obſtacle which this ſlope will oppoſe to its aſcent, which it could not do ſo eaſily were the ſlope ſituated at a greater diſtance from the burning fuel.

Fig. 5, 6, and 7, ſhow a plan, elevation, and ſection of a fire-place conſtructed or altered upon this principle. —The wall of the chimney in front at *a*, fig. 7. being only four inches thick, four inches more added to it for the width of the throat would have left the depth of the fire-place meaſured upon the hearth *b c* only eight inches, which would have been too little;—a niche *c* and *e* was therefore made in the new back of the fire-place for receiving the grate, which niche was ſix inches deep in the centre of it, below 13 inches wide, (or equal in width to the grate,) and 23 inches high; finiſhing above with a ſemicircular arch, which, in its higheſt part, roſe ſeven inches above the upper part of the grate.—The door-way for the chimney-ſweeper, which begins juſt above the top of the niche, may be ſeen diſtinctly in both the figures 6 and 7.—The ſpace marked *g*, fig. 7. behind this door-way, may either be filled with looſe bricks, or may be left void.—The manner in which the piece of ſtone *f*, fig. 7. which is put under the mantle of the chimney to reduce the height of the opening of the fire-place, is rounded off on the inſide in order to give a fair run to the column of ſmoke in its aſcent through the throat of the chimney, is clearly expreſſed in this figure. The plan fig. 5. and elevation fig. 6. ſhow how much the width of the opening of the fire-place in front is diminiſhed, and how the covings in the new fire-place are formed.

A perfect idea of the form and dimenſion of the fire-place in its original ſtate, as alſo after its alteration, may be had by a careful inſpection of theſe figures.

In chimneys, like that repreſented in figure 8, where the jambs A and B project far into the room, and where the front edge of the marble ſlab *o*, which forms the coving, does not come ſo far forward as the front of the jambs, the workmen in conſtructing the new covings are very apt to place them,—not in the line *c A*, which they ought to do,—but in the line *c o*, which is a great fault.—The covings of a chimney ſhould never range *behind* the front of the jambs, however thoſe jambs may project into the room;—but it is not abſolutely neceſſary that the covings ſhould *make a finiſh* with the internal front corners of the jambs, or that they ſhould be continued from the back *c*, quite to the front of the jambs at *A*.—They may finiſh in front at *a* and *b*; and ſmall corners *A*, *o*, *a*, may be left for placing the ſhovels, tongs, &c.

Were the new coving to range with the front edge of the old coving *o*, the obliquity of the new coving would commonly be too great;—or the angle *d c o* would exceed 135 degrees, *which it never ſhould do*,—or at leaſt never by more than a very few degrees. No inconvenience of any importance will ariſe from making the obliquity of the covings *leſs* than what is here recommended; but many cannot fail to be produced by making it much greater.

Theſe extracts, which we have made ſo liberally from Count Rumford's eſſay on chimney fire-places, will be ſufficient, we hope, to bring fully within the comprehenſion of thoſe who are acquainted with pneumatics and pneumatic chemiſtry the principles on which chimneys and fire-places ſhould be conſtructed; but ſuch as are in a great meaſure ſtrangers to theſe ſciences will do well to conſult the eſſay itſelf. With a benevolence which does him honour, the ingenious author has expreſſed a wiſh that his doctrines on this important ſubject may be widely propagated; and to encourage artiſts to ſtudy them, he has declared to the public in general, that "as he does not intend to take out himſelf, or to ſuffer others to take out, any patent for any invention of his which may be of public utility, all perſons are at full liberty to imitate them, and vend them, for their own emolument, when and where, and in any way they may think proper."

Chimney-Sweepers are a claſs of men who earn their ſubſiſtence by clearing chimneys of ſoot, which occaſions them to ſmoke. While chimneys continued to be built in ſo ſimple a manner, and of ſuch a width as they are ſtill obſerved to be in old houſes, they were ſo eaſily cleaned that this ſervice could be performed by a ſervant with a wiſp of ſtraw, or a little bruſhwood faſtened to a rope; but after the flues, in order to ſave room, were made narrower, or when ſeveral flues were united together, the cleaning of them became ſo difficult, that they required boys, or people of ſmall ſize, accuſtomed to that employment. The firſt chimney-ſweepers in Germany came from Savoy, Piedmont, and the neighbouring territories. Theſe for a long time were the only countries where the cleaning of chimneys was followed as a trade; and hence Profeſſor Beckmann concludes with great probability, that chimneys were invented in Italy. The Lotharingians, however, undertook the buſineſs of chimney-ſweeping alſo; on which account the duke of Lotharingia was ſtyled the *imperial fire-maſter*. The firſt Germans who condeſcended to clean chimneys were miners; and the chimney-ſweepers in that empire ſtill procure their boys from the foreſt of Hartz, where the greateſt mines are wrought. Very lately, and perhaps at preſent, the greater part of the chimney-ſweepers in Paris were Savoyards, many of them not above eight years of age, who, for the paltry ſum of five ſous, which they were obliged to ſhare with their avaricious maſter, would ſcramble, at the hazard of their lives, through a narrow funnel fifty feet in length, and with their beſoms clean it from ſoot and dirt. At what preciſe period chimney-ſweeping became a trade in England and Scotland, we have not been able to learn; but among us, as well as elſewhere, young boys are employed in this buſineſs, who are ſaid to be very harſhly treated by fellows who ſtole them from the doors of cottages in the country. That children have been ſometimes kidnapped by chimney-ſweepers, we can have no doubt; but that the practice is frequent, we do not believe. We think however that the buſineſs might be wholly aboliſhed; for a narrow funnel might certainly, if not very crooked, be ſwept by a bundle of ſtraw or bruſhwood faſtened to a rope, as well as one that is wider; and the bricks which ſeparate the contiguous

Fig. 3.

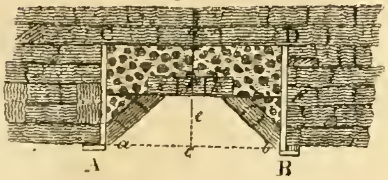


Fig. 5.

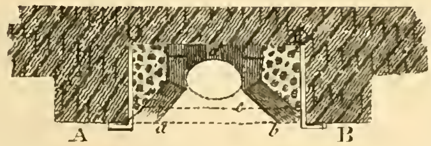


Fig. 8.

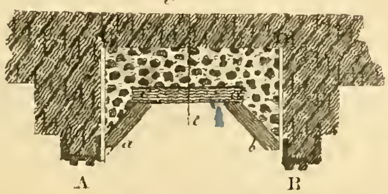


Fig. 4.

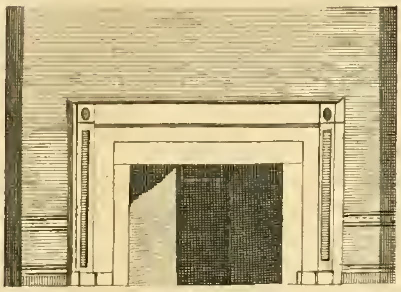


Fig. 7.

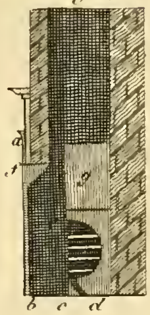


Fig. 6.

Scale 1 2 3 4 5 *of Feet*

CRANE

Fig.1.

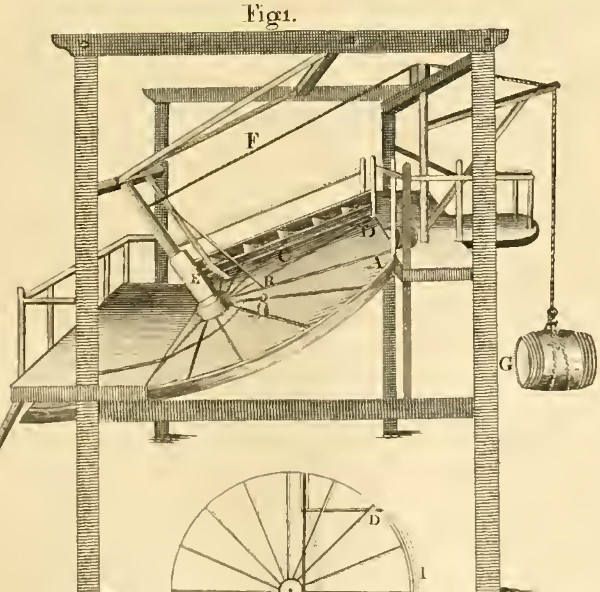


Fig.1

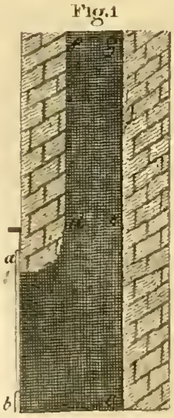
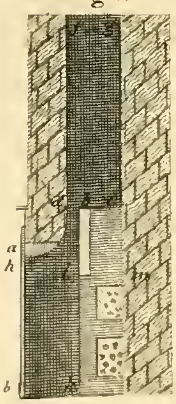


Fig.2.



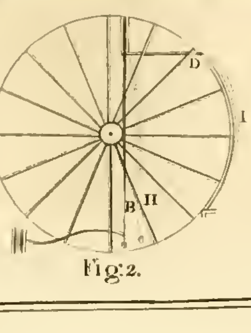


Fig.2.

B. Jones sc.

guous flues we know to be leſs injured by this method of ſweeping, when cautiouſly gone about, than by ſending boys up the chimneys.

On the 4th of July 1796, letters patent were granted to Daniel Davis, of the pariſh of St Giles Middleſex, for his invention of a machine, by which he propoſes to ſweep and cleanſe chimneys, and extinguiſh chimneys on fire, without any perſon going up the ſame, as is now the practice. The machine conſiſts of an apparatus of rack work, of various lengths, which, by means of a hand-turn, is made to aſcend the chimney. The lengths of the rack-work are joined together by means of mortiſes and tenons, with a ſpring which holds them faſt. In each length is a joint, by which the rack work will accommodate itſelf to angles or turns in the flues. To the firſt or uppermoſt length is affixed a bruſh of hair, or wire, or ſpunge, or other elaſtic ſubſtance, as the occaſion may require.

This invention is doubtleſs well calculated to anſwer the purpoſe intended, and may perhaps be the means of diminiſhing the number of thoſe objects of miſery, the unfortunate chimney-ſweepers.

CHINA is an empire of ſuch antiquity and extent, the laws and cuſtoms of the people are ſo ſingular, and the populouſneſs of the country ſo very great—that it has attracted much of the attention of Europeans ever ſince it was viſited in the 13th century by Marco Paulo the Venetian traveller. Of ſuch a country it would be unpardonable not to give ſome account in a work of this nature; but we have not, in truth, much to add to what has been ſaid of China and the Chineſe in the Encyclopædia. Since the article China in that work was publiſhed, the court of Pekin has indeed been viſited by an embaſſy from Great Britain, and the origin of the people, as well as the antiquity of their empire, has been inveſtigated by Sir William Jones with his uſual diligence; but from his memoir, publiſhed in the ſecond volume of the Aſiatic Reſearches, and from Sir George Staunton's account of the embaſſy, there is not much to be extracted which would be either amuſing or inſtructive to our readers.

We have already obſerved, from Groſier and others, that the Chineſe not only lay claim to the higheſt antiquity, but even contend that their firſt emperor was the firſt man. Both theſe poſitions are controverted by Sir William Jones, who, though he allows the Chineſe empire to be very ancient when compared with the oldeſt European ſtate, is yet decidedly of opinion that it was not founded at an earlier period than the 12th century before the Chriſtian era; and that the people, ſo far from being aborigines, are a mixed race of Tartars and Hindoos. He begins his inveſtigation with aſking, "Whence came the ſingular people who long had governed China, before they were conquered by the Tartars? On this problem (ſays he‡) four opinions have been advanced, and all rather peremptorily aſſerted than ſupported by argument and evidence. By a few writers it has been urged, that the *Chineſe* are an original race, who have dwelled for ages, if not from eternity, in the land which they now poſſeſs. By others, and chiefly by the miſſionaries, it is inſiſted that they ſprung from the ſame ſtock with the *Hebrews* and the *Arabs*. A third aſſertion is that of the Arabs themſelves, and of M. Pauw, who hold it indubitable, that they were originally *Tartars*, deſcending in wild clans from the ſteeps of Imaus: And a fourth, at leaſt as dogmatically pronounced as any of the preceding, is that of the *Brahmans*, who decide, without allowing any appeal from their deciſion, that the *Chinas* (for ſo they are named in *Sanſcrit*) were Hindoos of the military caſt, who, abandoning the privileges of their tribe, rambled in different bodies to the north-eaſt of *Bengal*; and forgetting by degrees the rites and the religion of their anceſtors, eſtabliſhed ſeparate principalities, which were afterwards united in the plains and valleys which are now poſſeſſed by them."

‡ *Aſiatic Reſearches*, vol. ii. mem. 25.

Of theſe opinions, Sir William having very completely demoliſhed the firſt three, proceeds to eſtabliſh the fourth, which he conſiders as intereſting as well as new in Europe. In the Sanſcrit inſtitutes of civil and religious duties, revealed, as the Hindoos believe, by Menu the ſon of Brahma, we find (ſays he) the following curious paſſage: 'Many families of the military claſs, having gradually abandoned the ordinances of the *Veda*, and the company of *Brahmans*, lived in a ſtate of degradation; as the people of *Pundraca* and *Odra*, thoſe of *Dravira* and *Camboja*, the *Yavanas* and *Sacas*, the *Paradas* and *Pahlavas*, the Chinas, and ſome other nations.' A full comment on this text (continues the preſident) would be ſuperfluous; but ſince the teſtimony of the Indian author, who, though not a divine perſonage, was certainly a very ancient lawyer, moraliſt, and hiſtorian, is direct and poſitive, diſintereſted and unſuſpected, it would decide the queſtion before us if we could be ſure that the word *China* ſignifies a *Chineſe*." Of this fact Sir William Jones took the very beſt methods to be ſatisfied. He conſulted a number of Pandits ſeparately, who all aſſured him that the word *China* has no other ſignification in *Sanſcrit*; that the *Chinas* of Menu ſettled in a fine country to the north-eaſt of *Gaur*, and to the eaſt of *Camarup* and *Napal*; that they had long been, and ſtill are, famed as ingenious artificers; and that they (the Pandits) had themſelves ſeen old Chineſe idols, which bore a manifeſt relation to the primitive religion of India. He then laid before one of the beſt informed *Pandits* a map of Aſia; and when his own country was pointed out to him, the *Pandit* immediately placed his finger on the north-weſtern provinces of China, as the place where he ſaid the *Chinas* of Menu firſt eſtabliſhed themſelves.

In the opinion of Sir William Jones, this is complete evidence that the Chineſe are deſcended from an Indian race; but he does not believe that the Chineſe empire, as we now call it, was formed when the laws of Menu were collected; and for his calling this fact in queſtion, he offers reaſons, which to us are perfectly ſatisfactory. By a diligent and accurate compariſon of ancient Sanſcrit writings, he has been able to fix the period of the compilation of thoſe laws at between 1000 and 1500 years before Chriſt; but by the evidence of Confucius himſelf, he proves, that if the Chineſe empire was formed, it could be only in its cradle in the 12th century before our era. In the ſecond part of the work, intitled *Lún Yú*, Confucius declares, that "although he, like other men, could relate, as mere leſſons of morality, the hiſtories of the firſt and ſecond imperial houſes, yet, *for want of evidence*, he could give no certain account of them." Now, ſays Sir William, if the Chineſe themſelves do not pretend that any hiſtorical monument exiſted in the age of Confucius preceding the rife of their third dynafty, about 1100 years before the Chriftian epoch, we may juftly conclude, that their empire was then in its infancy, and did not grow to maturity till fome ages afterwards. Nay, he is inclined to bring its origin ftill lower down. "It was not, fays he, till the eighth century before the birth of our Saviour, that a fmall kingdom was erected in the province of *Shen-fi*, the capital of which ftood nearly in the 35th degree of northern latitude, and about five degrees to the weft of *Si-gan*. That country and its metropolis were both called *Chin*; and the dominion of its princes was gradually extended to the eaft and weft. The territory of *Chin*, fo called by the old Hindoos, by the Perfians, and by the Chinefe, gave its name to a race of emperors, whofe tyranny made their memory fo unpopular, that the modern inhabitants of China hold the word in abhorrence, and fpeak of themfelves as the people of a milder and more virtuous dynafty: but it is highly probable, that the whole nation defcended from the *Chinas* of Menu, and mixing with the *Tartars*, by whom the plains of *Honan* and the more fouthern provinces were thinly inhabited, formed by degrees the race of men whom we now fee in poffeffion of the nobleft empire in Afia."

In fupport of this opinion, which the accomplifhed author offers as the refult of long and anxious inquiries, he obferves, that the Chinefe have no ancient monuments from which their origin can be traced, even by plaufible conjecture; that their fciences are wholly *exotic*; that their mechanic arts have nothing in them which any fet of men, in a country fo highly favoured by nature, might not have difcovered and improved; that their philofophy feems yet in fo rude a ftate as hardly to deferve the appellation; and that their popular religion was imported from *India* in an age comparatively modern. He then inftitutes a comparifon between the mythology of the Chinefe and that of the Hindoos; of which the refult is, that the former people had an *ancient* fyftem of ceremonies and fuperftitions which has an apparent affinity with fome parts of the oldeft Indian worfhip. "They believed in the agency of genii or tutelary fpirits, prefiding over the ftars and the clouds; over lakes and rivers, mountains, valleys, and woods; over certain regions and towns; over all the elements, of which, like the Hindoos, they reckoned five; and particularly over *fire*, the moft brilliant of them. To thofe deities they offered victims on high places. And the following paffage from one of their facred books, fays Sir William, is very much in the ftyle of the Brahmans: 'Even they who perform a facrifice with due reverence, cannot perfectly affure themfelves that the divine fpirits accept their oblations; and far lefs can they, who adore the gods with languor and ofcitancy, clearly perceive their facred illapfes.' Thefe (continues the prefident) are imperfect traces indeed, but they *are* traces of an affinity between the religion of Menu and that of the *Chinas*, whom he names among the apoftates from it; and befides them, we difcover many other very fingular marks of relation between the Chinefe and the old Hindoos.

"This relation (he thinks) appears in the remarkable period of 432,000, and the cycle of 60 years; in the predilection for the myftical number *nine*; in many fimilar fafts and great feftivals, efpecially at the folftices and equinoxes; in the obfequies, confifting of rice and fruits offered to the manes of their anceftors; in the dread of dying childlefs, left fuch offerings fhould be intermitted; and perhaps in their common abhorrence of *red* objects, which the Indians carried fo far, that Menu himfelf, where he allows a *Brahman* to trade, if he cannot otherwife fupport life, abfolutely forbids his trading in any fort of *red* cloths, whether linen, or woollen, or made of woven bark. In a word, fays Sir William Jones, all the circumftances which have been mentioned feem to prove (as far as fuch a queftion admits proof), that the Chinefe and Hindoos were originally the fame people; but having been feparated near 4000 years, they have retained few ftrong features of their ancient confanguinity, efpecially as the Hindoos have preferved their old language and ritual, while the Chinefe very foon loft both; and the Hindoos have conftantly intermarried among themfelves, while the Chinefe, by a mixture of Tartarian blood from the time of their firft eftablifhment, have at length formed a race diftinct in appearance both from Indians and Tartars."

Sir George Staunton, who accompanied the Earl of Macartney on his embaffy to the emperor of China, does not indeed directly controvert this reafoning; but overlooking it altogether, gives to the Chinefe a much higher antiquity than Sir William Jones is inclined to allow them. Taking it for granted that their *cycle* is their own, and that it is not the offspring of aftronomical fcience, but of repeated obfervations, he feems to give implicit credit to thofe annals of the empire which almoft every other writer has confidered as fabulous.

"Next to the ftudies which teach the economy of life, the Chinefe (fays he) value moft the hiftory of the events of their own country, which is, to them, the globe; and of the celeftial movements which they had an opportunity of obferving at the fame time." In regard to the former, he tells us, that "from about *three* centuries before the Chriftian era the tranfactions of the Chinefe empire have been regularly, and without any intervening chafm, recorded both in official documents and by private contemporary writers. Nowhere had hiftory become fo much an object of public attention, and nowhere more the occupation of learned individuals. Every confiderable town throughout the empire was a kind of univerfity, in which degrees were conferred on the proficient in the hiftory and government of the ftate. Hiftorical works were multiplied throughout. The accounts of *recent* events were expofed to the correction of the witneffes of the facts, and compilations of former tranfactions to the criticifms of rival writers." In regard to the latter, the movements of the heavenly bodies, he thinks that in no country are there ftronger inducements or better opportunities to watch them than in China; and hence he infers, that the cycle of fixty years is of Chinefe formation. "In a climate (fays he) favourable to aftronomy, the balance of hours beyond the number of days during which the fun appeared to return oppofite to, and to obfcure, or to mix among the fame fixed ftars, might be afcertained in a fhort time; and occafioned the addition of a day to every fourth year, in order to maintain regularity in the computation of time, in regard to the return of the feafons; but many ages muft have paft before a period could have been difcovered, in which the unequal returns of the fun and moon were fo accurately adjufted, that at its termination

tion the new and full moons ſhould return, not only to the ſame day, but within an hour and a half of the time they had happened, when the period commenced. The knowledge of ſuch a period or cycle could be obtained only by a multiplicity of careful and accurate obſervations. Many revolutions of thoſe great luminaries muſt have been completed, and numberleſs conjunctions have paſt over, before their returns could be aſcertained to happen in the ſame day, at the end of nineteen years. The ſmall difference of time between the returning periods of this cycle, was partly leſſened by the intervention of another of 60 years, or of 720 revolutions of the moon, which, with the ſettled intercalation of 22 lunations, were at firſt ſuppoſed to bring a perfect coincidence of the relative poſitions of the ſun and moon: but even according to this period, every new year was made conſtantly to recede, in a very ſmall degree, which the Chineſe corrected afterwards from time to time. This cycle anſwered a double purpoſe, one as an era for chronological reckoning, and the other as a regulating period for a luni-ſolar year. Each year of the cycle is diſtinguiſhed by the union of two characters, taken from ſuch an arrangement of an unequal number of words placed in oppoſite columns, that the ſame two characters cannot be found again together for ſixty years. The firſt column contains a ſeries of ten words, the other twelve; which laſt are, in fact, the ſame that denote the twelve hours or diviſions of the day, each being double the European hour. The firſt word or character of the firſt ſeries or column of ten words, joined to the firſt word of the ſecond ſeries or column of twelve, marks the firſt year of the cycle; and ſo on until the firſt ſeries is exhauſted, when the eleventh word of the ſecond ſeries, combined with the firſt of the firſt ſeries, marks the eleventh year of the cycle; and the twelfth or laſt of the ſecond ſeries, joined with the ſecond of the firſt ſeries, ſerves for denoting the twelfth year. The third of the firſt ſeries becomes united in regular progreſſion with the firſt of the ſecond ſeries, to mark the thirteenth year; and proceeding by this rule, the firſt character in the firſt and in the ſecond ſeries cannot come again together for ſixty years, or until the firſt year of the ſecond cycle. The Chriſtian year 1797 anſwers to the 54th year of the 68th Chineſe cycle, which aſcertains its commencement to have been 2277 years before the birth of Chriſt; unleſs it be ſuppoſed that the official records and public annals of the empire, which bear teſtimony to it, ſhould all be falſified, and that the cycle when firſt eſtabliſhed ſhould have been antedated; which is indeed as little probable as that the period, for example, of the Olympiads ſhould be aſſerted to have commenced many ages prior to the firſt Olympic games."

This is a very poſitive deciſion againſt the opinion of a man whoſe talents and knowledge of oriental learning were ſuch as to give to his opinions on ſuch ſubjects the greateſt weight. If the ſtatements and reaſonings of Sir George Staunton be accurate, the Chineſe empire muſt have ſubſiſted at leaſt 3000 years before the Chriſtian era; for he ſays expreſsly, that *many ages* muſt have elapſed before the commencement of that cycle, which, according to him, commenced 2277 years before the birth of Chriſt. But ſurely Confucius was as well acquainted with the ancient annals of his own country, and the credibility which is due to them, as any man of the preſent age, whether Chineſe or European; and we have ſeen, that he conſidered none of them as authentic which relate events previous to the 11th century before our era. Even this is by much too early a period at which to rely upon them with implicit confidence, if it be true, as Sir George informs us, that the tranſactions of the empire have been regularly recorded only from about *three* centuries before the birth of Chriſt. With reſpect to the cycle, there is every probability that it was derived from India, where we know that aſtronomy has been cultivated as a ſcience from time immemorial, and where, we have ſhewn in another place, that the commencement of the cycle was actually antedated (ſee PHILOSOPHY, n° 9. *Encycl.*) We have therefore no heſitation in preferring Sir William Jones's opinion of the origin of the Chineſe empire to Sir George Staunton's; not merely becauſe we believe the former of theſe gentlemen to have been more converſant than the latter with Chineſe literature, but becauſe we think his reaſoning more conſiſtent with itſelf, and his concluſion more conſonant to that outline of chronology, which, as he obſerves, has been ſo correctly traced for the laſt 2,000 years, that we muſt be hardy ſceptics to call it in queſtion.

There is another point very nearly related indeed to this about which theſe two learned men likewiſe differ. Sir George Staunton informs us, that "no accounts of a general deluge are mentioned in Chineſe hiſtory." Sir William Jones, on the other hand, in the diſcourſe already quoted, ſays, "I may aſſure you, after full inquiry and conſideration, that the Chineſe, like the Hindoos, believe this earth to have been wholly covered with water, which, in works of undiſputed authenticity, they deſcribe as *flowing abundantly, then ſubſiding, and ſeparating the higher from the lower age of mankind.*" To which of theſe authors ſhall we give credit? The high antiquity which Sir George Staunton aſſigns to the Chineſe empire rendered it neceſſary for the perſons from whom he drew his information to get quit by any means of an univerſal deluge. The ſyſtem of Sir William Jones left him at liberty to admit or reject that event according to evidence; and in addition to the authentic records to which he appeals, he quotes a mythological fable of the Chineſe, and another of the Hindoos, which, though he lays not upon them any great ſtreſs, appear to us, when compared together, not only to corroborate his opinion reſpecting the deſcent of the Chineſe, but likewiſe to ſhew that both they and the Hindoos have preſerved a traditionary account of the deluge very ſimilar to that which is given by Moſes. The Chineſe fable is this: "The mother of FO-HI was the *daughter of Heaven*, ſurnamed *Flower-loving*; and as the nymph was walking alone on the brink of a river with a ſimilar name, ſhe found herſelf on a ſudden encircled with a *rainbow*; ſoon after which ſhe became pregnant, and at the end of twelve years was delivered of a ſon, radiant as herſelf, who among other titles, had that of *Sui*, or *the Star of the Year.*" In the mythological ſyſtem of the Hindoos, "the nymph ROHINI, who preſides over the fourth lunar manſion, was the favorite miſtreſs of SOMA or the Moon, among whoſe numerous epithets we find *Cumudanáyaca*, or delighting in a ſpecies of *water-flower* that bloſſoms at night. The offspring of ROHINI and SOMA was BUDHA, regent of a planet; and he married ILA, whoſe father

China.

ther was preserved in a MIRACULOUS ARK from an universal deluge." The learned president shews, that according to the Brahmans, the Chinese descended from BUDHA: and he mentions a divine personage connected with the Chinese account of the birth of FO-HI, whose name was NIU-VA. But if all these circumstances be laid together, it will appear, we think, pretty evident, that the two ancient nations have preserved the same tradition of an universal deluge, and that the Chinese RAINBOW and NIU VA, with the Indian ARK, point to the flood of NOAH.

To Sir William Jones's derivation of the Chinese from the Hindoos, the state of their written language may occur as an objection; for since it is certain that alphabetical characters were in use among the Hindoos before the period at which he places the emigration of the *Chinas*, how, it may be asked, came these people to drop the mode of writing practised by their ancestors, and to adopt another so very inconvenient as that which the Chinese have used from the foundation of their empire? The force of this objection, however, will vanish, when it is remembered that the *Chinas* were of the military cast; that they had gradually abandoned the ordinances of the Veda, and were in consequence degraded; and that they rambled from their native country in small bodies. We do not know that the military cast among the Hindoos was ever much devoted to letters; there is the greatest reason to believe that a degraded cast would neglect them; and it is certain that small bodies of men, wandering in deserts, would have their time and their attention completely occupied in providing for the day that was passing over them. That the *Chinas* should have forgotten the alphabetical characters of the Hindoos is therefore so far from being an objection to Sir William Jones's account of their descent from that people, that it is the natural consequence of the manner in which he says they rambled from Hindostan to the northern provinces of what now constitutes the Chinese empire.

Of the origin of the characters which are used by this singular people, the illustrious president of the Asiatic Society gives the following account from a Chinese writer, named LI YANG PING. "The earliest of them were nothing more than the outlines of visible objects, earthly and celestial; but as things merely intellectual could not be expressed by those figures, the grammarians of *China* contrived to represent the various operations of the mind by metaphors drawn from the productions of nature. Thus the idea of roughness and of rotundity, of motion and rest, were conveyed to the eye by signs representing a mountain, the sky, a river, and the earth. The figures of the sun, the moon, and the stars, differently combined, stood for smoothness and splendour, for any thing artfully wrought or woven with delicate workmanship. Extension, growth, increase, and many other qualities, were painted in characters taken from the clouds, from the firmament, and from the vegetable part of the creation. The different ways of moving, agility and slowness, idleness and diligence, were expressed by various insects, birds, fishes, and quadrupeds. In this manner passions and sentiments were traced by the pencil, and ideas not subject to any sense were exhibited to the sight; until by degrees new combinations were invented, new expressions added, the characters deviated imperceptibly from their primitive shape, and the Chinese language became not only clear and forcible, but rich and elegant in the highest degree*."

China.

* *Asiatic Researches*, vol. ii. Memoir 13.

Of this language, both as it is spoken and written, Sir George Staunton has given an account so clear and scientific, that it will undoubtedly place him high among the most eminent philologists of the 18th century. As there is nothing relating to the Chinese more wonderful than their language, which is very little understood in Europe, we shall lay before our readers a pretty copious abstract of what he says on the subject, referring them for further information to his account of Lord Macartney's Embassy to China.

"In the Chinese tongue (says Sir George) the sounds of several letters in most alphabets are utterly unknown, and the organs of a native advanced in life cannot pronounce them. In endeavouring to utter the sounds of B, D, R, and X, for instance, he substitutes some other sounds to which the same organ has been accustomed; L for R, and, as we have reason to think from some expressions of Sir William Jones's, F for B. The nice distinctions between the tones and accents of words nearly resembling each other in sound, but varying much in sense, require a nicety of ear to distinguish, and of vocal powers to render them exactly. Synonymous words are therefore frequently introduced in Chinese dialogue to prevent any doubt about the intended sense; and if in an intricate discussion any uncertainty should still remain as to the meaning of a particular expression, recourse is had to the ultimate criterion of tracing with the finger in the air, or otherwise, the form of the character, and thus ascertaining at once which was meant to be expressed. In a Chinese sentence there is no marked distinction of substantives, adjectives, or verbs; nor any accordance of gender, number, and case. A very few particles denote the past, the present, and the future: nor are those auxiliaries employed when the intended time may be otherwise inferred with certainty. A Chinese who means to declare his intention of departing to-morrow, never says that he *will* depart to-morrow; because the expression of the morrow is sufficient to ascertain that his departure must be future. The plural number is marked by the addition of a word, without which the singular always is implied. Neither the memory nor the organs of speech are burthened with the pronunciation of more sounds to express ideas than are absolutely necessary to mark their difference. The language is entirely monosyllabic. A single syllable always expresses a complete idea. Each syllable may be sounded by an European consonant preceding a vowel, sometimes followed by a liquid. Such an order of words prevents the harshness of succeeding consonants sounding ill together; and renders the language as soft and harmonious as the Italian is felt to be, from the rarity of consonants, and the frequency of its vowel terminations.

"The names or sounds, by which men may be first supposed to have distinguished other animals, when occasion offered to designate them in their absence, were attempts at an imitation of the sounds peculiar to those beings; and still, in Chinese, the name, for example, of a cat, is a pretty near resemblance of its usual cry. It occurred as naturally to endeavour, in speaking, to imitate the voice, if practicable, as it was in writing to sketch a rude figure of the object of description. It is observable,

observable, that the radical words of most languages, separated from the servile letters, which mark their inflections, according to their conjugations or declensions, are monosyllabic. A part of each radical word is retained in composition to denote the meaning and etymology of the compound, which thus becomes polysyllabic; but the Chinese grammarians, aware of the inconvenience resulting from the length and complication of sounds, confined all their words, however significant of combined ideas, to single sounds; and retained only in writing, some part at least of the form of each character, denoting a simple idea, in the compound characters conveying complex ideas."

This is a very plausible, and perhaps the true account of the monosyllabic form of the Chinese language; but it is proper to state the different account which is given of this peculiarity by Sir William Jones. "It has arisen, according to him, from the singular habits of the people; for though their common tongue be so *musically* accented as to form a kind of recitative, yet it wants those *grammatical* accents, without which all human tongues would appear monosyllabic. Thus *Amita*, with an accent on the first syllable, means, in the *Sanscrit* language *immeasurable*, and the natives of Bengal pronounce it *Omito;* but when the religion of Buddha, the son of Máyá, was carried into *China*, the people of that country, unable to pronounce the name of their new god, called him Foe, the son of Mo-ye; and divided his epithet *Amita* into three syllables O-mi-to, annexing to them certain ideas of their own, and expressing them in writing by three distinct symbols. Hence it is that they have clipped their language into monosyllables, even when the ideas expressed by them, and the written symbols for those ideas, are very complex."

"In the Chinese language, Sir George Staunton informs us, that there is a certain order, or settled syntax, in the succession of words in the same sentence; a succession fixed by custom differently in different languages, but founded on no rule or natural order of ideas, as has been sometimes supposed; for though a sentence consists of several ideas, to be rendered by several words, these ideas all exist and are connected together in the same instant; forming a picture or image, every part of which is conceived at once. The formation of Chinese sentences is often the simplest and most artless possible, and such as may naturally have occurred at the origin of society. To interrogate, for example, is often at least to require the solution of a question, whether the subject of doubt be in a particular way or the contrary; and accordingly, a Chinese inquiring about his friends health, will sometimes say, *hou, poo hou?* The literal meaning of which words is, "well, not well?" A simple character repeated stands sometimes for more than one of the objects which singly it denotes, and sometimes for a collective quantity of the same thing. The character of *moo* singly is a tree, repeated is a thicket, and tripled is a forest.

"In Chinese there are scarcely fifteen hundred distinct sounds. In the written language there are at least eighty thousand characters or different forms of letters, which number divided by the first gives nearly fifty senses or characters upon an average to every sound expressed; a disproportion, however, that gives more the appearance than the reality of equivocation and uncertainty to the oral language of the Chinese.

"The characters of the Chinese language were originally traced, in most instances, with a view to express either real images, or the allegorical signs of ideas: a circle, for example, for the sun, and a crescent for the moon. A man was represented by an erect figure, with lines to mark the extremities. It was evident that the difficulty and tediousness of imitation will have occasioned soon a change to traits more simple and more quickly traced. Of the entire figure of a man, little more than the lower extremities only continue to be drawn, by two lines forming an angle with each other. A faint resemblance, in some few instances, still remains of the original forms in the present hieroglyphic characters; and the gradation of their changes is traced in several Chinese books. Not above half a dozen of the present characters consist each of a single line; but most of them consist of many, and a few of so many as seventy different strokes. The form of those characters has not been so flux as the sound of words, as appears in the instance of almost all the countries bordering on the Chinese Sea or Eastern Asia, where the Chinese written, but not the oral language, is understood; in like manner, as one form of Arabic figures to denote numbers, and one set of notes for music, are uniform and intelligible throughout Europe, notwithstanding the variety of its languages.

"A certain order or connection is to be perceived in the arrangement of the written characters of the Chinese; as if it had been formed originally upon a system to take place at once, and not grown up, as other languages, by slow and distant intervals. Upwards of two hundred characters, generally consisting each of a few lines or strokes, are made to mark the principal objects of nature, somewhat in the manner of Bishop Wilkin's divisions, in his ingenious book on the subject of universal language, or real character. These may be considered as the genera or roots of language, in which every other word or species, in a systematic sense, is referred to its proper genus. The heart is a genus, of which the representation of a curve line approaches somewhat to the form of the object; and the species referable to it include all the sentiments, passions, and affections, that agitate the human breast. Each species is accompanied by some mark denoting the genus or heart. Under the genus *hand* are arranged most trades and manual exercises. Under the genus *word* every sort of speech, study, writing, understanding, and debate. A horizontal line marks a unit; crossed by another line it stands for ten, as it does in every nation which repeats the units after that number. The five elements, of which the Chinese suppose all bodies in nature to be compounded, form so many genera, each of which comprehends a great number of species under it. As in every compound character or species, the abridged mark of the genus is discernible by a student of that language, in a little time he is enabled to consult the Chinese dictionary, in which the compound characters or species are arranged under their proper genera. The characters of these genera are placed at the beginning of the dictionary, in an order which, like that of the alphabet, is invariable, and soon becomes familiar to the learner. The species under each genus follow each other, according to the number of strokes of which each consists, independently of the one or few which serve to point out the genus. The species wanted is thus soon found out. Its meaning and pronunciation are given through other words in common use; the first of which denotes its signification and the other its sound. When no one common word is found to render exactly the same sound, it is communicated by two words with marks, to inform the inquirer that the consonant of the first word and the vowel of the second joined together form the precise sound wanted.

"The composition of many of the Chinese characters often displays considerable ingenuity, and serves also to give an insight into the opinions and manners of the people. The character expressive of happiness includes abridged marks of land, the source of their physical, and of children that of their moral, enjoyments. This character, embellished in a variety of ways, is hung up almost in every house. Sometimes written by the hand of the emperor, it is sent by him as a compliment, which is very highly prized, and such as he was pleased to send to the embassador.

"Upon the formation, changes, and allusions of compound characters, the Chinese have published many thousand volumes of philological learning. Nowhere does criticism more abound, or is more strict. The introduction or alteration of a character is a serious undertaking, and seldom fails to meet with opposition. The most ancient writings of the Chinese are still classical amongst them. The language seems in no instance to have been derived from or mixed with any other. The written seems to have followed the oral language soon after the men who spoke it were formed into a regular society. Though it is likely that all hieroglyphical languages were originally founded on the principles of imitation, yet in the gradual progress towards arbitrary forms and sounds, it is probable that every society deviated from the originals in a different manner from the others; and thus for every independent society there arose a separate hieroglyphic language. As soon as a communication took place between any two of them, each would hear names and sounds not common to both; each reciprocally would mark down such names in the sounds of its own characters, bearing, as hieroglyphics, a different sense. In that instance, consequently, those characters cease to be hieroglyphics, and were merely marks of sound. If the foreign sounds could not be expressed but by the use of a part of two hieroglyphics, in the manner mentioned to be used sometimes in Chinese dictionaries, the two marks joined together become in fact a syllable. If a frequent intercourse should take place between communities speaking different languages, the necessity of using hieroglyphics merely as marks of sound would frequently recur. The practice would lead imperceptibly to the discovery that, with a few hieroglyphics, every sound of the foreign language might be expressed; and the hieroglyphics which answered best this purpose, either as to exactness of sound or simplicity of form, would be selected for this particular use; and serving as so many letters, would form in fact together what is called an alphabet. Thus, the passage from hieroglyphic to alphabetic writing may naturally be traced, without the necessity of having 'recourse to divine instruction, as some learned men have conjectured, on the ground that the art of writing by an alphabet is too refined and artificial for untutored reason.'

"The Chinese printed character is the same as is used in most manuscripts, and is chiefly formed of straight lines in angular positions, as most letters are in Eastern tongues, especially the Sanscrit; the characters of which, in some instances, admit of additions to their original form, producing a modification of the sense. A running hand is used by the Chinese only on trivial occasions, or for private notes, or for the ease and expedition of the writer; and differs from the other as much as an European manuscript does from print. There are books with alternate columns of both kinds of writing for their mutual explanation to a learner.

"The principal difficulty in the study of Chinese writings arises from the general exclusion of the auxiliary particles of colloquial language, that fix the relation between indeclinable words, such as are all those of the Chinese language. The judgment must be constantly exercised by the student, to supply the absence of such assistance. That judgment must be guided by attention to the manners, customs, laws, and opinions of the Chinese, and to the events and local circumstances of the country, to which the allusions of language perpetually refer. If it in general be true, that a language is difficult to be understood in proportion to the distance of the country where it is spoken, and that of him who endeavours to acquire it, because in that proportion the allusions to which language has continually recourse are less known to the learner, some idea may be conceived of the obstacles which an European may expect to meet in reading Chinese, not only from the remoteness of situation, but from the difference between him and the native of China in all other respects. The Chinese characters are in fact sketches or abridged figures, and a sentence is often a string of metaphors. The different relations of life are not marked by arbitrary sounds, simply conveying the idea of such connection; but the qualities naturally expected to arise out of such relations become frequently the name by which they are respectively known. Kindred, for example, of every degree is thus distinguished with a minuteness unknown in other languages. That of China has distinct characters for every modification known by them of objects in the physical and intellectual world. Abstract terms are no otherwise expressed by the Chinese than by applying to each the name of the most prominent objects to which it might be applied, which is likewise indeed generally the case of other languages. Among the Latins the abstract idea of virtue, for example, was expressed under the name of valour or strength *(Virtus)*, being the quality most esteemed among them, as filial piety is considered to be in China. The words of an alphabetic language being formed of different combinations of letters or elemental parts, each with a distinct sound and name, whoever knows and combines these together, may read the words without the least knowledge of their meaning; not so hieroglyphic language, in which each character has indeed a sound annexed to it, but which bears no certain relation to the unnamed lines or strokes of which it is composed. Such character is studied and best learned by becoming acquainted with the idea attached to it; and a dictionary of hieroglyphics is less a vocabulary of the terms of one language with the correspondent terms in another, than an encyclopædia

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cyclopædia containing explanations of the ideas themſelves repreſented by ſuch hieroglyphics. In ſuch ſenſe only can the acquiſition of Chineſe words be juſtly ſaid to engroſs moſt of the time of men of learning among them. The knowledge of the ſciences of the Chineſe, however imperfect, and of their moſt extenſive literature, is certainly ſufficient to occupy the life of man. Enough, however, of the language is imperceptibly acquired by every native, and may, with diligence, be acquired by foreigners for the ordinary concerns of life; and further improvements muſt depend on capacity and opportunity."

Next to the ſingular ſtructure of the oral and written language of the Chineſe, there is perhaps nothing in their hiſtory more ſurpriſing to a native of Europe than the number of the people, and the means by which they contrive to procure ſubſiſtence, without foreign trade, in a country ſo crouded, and at the ſame time not everywhere of a fertile ſoil. In the Encyclopædia, the population of this vaſt empire is ſtated, from M. Groſier, at 200 millions: but great as this is, when compared with the population of every other extenſive country, it appears to be far ſhort of the truth. Sir George Staunton has publiſhed a ſtatement, taken from one of the public offices in the capital, and given by a great and reſpectable manderin to Lord Macartney, in which it is ſhewn that China Proper contains not fewer than 333 millions of inhabitants. As the extent of the country is 1,297,999 ſquare miles, there are of courſe very near 260 inhabitants to every ſquare mile; and of theſe miles a very conſiderable proportion conſiſts of nothing but barren rocks. That this account is accurate there can be little doubt; for the extent of the provinces was aſcertained by aſtronomical obſervations, as well as by admeaſurement; and the number of individuals is regularly taken in each diviſion of a diſtrict by a tythingman, or every tenth maſter of a family. Theſe returns are collected by officers reſident ſo near as to be capable of correcting any groſs miſtake, and are all lodged in the great regiſter of Pekin.

For this exceſſive population our author ſatisfactorily accounts. Celibacy, ſays he, is rare in China, even in the military profeſſion; the marriages are prolific as well as early, and the influence of the patriarchal ſyſtem, to be explained afterwards, is ſuch, that a man's children adds to his wealth. It is reckoned a diſcredit to be without offspring; and they who have none adopt others, who become theirs excluſively. In caſe of marriage, ſhould a wife prove barren, a ſecond may be eſpouſed in the lifetime of the firſt. The opulent, as in moſt parts of the Eaſt, are allowed, without reproach, to keep concubines, of whom the children are conſidered as being thoſe of the legitimate wife, and partake in all the rights of legitimacy. "Accidents ſometimes of extraordinary drought, and ſometimes of exceſſive inundations, occaſionally produce famine in particular provinces, and famine diſeaſe; but there are few drains from moral cauſes either of emigration or foreign navigation. The number of manufacturers, whoſe occupations are not always favourable to health, whoſe conſtant confinement to particular ſpots, and ſometimes in a cloſe or tainted atmoſphere, muſt be injurious, and whoſe reſidence in towns expoſes them to irregularities, bears but a very ſmall proportion to that of huſbandmen in China. In general there ſeems to be no other bounds to Chineſe populouſneſs than thoſe which the neceſſity of ſubſiſtence may put to it. Theſe boundaries are certainly more enlarged than in other countries. The whole ſurface of the empire is, with trifling exceptions, dedicated to the production of food for man alone. There is no meadow, and very little paſture; nor are fields cultivated in oats, beans, or turnips, for the ſupport of cattle of any kind. Few parks or pleaſure grounds are ſeen, excepting thoſe belonging to the emperor. Little land is taken up for roads, which are few and narrow, the chief communication being by water. There are no commons, or lands ſuffered to lie waſte by the neglect, or the caprice, or for the ſport of great proprietors. No arable land lies fallow. The ſoil, under a hot and fertilizing ſun, yields annually, in moſt inſtances, double crops, in conſequence of adapting the culture to the ſoil, and of ſupplying its defects by mixture with other earths, by manure, by irrigation, by careful and judicious induſtry of every kind. The labour of man is little diverted from that induſtry to miniſter to the luxuries of the opulent and powerful, or in employments of no real uſe. Even the ſoldiers of the Chineſe army, except during the ſhort intervals of the guards, which they are called to mount, or the exerciſes, or other occaſional ſervices which they perform, are moſtly employed in agriculture. The quantity of ſubſiſtence is increaſed alſo by converting more ſpecies of animals and vegetables to that purpoſe than is uſual in other countries. And even in the preparation of their food, the Chineſe have economy and management."

The government of China is deſpotic; and it is a curious ſpectacle to behold ſo large a proportion of the whole human race, connected together in one great ſyſtem of polity, ſubmitting quietly, and through ſo conſiderable an extent of country, to one great ſovereign; and uniform in their laws, their manners and their language, but differing eſſentially in each of theſe reſpects from every other portion of mankind; and neither deſirous of communicating with nor forming any deſigns againſt the reſt of the world. To produce ſuch a phenomenon, many cauſes muſt be combined; but perhaps the principal are to be found in the patriarchal ſyſtem already mentioned, in the laws and cuſtoms of the empire, and in the belief that the emperor is the vicegerent of heaven, and guided in all his actions by divine inſpiration.

The patriarchal ſyſtem is founded upon that filial piety which the philoſophers of China have uniformly repreſented as the greateſt of human virtues. Theſe ſages, while they ſucceſsfully inculcated this duty, have left parental affection to its own natural influence; and hence in China parents are leſs frequently neglected than infants are expoſed. The laws of the empire, to corroborate the diſpoſition to filial obedience, furniſh an opportunity for puniſhing any breach of it, by leaving a man's offspring entirely within his own power: and hence it is, that with the poor, marriage, as we have ſaid, is a meaſure of prudence; becauſe the children, particularly the ſons, are bound to maintain their parents.

A Chineſe dwelling is generally ſurrounded by a wall ſix or ſeven feet high. Within this incloſure a whole family, of three generations, with all their reſpective wives and children, will frequently be found. One ſmall room is made to ſerve for the individuals of each branch of the family, fleeping in different beds, divided only by mats hanging from the ceiling. One common room is ufed for eating.

The prevalence of this cuftom of retaining the feveral branches of a family under the fame roof, is attended with important effects. It renders the younger temperate and orderly in their conduct under the authority and example of the older; and it enables the whole to fubfift, like foldiers in a mefs, with more economy and advantage. As the venerable patriarch of each habitation prefides over his defcendants with the authority of a magiftrate; fo the different orders of magiftrates are, in their different diftricts and provinces looked up to with the veneration due from children to their parents, while the emperor is revered as the grand patriarch of the whole empire.

Another thing which contributes much to the permanency of the government, and the internal quiet of the empire is, that in China there is lefs inequality in the fortunes than in the conditions of men. The ancient annals of the empire teftify, that for a long period of time, the earth, like the other elements of nature, was enjoyed by its inhabitants almoft in common. Their country was divided into fmall equal diftricts; every diftrict was cultivated conjointly by eight labouring families, which compofed each hamlet; and they enjoyed all the profit of their labours, except a certain fhare of the produce referved for public expences. It is true, indeed, that after a revolution, deplored in all the Chinefe hiftories, which happened prior to the Chriftian era, the ufurper granted all the lands away to the partners of his victories, leaving to the cultivators of the foil a fmall pittance only out of the revenue which it yielded. Property in land alfo became hereditary: but in procefs of time, the moft confiderable domains were fubdivided into very moderate parcels by the fucceffive diftribution of the poffeffions of every father equally among all his fons; the daughters being always married without dower. It very rarely happened that there was but an only fon to enjoy the whole property of his deceafed parents; and it could fcarcely be increafed by collateral fucceffion.

From the operations of all thofe caufes, there was a conftant tendency to level wealth; and few could fucceed to fuch an accumulation of it as to render them independent of any efforts of their own for its increafe. Befides, wealth alone confers in China but little importance, and no power; nor is property, without office, always perfectly fecure. There is no hereditary dignity, which might accompany, and give it pre-eminence and weight. The delegated authority of government often leans more heavily on the unprotected rich than on the poor, who are lefs objects of temptation. And it is a common remark among the Chinefe that fortunes, either by being parcelled out to many heirs, or by being loft in commercial fpeculations, gaming, or extravagance, or extorted by oppreffive mandarines, feldom continue to be confiderable in the individuals of the fame family beyond the third generation. To afcend again the ladder of ambition, it is neceffary, by long and laborious ftudy to excel in the learning of the country, which alone qualifies for public employments.

There are properly but three claffes of men in China: men of letters, from whom the mandarines are taken; cultivators of the ground; and mechanics, including merchants. In Pekin alone is conferred the higheft degree of literature upon thofe who, in public examinations, are found moft able in the fciences of morality and government, as taught in the ancient Chinefe writers, with which ftudies the hiftory of their country is intimately blended. Among fuch graduates, all the civil offices in the ftate are diftributed by the emperor; and they compofe all the great tribunals of the empire. The candidates for thofe degrees are fuch as have fucceeded in fimilar examinations in the principal city of each province. Thofe who have been chofen in the cities of the fecond order, or chief town of every diftrict in the province, are the candidates in the provincial capital. They who fail in the firft and fecond claffes, have ftill a claim on fubordinate offices, proportioned to the clafs in which they had fucceeded. Thofe examinations are carried on with great folemnity, and apparent fairnefs. Military rank is likewife given to thofe who are found upon competition to excel in the military art, and in warlike exercifes. This diftribution of offices contributes greatly to the peace of the empire; for the people cheerfully fubmit to the authority of thofe whom they believe to be placed over them by merit alone, and love that conftitution which brings within the reach of the meaneft fubject, who has talents and induftry, the higheft ftation next to the fupreme.

"The great tribunals are fituated, for the fake of convenience, near the fouthern gate of the imperial palace at Pekin. To them accounts of all the tranfactions of the empire are regularly tranfmitted. They are councils of reference from the emperor, to whom they report every bufinefs of moment, with the motives for the advice which they offer on the occafion. There is a body of doctrine compofed from the writings of the earlieft ages of the empire, confirmed by fubfequent lawgivers and fovereigns, and tranfmitted from age to age with increafing veneration, which ferves as rules to guide the judgment of thofe tribunals. This doctrine feems, indeed, founded on the broadeft bafis of univerfal juftice, and on the pureft principles of humanity.

"His Imperial majefty generally conforms to the fuggeftions of thofe tribunals. One tribunal is directed to confider the qualifications of the different mandarines for different offices, and to propofe their removal when found incapable or unjuft. One has for object the prefervation of the manners or morals of the empire, called by Europeans *the tribunal of ceremonies*, which it regulates on the maxim, that exterior forms contribute not a little to prevent the breach of moral rules. The moft arduous and critical is the tribunal of cenfors; taking into its confideration the effect of fubfifting laws, the conduct of the other tribunals, of the princes and great officers of ftate, and even of the emperor himfelf. There are feveral fubordinate tribunals; fuch as thofe of mathematics, of medicine, of public works, of literature and hiftory. The whole is a regular and confiftent fyftem eftablifhed at a very early period, continued with little alterations through every dynafty, and revived after any interruption from the caprice or paffions of particular princes. Whatever deviation has been made by the prefent family on the throne, arifes from the admiffion of as many Tartars as Chinefe into every tribunal." The opinions of the former are fuppofed always to preponderate; and many of them are indeed men of confiderable talents and ftrength of mind, as well

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well as polished manners. They are, however, in general, fitter for military than civil offices. The hardy education, the rough manners, the active spirit, the wandering disposition, the loose principles, and the irregular conduct, of the Tartar, fit him better for the profession, practice, and pursuits of war, than the calm, regulated, and domestic habits of the Chinese. Warriors seem naturally the offspring of Tartary, as literati are of China; and accordingly, the principal military commands are conferred on natives of the former country, as, with many exceptions indeed, the chief civil offices are on those of the latter.

A military mandarin, who was much with Lord Macartney, and was himself a distinguished officer, asserted, that, "including Tartars, the total of the army in the pay of China, amounted to 1,000,000 infantry, and 800,000 cavalry. From the observations made by the embassy in the course of their travels through the empire, of the garrisons in the cities of the several orders, and of the military posts at small distances from each other, there appeared nothing unlikely in the calculation of the infantry; but they met few cavalry. If the number mentioned really do exist, a great proportion of them must have been in Tartary, or on some service distant from the route of the embassy.

"Of the troops, especially cavalry, a vast number are Tartars, who have a higher pay than their Chinese fellow-soldiers. The principal officers of confidence in the army are Tartars also. None of either nation are received into the service, but such as are healthy, strong, and sightly. The pay and allowances of a Chinese horseman are three Chinese ounces, heavier than European ounces, and three-tenths of an ounce, of silver, and fifteen measures or rations (the weight not mentioned) of rice every lunar month. A Tartar horseman, seven similar ounces of silver, and 20 measures of rice for the same period. A Chinese foot soldier has one ounce and six-tenths of an ounce of silver, and ten measures of rice; and a Tartar of the same description has two ounces of silver, and ten measures of rice every lunar month. The emperor furnishes the arms, accoutrements, and the upper garment, to all the soldiers. Beside their ordinary pay and allowances, they also receive donations from the emperor on particular occasions; as when they marry, and when they have male children born. On the death of their parents they obtain 'a gift of consolation;' as do their families when the soldiers themselves die.

"The public revenues of China Proper are said to be little less than 200,000,000 of ounces of silver, which may be equal to about 66,000,000 of pounds sterling; or about three times those of France before the late subversion. From the produce of the taxes all the civil and military expences, and the incidental and extraordinary charges are first paid upon the spot out of the treasuries of the respective provinces, where such expences are incurred; and the remainder is remitted to the Imperial treasury at Pekin. This surplus amounted, in the year 1792, to the sum of 36,614,328 ounces of silver, or 12,204,776 pounds sterling, according to an account taken in round numbers. In case of insurrections, or other occurrences requiring extraordinary expences, they are generally levied by additional taxes on the provinces adjacent to the scene of action, or connected with the occasion of the expence.

"In the administration of the vast revenue of the state, the opportunities of committing abuses are not often neglected; as may be inferred from the frequent confiscation to the emperor, in consequence of such transgressions. It is indeed affirmed, that much corruption and oppression prevail in most of the public departments, by which considerable fortunes are acquired, notwithstanding the modicity of the public salaries."

With such a standing army, and so vast a revenue, it will no longer appear wonderful that one man should govern with despotic sway, even the immense multitude of people who inhabit the empire of China, especially trained up as those people are in habits of filial submission to their superiors. But there are some circumstances in the system of Chinese policy, not yet mentioned, which contribute perhaps more than even these habits and that power to preserve the stability of the government. The emperor reserves to himself alone the right of relieving the wants of the poor, produced by famine or any other unforeseen calamity. On such occasions he always comes forward. He orders the public granaries to be opened; remits the taxes to those who are visited with misfortune; affords assistance to enable them to retrieve their affairs; and appears to his subjects as standing almost in the place of Providence in their favour. He is perfectly aware by how much a stronger chain he thus maintains his absolute dominion, than the mere dread of punishment would afford. The emperor, to whom the British embassy was sent, shewed himself so jealous of retaining the exclusive privilege of benevolence to his subjects, that he not only rejected, but was offended at, a proposal once made to him by some considerable merchants, to contribute towards the relief of a suffering province; whilst he scrupled not, at the same time, to accept the donation of a rich widow towards the expences of a war in which he was engaged.

This veneration, excited towards the emperor by his apparent benevolence, is increased by an opinion zealously instilled into the people, that he has the faculty of predicting future events of the greatest importance. The Chinese, given up to the dotages of judicial astrology, are firmly persuaded that eclipses of the sun and moon have a powerful influence on the operations of nature and the transactions of mankind; and the periods of their occurrence become, of course, objects of attention and solicitude. The government of the country, ever anxious to establish its authority in the general opinion of its superior wisdom and constant care for the welfare of the people, employs the European missionaries at Pekin (for it is doubtful if any one of the natives has so much science) to calculate eclipses, and then announces them to the people with that solemnity which is fitted to ensure veneration for the superintending power whence such knowledge is immediately derived to them. Eclipses of the sun, in particular, are considered as ominous of some general calamity; and as great pains are taken to inspire them with a belief that their prosperity is owing to the wisdom and virtues of their sovereign, so they are tempted to attribute to some deficiency on his part whatever they think portentous. To this prejudice the emperor finds it prudent to accommodate his conduct. He never ventures on any undertaking of importance at the approach of a solar eclipse, but affects to withdraw himself from the presence of his courtiers, to examine strictly into his late adminiftration of the empire, in order to correct any error, for the commiffion of which the eclipfe may have been an admonition. On thefe occafions he invites his fubjects to give him freely their advice: but it is plain that advice muft be offered with great deference to a being for whofe admonition the motions of the fun and moon are believed to be regulated; and while fuch notions are implicitly admitted, the perfon of the Chinefe emperor, as well as his authority, muft be looked upon by his fubjects as fomething more than human.

This is in fact the cafe. He is not only approached in perfon with teftimonies of the utmoft refpect, but is adored when abfent with all the rites and ceremonies which are ufed by the Chinefe in the worfhip of their divinities. On his birth-day, at the new and full moon, and probably on other feftivals, all the mandarines refident in the neighbourhood of any of his numerous palaces affemble about noon, and repairing to the palace, folemnly proftrate themfelves nine times before the throne, their foreheads ftriking the floor each time; whilft incenfe is burning on tripods on each fide of it, and offerings are made, on an altar before it, of tea and fruits to the fpirit of the abfent emperor. Over the throne are feen the Chinefe characters of glory and perfection; and the name of the Deity is given to the emperor, who is confidered by his votaries as poffeffing in fome fenfe the attribute of ubiquity. Mr Barrow, one of the gentlemen of the embaffy, was prefent at *Yuen-min-yuen*, one of the imperial palaces, when thefe idolatrous rites of adoration were performed, and he was affured that they took place on that day in all parts of the empire, the proftraters being every where attentive to turn their faces towards the capital.

That he who claims adoration in his abfence does not appear on his birth-day to receive the compliments of his fubjects, will not furprife the reader. The manner in which that feftival is celebrated at the palace, where the emperor happens to be refident, is thus defcribed by Sir George Staunton, who witneffed this more than auguft ceremony at the palace of *Zhe-hal* in Tartary. "The princes, tributaries, ambaffadors, great officers of ftate, and principal mandarines, were affembled in a vaft hall; and upon particular notice, were introduced into an inner building, bearing, at leaft, the femblance of a temple. It was chiefly furnifhed with great inftruments of mufic, among which were fets of cylindrical bells, fufpended in a line from ornamented frames of wood, and gradually diminifhing in fize from one extremity to the other, and alfo triangular pieces of metal arranged in the fame order as the bells. To the found of thefe inftruments a flow and folemn hymn was fung by eunuchs, who had fuch a command of their voices as to refemble the effect of the mufical glaffes at a diftance. The performers were directed, in gliding from one tone to another, by the ftriking of a fhrill and fonorous cymbal; and the judges of mufic among the gentlemen of the embaffy were much pleafed with their execution. The whole had indeed a grand effect. During the performance, and at particular fignals, nine times repeated, all the perfons proftrated themfelves nine times, except the ambaffador and his fuite, who made a profound obeifance (A). But he whom it was meant to honour, continued, as if it were in imitation of the Deity, invifible the whole time."

That the awful impreffion meant to be made upon the minds of men by this apparent worfhip of a fellow-mortal might not be too quickly effaced, all fcenes of fport and gaiety were poftponed to the next day, when a variety of entertainments was exhibited in the prefence of the emperor, furrounded by his court and tributary princes.

Notwithftanding the general veneration of the Chinefe for the perfon and government of their emperor, the mandarines afferted that a fect had for ages fubfifted in the country, whofe chief principles were founded on an antipathy to monarchy, and who nourifhed hopes of at laft fubverting it. Their meetings were held in the utmoft fecrecy, and no man avowed any knowledge of them; but a fort of inquifition was faid to be eftablifhed in order to find them out, and they who were fufpected of fuch fentiments were cut off, or hunted out of fociety. Should the French declaration of the rights of man, which, through the zeal of its authors, has been tranflated into one of the languages of India, find its way into China (of which the court is faid to be much afraid), it would indeed be a powerful engine in the hands of this fecret fect to fap the foundations of the ancient government. The minds of many of the Chinefe are far from fatisfied with their condition, which lays both their perfons and their fortunes at the mercy of the mandarines. No private man in China is exempted from corporal punifhment, which may be inftantly inflicted on him at the nod of a magiftrate; and when he has occafion to fpeak to a great mandarine, he is obliged, by the police of the country, to throw himfelf on his knees, and in that pofture to communicate his bufinefs. The mandarine himfelf, on the other hand, lies under the hardfhip of being frequently refponfible for events which he could not controul. Upon the general principal that it is his duty to watch over the morals of the people, he is in many cafes confidered as a criminal for not preventing crimes which he had not been able to prevent. The mandarines are thus aware of not being guaranteed by good conduct againft difgrace; and feeling the chagrin of infecurity, many of them

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(A) The Chinefe court, which confiders all other fovereigns as fubordinate to their own, exacts from foreign minifters, as well as from natives of the empire, nine proftrations upon their firft introduction to the emperor. This demand was made, in the laft century, of the Dutch, who inftantly complied with it in hopes of obtaining in return fome lucrative advantages; and the confequence was, that their ambaffador was treated with neglect, and difmiffed without promife of the fmalleft favour. It was likewife made of a Ruffian ambaffador in the prefent century; but he would not comply with it, until a regular agreement was made for its return, on a like occafion, to his own fovereign. Lord Macartney, who was repeatedly urged to go through the fame abject ceremony, difplayed fuch firmnefs and addrefs, that after much evafion it was at laft announced to him, that his imperial majefty would be fatisfied with the fame form of refpectful obedience that the Englifh are in the habit of paying to their own fovereign; and upon thefe terms his lordfhip was introduced and gracioufly received.

China. them muſt doubtleſs be ripe for a revolt. Fear may keep them quiet during the reign of a ſovereign poſſeſſed of abilities and vigilance; but the maxims which regulate the imperial ſucceſſion are ſuch, that a firm confederacy could hardly fail at the death of an emperor to introduce great changes into the conſtitution. The throne of China is neither hereditary nor elective. The choice of a ſucceſſor is left entirely to the reigning prince, who may exclude, as has been inſtanced, even his own offſpring and family. To prevent commotions and fraud, it is no uncommon practice for the emperor, during his lifetime, to declare his ſucceſſor; for when his ſucceſſion is ſettled by a written teſtament, the throne is not always filled by him for whom it was deſtined. The father of the emperor to whom the British embaſſy was ſent, is ſaid to have obtained poſſeſſion of the throne by ſuddenly entering the palace in the laſt moments of his predeceſſor, and ſubſtituting his own name in a teſtament intended for the exaltation of another.

To what has been ſaid in the Encyclopædia of the religion of the Chineſe, we have here very little to add. Various deities are worſhipped in the empire by very different rites and ceremonies; but there is in China no ſtate religion. None is paid, preferred, or encouraged by it. The emperor is of one faith; many of the mandarines of another; and the majority of the common people of a third, which is that of Fo. The men of letters venerate rather than adore Confucius; and meet to honour and celebrate his memory in halls of a ſimple but neat conſtruction. The numerous and lower claſſes of the people are leſs able than inclined to contribute much towards the erection of large and coſtly edifices for public worſhip: their attention is almoſt wholly engaged by their houſehold gods; for every houſe has its altar and its deities.

"No people are, in fact, more ſuperſtitious than the common Chineſe. Beſide the habitual offices of devotion on the part of the prieſts and females, the temples are particularly frequented by the diſciples of Fo previouſly to any undertaking of importance; whether to marry, or go a journey, or conclude a bargain, or change ſituation, or for any other material event in life, it is neceſſary firſt to conſult the ſuperintendant deity. This is performed by various methods. Some place a parcel of conſecrated ſticks, differently marked and numbered, which the conſultant, kneeling before the altar, ſhakes in a hollow bamboo, until one of them falls on the ground; its mark is examined, and referred to a correſpondent mark in a book which the prieſt holds open, and ſometimes even it is written upon a ſheet of paper paſted upon the inſide of the temple. Polygonal pieces of wood are by others thrown into the air. Each ſide has its particular mark; the ſide that is uppermoſt when fallen on the floor is in like manner referred to its correſpondent mark in the book or ſheet of fate. If the firſt throw be favourable, the perſon who made it proſtrates himſelf in gratitude, and undertakes afterwards with confidence the buſineſs in agitation. But if the throw ſhould be adverſe, he tries a ſecond time, and the third throw determines, at any rate, the queſtion. In other reſpects, the people of the preſent day ſeem to pay little attention to their prieſts. The temples are, however, always open for ſuch as chooſe to conſult the decrees of heaven. They return thanks when the oracle proves propitious to their wiſhes. Yet they oftener caſt lots to know the iſſue of a projected enterpriſe than ſupplicate for its being favourable; and their worſhip conſiſts more in thankſgiving than in prayer.

"The Chineſe are ſaid ſeldom to carry the objects to be obtained by their devotion beyond the benefits of this life. Yet the religion of Fo profeſſes the doctrine of the tranſmigration of ſouls, and promiſes happineſs to the people on conditions, which were no doubt originally intended to conſiſt in the performance of moral duties: but in lieu of which are too frequently ſubſtituted thoſe of contributions towards the erection or repair of temples, the maintenance of prieſts, and a ſtrict attention to particular obſervances. The neglect of theſe is announced as puniſhable by the ſouls of the defaulters paſſing into the bodies of the meaneſt animals, in whom the ſufferings are to be proportioned to the tranſgreſſions committed in the human form."

Though the Chineſe artiſts are very ingenious as mere workmen, there is hardly any thing which deſerves the name of ſcience in the whole empire. So little is the ſtudy of mathematics cultivated, that there are few ſhopkeepers in China who can perform the ordinary operations of arithmetic; but caſt up their accounts by means of an inſtrument called *Swanpan* (See Swanpan, *Encycl.*). Though the compoſition of gunpowder was certainly known in China much earlier than in Europe, and though the Chineſe had employed it from the beginning in blaſting rocks, and in making a vaſt variety of fire-works; yet Sir George Staunton ſeems convinced, that they never thought of the invention of guns till they were taught by the Europeans to introduce them into their armies.

The ſtate of phyſic in this vaſt country is extremely low, being nowhere taught in public ſchools or colleges. "A young man, who wiſhes to become a phyſician, has no other way of acquiring medical knowledge than by engaging himſelf to ſome practitioner as an apprentice. He has thus the opportunity of ſeeing his maſter's practice, of viſiting his patients with him, and of learning ſuch parts of his knowledge and ſecrets as the other chooſes to communicate to him. The emoluments of the profeſſion ſeldom exceed the ſkill of the practitioner. As many copper coin as ſcarcely are equal to ſixpence ſterling is ſaid to be the uſual fee among the people; and perhaps quadruple among the mandarines. Medicine is not divided in China into diſtinct branches as in moſt parts of Europe. The ſame perſon acts as phyſician, ſurgeon and apothecary. The ſurgical part of the profeſſion is ſtill more backward than the others. Amputation, in caſes of compound fracture and gangrene, is utterly unknown; and death is the ſpeedy conſequence of ſuch accidents. The Chineſe method of inoculation, which was introduced into the empire about the beginning of the tenth century of our era, is as follows: When the diſeaſe breaks out in any diſtrict, the phyſicians of the place carefully collect a quantity of ripe matter from puſtules of the proper ſort; which being dried and pulveriſed is cloſely ſhut up in a porcelain jar, ſo as to exclude from it the atmoſpheric air; and in this manner it will retain its properties for many years. When the patient has been duly prepared by medicines, generally of an aperient kind, and ſtrictly dieted for a ſhort time, a lucky day is choſen to ſprinkle a little a little of the variolous powder upon a ſmall piece of fine cotton wool, and to inſert it into the noſtrils of the patient.

"No male phyſician is allowed to attend a pregnant woman, and ſtill leſs to practiſe midwifery; in the indelicacy of which both ſexes ſeem to agree in China. There are books written on that art for the uſe of female practitioners, with drawings of the ſtate and poſition of the infant at different periods of geſtation; together with a variety of directions and preſcriptions for every ſuppoſed caſe that may take place: the whole mixed with a number of ſuperſtitious obſervances.

Many practitioners of phyſic take the advantage, as elſewhere, of the obſcurity in which that art is involved, and of the ignorance and credulity of the people, to gain money by the ſale of noſtrums and ſecrets of their own. They diſtribute hand bills, ſetting forth the efficacy of their medicines, with atteſted cures annexed to them. And there is one ſect which boldly arrogates to itſelf the poſſeſſion of a medical ſecret *not to die!* To thoſe who had all the enjoyments of this life, there remained unaccompliſhed no other wiſh than that of remaining forever in it. And accordingly ſeveral ſovereigns of China have been known to cheriſh the idea of the poſſibility of ſuch a medicine. They had put themſelves, in full health, under the care of thoſe religious empirics, and took large draughts of the boaſted beverage of immortality. The compoſition did not conſiſt of merely harmleſs ingredients; but probably of ſuch extracts and proportions of the poppy, and of other ſubſtances and liquors, as occaſioning a temporary exaltation of the imagination, paſſed for an indication of its vivifying effects. Thus encouraged, they had recourſe to frequent repetitions of the doſe, which brought on quickly languor and debility of ſpirits, and the deluded patients often became victims to deceit and folly in the flower of their age.

"There are in China no profeſſors of the ſciences connected with medicine. The human body is never, unleſs privately, diſſected there. Books, indeed, with drawings of its internal ſtructure, are ſometimes publiſhed; but theſe are extremely imperfect, and conſulted, perhaps, oftener to find out the name of the ſpirit under whoſe protection each particular part is placed, than for obſerving its form and ſituation.

"It is a matter of doubt whether natural hiſtory, natural philoſophy, or chemiſtry, be, as ſciences, much more improved than anatomy in China. There are ſeveral treatiſes, indeed, on particular ſubjects, in each. The Chineſe likewiſe poſſeſs a very voluminous Encyclopædia, containing many facts and obſervations relative to them; but from the few reſearches which the gentlemen of the embaſſy had leiſure or opportunity to make during their ſhort viſit to the country, they perceived no traces of any general ſyſtem or doctrine by which ſeparate facts or obſervations were connected and compared, or the common properties of bodies aſcertained by experiment; or where kindred arts were conducted on ſimilar views, or rules framed, or deductions drawn from analogy, or principles laid down to conſtitute a ſcience."

Of all people the Chineſe are perhaps the moſt eager in their curioſity about foreigners coming among them, and the moſt indifferent about the countries of ſuch foreigners. They have been always in the habit of confining their ideas to their own country, emphatically ſtyled *the middle kingdom.* No Chineſe ever thinks of quitting it, except a few of deſperate fortunes, reſiding near the ſea coaſt, or ſea-faring men, who form a claſs, in a great meaſure apart from ſociety. Even foreign commodities conſumed in China remind them only of Canton, whence they receive them, as if produced in it; and theſe commodities they conſider, perhaps properly, as of no real benefit to the empire. Regions out of Aſia are ſcarcely mentioned in their books, or noticed in their diſtorted maps; and the great body of the people would be little gratified with accounts of ſuch regions which did not contain tales of wonders not performed at home, or of powers exerted beyond the ordinary boundaries of nature.

CHINCA, a large and pleaſant valley in the dioceſe of Lima, in Peru. Pizarro deſired the king of Spain that this might be the limits of his government on the S. and that the river St Jago ſhould bound it on the N. The valley bears good wheat, and Spaniſh vines thrive well in it.—*Morse.*

CHINESE PUMP. See PUMP in this Supplement.

CHINESE WEIGHTS are ſo very different in many reſpects from thoſe in uſe elſewhere, that it will at leaſt gratify the curioſity of our readers to take ſome notice of them in this Work. Of theſe weights Charles Coquebert has preſented a ſpecimen to the Philomathematical Society in Paris. They are made of copper, and bear a great reſemblance in form to the body of a violin. Like that inſtrument they are rounded off at the extremities, and indented on the ſides to admit the fingers. The faces are flat and parallel, and have Chineſe characters engraven on the upper ſurface; They advance in a regular decimal progreſſion, of which Coquebert has diſcovered four diſtinct ſeries, the units of which are in the proportion of 1, 10, 100, 1000. Inſtead of employing a combination of one, two, four, and eight units, or after the new ſyſtem of one, two, and five units, the Chineſe have a diſtinct weight for every intermediate number between one and ten. Thus they have weights of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, &c. Of courſe, thoſe weights which ſtand related to each other in the proportion of 6 to 7, 7 to 8, 8 to 9, 9 to 10, differ ſo little in ſize, that it would be impoſſible to diſtinguiſh them without the help of the characters which are engraven upon the face. This is confeſſedly a defect in the ſyſtem. Of the four different ſeries exhibited to the ſociety, the higheſt bears in China the name of *kin*, and is nearly of equal value with a pound avoirdupois. The kin contains ten times the number of units of the next inferior weight, which the Chineſe denominate *leang* or *loam*, and which the Europeans call *tael*, *taille*, or Chineſe *ounce*. This ounce is divided into ten *tſien*, which anſwers nearly to our drachm. The tſien is again ſubdivided into ten *fen*. The Chineſe extend the decimal ſubdiviſion of their weights conſiderably farther. They have diſtinct names, which are all monoſyllabic, for nine ſeries below the fen. Suppoſing the kin to ſtand for unity, they have,

1,	0	0	0	0	0	0	0	0	0	0	0	0
kin	leang	tſien	fen	li	hav	ſen	tehin	vai	miao	mo	tſun	ſun

The Chineſe weights, compared with the greateſt preciſion,

precision, and with the help of the best instruments, bear the following proportion to our weights: The kin is equal to one pound 12 ounces 2 drachms 24 grains; the leang one ounce one drachm 60 grains; the tien 70 grains $\frac{8}{10}$; the fen 7 grains $\frac{8}{100}$. Consequently the last of this series, the sun, amounts to no more than 0 grains 000000000708.

Chinese Wheel is an engine employed in the province of *Kiang-see*, and probably through the whole empire, for raising water from rivers to irrigate plantations of sugar canes, on a sandy soil, considerably elevated above the level of the river. By Sir George Staunton, who says that it is ingenious in its contrivance, cheap in its materials, easy in its operation, and effectual to its purpose, it is thus described:

"Two hard wood posts or uprights are firmly fixed in the bed of the river, in a line perpendicular to its bank. These posts support the axis about ten feet in length, of a large and durable wheel, consisting of two unequal rims, the diameter of one of which, closest to the bank, being about fifteen inches shorter than that of the outer rim; but both dipping in the stream, while the opposite segment of the wheel rises above the elevated bank. This double wheel is connected with the axis, and is supported by 16 or 18 spokes obliquely inserted near each extremity of the axis, and crossing each other at about two-thirds of their length. They are there strengthened by a concentric circle, and fastened afterwards to the rims: the spokes inserted in the interior extremity of the axis reaching the outer rim, and those proceeding from the exterior extremity of the same axis, reaching the inner and smaller rim. Between the rims and the crossing of the spokes is woven a kind of close basket-work, serving as ladle-boards or floats, which meeting successively the current of the stream, obey its impulse, and turn round the wheel. To both its rims are attached small tubes or spouts of wood, with an inclination of about 25 degrees to the horizon, or to the axis of the wheel. The tubes are closed at their outer extremity, and open at the opposite end. By this position, the tubes which happen in the motion of the wheel to be in the stream with their mouths or open ends uppermost, fill with water. As that segment of the wheel rises, the mouths of the tubes attach to it, alter their relative inclination, but not so much as to let their contents flow out till such segment of the wheel becomes the top. The mouths of those tubes are then relatively depressed, and pour the water into a wide trough placed on posts, from whence it is conveyed as may be wanted among the canes.

"The only materials employed in the construction of this water-wheel, except the nave or axis, and the posts on which it rests, are afforded by the bamboo. The rims, the spokes, the ladle-boards or floats, and the tubes or spouts, and even the cords, are made of entire lengths, or single joints, or large pieces, or thin slices of the bamboo. Neither nails, nor pins, nor screws, nor any kind of metal enters into its construction. The parts are bound together firmly by cordage, also of slit bamboo. Thus at a very trifling expence, is constructed a machine, which, without labour or attendance will furnish, from a considerable depth, a reservoir with a constant supply of water adequate to every agricultural purpose.

"These wheels are from 20 to 40 feet in diameter, according to the height of the bank and consequent elevation to which the water is to be raised. Such a wheel is capable of sustaining with ease 20 tubes or spouts, of the length of four feet, and diameter two inches in the clear. The contents of such a tube would be equal to six-tenths of a gallon, and a periphery of 20 tubes, twelve gallons. A stream of a moderate velocity would be sufficient to turn the wheel at the rate of four revolutions in one minute, by which would be lifted 48 gallons of water in that short period; in one hour, 2880 gallons; and 69120 gallons, or upwards of 300 tons of water, in a day."

Sir George, who saw this wheel in motion, thinks it preferable in many respects to any machine yet in use for similar purposes. He observes, that, while it approaches near to the Persian wheel, of which a description and figure is given in the article Hydrostatics *(Encycl.)*, it is more simple than that wheel in its contrivance, and much less expensive. This is indeed true; but the simplest engine of the kind, and therefore the best that has yet been invented, is perhaps that which is employed to throw water into the moss of Blair Drummond in Perthshire. See Moss *(Encycl.)*

CHIPPAWAY, an inconsiderable place near the falls of Niagara, 10 miles from Queenstown.—*Morse.*

CHIPPEWAY *River* runs S. westward into Mississippi River in that part where the confluent waters form lake Pepin, in N. lat. 44. W. long. 93. 54.—*ib.*

CHISSEL, a fort in the state of Tennessee, 24 miles from English ferry, on New river; 43 from Abingdon, and 107 from Long island, on Holston.—*ib.*

CHITTENDEN *Co.* in Vermont, lies on lake Champlain, between Franklin co. on the N. and Addison S.; La Moille river passes through its N. W. corner, and Onion river divides it nearly in the center. Its chief town is Burlington. This county contained, by the census of 1791, 44 townships and 7301 inhabitants. Since that time the northern counties have been taken from it, so that neither its size or number of inhabitants can now be ascertained.—*ib.*

Chittenden, a township in Rutland co. Vermont, contains 159 inhabitants. The road over the mountain passes through this township. It lies 7 miles E. from the fort on Otter creek, in Pittsford, and about 60 N. by E. from Bennington.—*ib.*

Chittenengo, or *Canaserage*, a considerable stream which runs northerly into lake Oneida in the state of New-York.—*ib.*

CHOCOLATE *Creek*, a head-water of Tioga River in New-York, whose mouth lies 10 miles S. W. of the Painted Post.—*ib.*

CHOCOPE, a town in the jurisdiction of Truxillo, in S. America, in Peru; 14 leagues southward of St Pedro. Here are about 90 or 100 houses, and about 60 or 70 families, chiefly Spaniards, with some of the other casts, but not above 25 Indian families. It has a church built of brick, both large and decent. The people here mention a rain that fell in 1726, which lasted 40 nights, beginning constantly at 4 or 5 in the evening, and ceasing at the same hour next morning, which laid most of the houses in ruins. S. lat. 7. 46.—*ib.*

CHOCORUA, a mountain in Grafton co. New-Hampshire, on the N. line of Stafford co. N. of Tamworth.—*ib*

CHOCUITO, or rather *Chucuito*, or *Titi Caca*, a large

large lake near Paria, in S. America, and in Peru, into which a great number of rivers empty themfelves. It is 240 miles in circumference, and in fome parts 80 fathoms deep; yet the water cannot be drunk, it is fo very turbid. It abounds in fifh, which they dry and falt, and exchange with the neighboring provinces for brandy, wines, meal, or money. It is faid the ancient Yncas, on the conqueft of Peru, by the Spaniards, threw into this lake, all their riches of gold and filver. It was this lake into which the Ynca Huana Capac, threw the famous chain of gold, the value of which was immenfe. It abounds with flags and rufhes, of which Capac Vupanchi, the fifth Ynca, built a bridge, for tranfporting his army to the other fide.—*ib.*

CHOISEUL *Bay*, on the N. W. coaft of the iflands of the Arfacides, W. of Port Praflin. The inhabitants on this bay, like thofe at Port Praflin, have a cuftom of powdering their hair with lime, which burns it and gives it a red appearance.—*ib.*

CHOPINE, Choppine, or Chopeene, a high fhoe, or rather clog, worn 200 years ago, by the Italians.

Tom Coryat, in his Crudities 1611, p. 262, calls them *chapineys*, and gives the following account of them: "There is one thing ufed of the Venetian women and fome others dwelling in the cities and towns fubject to the figniory of Venice, that is not to be obferved, I thinke, amongft any other women in Chriftendome, which is fo common in Venice, that no women whatfoever goeth without it, either in her houfe or abroad, *a thing made of wood and covered with leather of fundry colors, fome with white, fome redde, fome yellow. It is called a* chapiney, *which they wear under their fhoes.* Many of them are curioufly painted; fome alfo of them I have feen fairly gilt; fo uncomely a thing, in my opinion, that it is pitty this foolifh cuftom is not cleane banifhed and exterminated out of the citie. *There are many of thefe chapineys of a great height, even half a yard high,* which maketh many of their women that are very fhort feem much taller than the talleft women we have in England. Alfo I have heard it obferved among them, that by how much the nobler a women is, by fo much the higher are her *chapineys.* All their gentlewomen, and moft of their wives and widows that are of any wealth, are affifted eyther by men or women when they walke abroad, to the end they may not fall. They are borne up moft commonly by the left arme, otherwife they might quickly take a fall."

CHOPTANK, a large navigable river on the eaftern fhore of Maryland, emptying into Chefapeak bay. —*Morse.*

CHOWAN *Co.* in Edenton diftrict, N. Carolina, on the N. fide of Albemarle found. It contains 5011 inhabitants, of whom 2588 are flaves. Chief town, Edenton.—*ib.*

Chowan *River*, in N. Carolina, falls into the N. W. corner of Albemarle found. It is 3 miles wide at the mouth, but narrows faft as you afcend it. It is formed 5 miles from the Virginia line, by the confluence of Meherrin, Nottaway, and Black rivers, which all rife in Virginia.—*ib.*

CHOWDRY, in Bengal, the poffeffor of feveral *Talooks.* It is alfo ufed as fynonymous with *Talookdar*, anciently a collector. See Talook in this Supplement.

CHRISOM was not, as is faid in the Encyclopædia, a face-cloth or piece of linen laid over the child's head when it was baptized; but it was a white vefture or garment, which, immediately after it was baptized, the prieft put upon it, faying, "Take this white vefture as a token of the innocency which, by God's grace in this holy facrament of baptifm, is given unto thee, and for a fign whereby thou art admonifhed, fo long as thou liveft, to give thyfelf to innocence of living, that after this tranfitory life thou mayeft be partaker of life everlafting. Amen."

As foon as the prieft had pronounced thefe words, he anointed the infant upon the head, faying, "Almighty God, the Father of our Lord Jefus Chrift, who hath regenerated thee by water and the Holy Ghoft, and hath given unto thee the remiffion of all thy fins; he vouchfafe to anoint thee with the unction of his Holy Spirit, and bring thee to the inheritance of everlafting life. Amen."

It was from this anointing or *chrifm* that the white garment got the name of *chrifom*, which, after being worn a few days, was offered to the prieft to be kept in the church or veftry, in order to be produced as evidence againft the perfon whofe chrifom it was, fhould he afterwards deny the faith in which he had been baptized. Thefe ceremonies were retained, for fome time after the reformation, in the church of England, which ordered the mother of the child (if the child was then alive, to offer, when fhe was churched, the *chrifom* and other accuftomed offerings. If the child died before its mother was churched, the *chrifom* was not given to the prieft, but employed as a fhroud, in which the body was buried; and hence it is that chrifoms are now enumerated, moft abfurdly indeed, in the weekly bills of mortality. We fay abfurdly; becaufe children who die unbaptized are called *chrifoms*, though the chrifom, when it was ufed, was never put on till baptifm. See *Whitby on the Book of Common Prayer, &c.*

CHRIST CHURCH, a parifh in Charlefton diftrict, S. Carolina, containing 2954 inhabitants, of whom 566 are whites, 2377 flaves.—*Morse.*

CHRISTIANA, a poft town in New-Caftle co Delaware, is fituated on a navigable creek of its name, 12 miles from Elkton, 9 S. W. of Wilmington, and 37 S. W. of Philadelphia. The town, confifting of about 50 houfes, and a prefbyterian church, ftands on a declivity which commands a pleafant profpect of the country towards the Delaware. It carries on a brifk trade with Philadelphia in flour. It is the greateft carrying place between the navigable waters of the Delaware and Chefapeak; which are 13 miles afunder at this place. It was built by the Swedes, in 1640, and thus called after their queen.—*ib.*

Christiana *Creek*, on which the above town is fituated, falls into Delaware river from the S. W. a little below Wilmington.

It is propofed to cut a canal of about 9 miles in length, in a S. weftern direction from this creek, at the town of Chriftiana (6 miles W. S. W. of New-Caftle) to Elk river in Maryland, about a mile below Elkton. —*ib.*

Christiana, St, one of the Marquefa ifles, called by the natives Waitahû, lies under the fame parallel with St Pedro, 3 or 4 leagues more to the weft. Refolution bay, near the middle of the W. fide of the ifland, is in lat. 9. 55. 30. S. long. 139. 8. 40. W. from Greenwich; and the W. end of Dominica N. 15. W.

Christiansburg ‖ Church.

W. Capt. Cook gave this bay the name of his ſhip. It was called Port Madre de Dios by the Spaniards. This iſland produces cotton of a ſuperior kind. A ſpecimen of it is depoſited in the muſeum of the Maſſ. Hiſt. Society.—*ib.*

CHRISTIANSBURG, the chief town of Montgomery co. Virginia. It contains very few houſes; has a court-houſe and gaol, ſituated near a branch of Little river, a water of the Kanhaway. N. lat. 37. 5.—*ib.*

CHRISTIANSTED, the principal town in the iſland of Santa Cruz, ſituated on the N. ſide of the iſland, on a fine harbor. It is the reſidence of the Daniſh governor, and is defended by a ſtone fortreſs.—*ib.*

CHRISTMAS *Iſland*, in the Pacific ocean, lies entirely ſolitary, nearly equally diſtant from the Sandwich iſlands on the N. and the Marqueſas on the S. It was ſo named by captain Cook, on account of his firſt landing there, on Chriſtmas day. Not a drop of freſh water was found by digging. A ſhip touching at this deſolate iſle muſt expect nothing but turtle, fiſh, and a few birds. It is about 15 or 20 leagues in circumference, and bounded by a reef of coral rocks, on the W. ſide of which there is a bank of fine ſand, extending a mile into the ſea, and affording good anchorage. N. lat. 1. 59. W. long. 157. 30.—*ib.*

CHRISTMAS *Sound*, in Terra del Fuego, South America, in N. lat. 55. 21. W. long. 69. 57.—*ib.*

CHRONOLOGICAL CHARACTERS are characters by which times are diſtinguiſhed. Of theſe ſome are natural or aſtronomical; others, artificial or hiſtorical. The natural characters are ſuch as depend on the motions of the ſtars or luminaries, as *eclipſes*, *ſolſtices*, *equinoxes*, the *different aſpects of the planets*, &c. The artificial characters are thoſe that have been invented and eſtabliſhed by men; as the *ſolar cycle*, the *lunar cycle*, &c. Hiſtorical chronological characters are thoſe ſupported by the teſtimony of hiſtorians, when they fix the *dates* of certain *events* to certain *periods*. *Hutton's Mathematical Dictionary.*

CHRONOSCOPE, a word ſometimes uſed to denote a pendulum or machine to meaſure time.

CHUCKIAH, in Bengal, the juriſdiction of a *Fogedar*. See FOGEDAR in this Supplement.

CHURCH is a word which has many different ſignifications, all ſufficiently explained in the Encyclopædia, where there is likewiſe given a conciſe *hiſtory* of the Chriſtian church (ſee HISTORY, Sect. ii.), defective, indeed, but perhaps not more ſo than was to be expected from the limits of the work and the extent of the ſubject.

Of the conſtitution of the primitive and apoſtolical church, no man can have a correct notion who has not taken the trouble to conſult the primitive and apoſtolical writers; for, as we have elſewhere obſerved, all modern compilers of eccleſiaſtical hiſtory are more or leſs prejudiced in behalf of the particular church to which they belong, and wreſt the language of the original writers ſo as to make them bear witneſs to the antiquity of *modes of faith* and *eccleſiaſtical polity*, which are not perhaps a hundred years old.

On this account we ſhall not here attempt to correct what we really think the miſtakes of him who compiled the ſection of eccleſiaſtical hiſtory in the Encyclopædia. Moſheim and Sir Peter King, whom he ſeems to have implicitly followed, were indeed great men; and it would be folly to deny that the *Hiſtory* of the former, and the *Inquiry* of the latter, *into the Conſtitution of the Primitive Church*, are works of learning and ingenuity; but it is not perhaps too much to ſay, that both authors wrote under the influence of prejudice. Our readers will diſcover how cloſely either the one or the other has adhered to truth, by ſtudying the eccleſiaſtical writers of the firſt four centuries. Such a ſtudy will make them acquainted with the doctrines, diſcipline, and worſhip of the church before it was incorporated with the ſtate; and we know not that kind of knowledge which is of more importance to the divine, however much it may be deſpiſed in this age of affected ſcience and real ignorance.

Of the principal churches at preſent exiſting, a pretty full account is given in the Encyclopædia, either under their different denominations, or under the titles of thoſe tenets by which they are chiefly diſtinguiſhed; ſo that from that Work alone a reader may form a tolerably accurate notion of the faith, worſhip, conſtitution, and diſcipline of the church of Rome, the churches of England and Scotland, the Lutheran and Calviniſtical churches on the continent of Europe, as well as of the various ſects which have ariſen in theſe kingdoms during the courſe of the laſt and preſent centuries. There is, however, one church which boaſts of a very high antiquity, and is certainly ſpread over a larger extent of country than all the other churches that we have mentioned, of which the account given in the Encyclopædia is exceedingly defective. Our readers will perceive that the church to which we allude is 1

The Greek church.

The Greek CHURCH, which comprehends in its boſom (A) a conſiderable part of Greece, the Grecian iſles, Wallachia, Moldavia, Egypt, Abyſſinia, Nubia, Lybia, Arabia, Meſopotamia, Syria, Cilicia, and Paleſtine, which are all under the juriſdiction of the patriarchs of Conſtantinople, Alexandria, Antioch, and Jeruſalem. If to theſe we add the whole of the Ruſſian empire in Europe, great part of Siberia in Aſia, Aſtracan, Caſan, and Georgia—it will be evident that the Greek church has a wider extent of territory than the Latin, with all the branches which have ſprung from it; and that it is with great impropriety that the church of Rome is called by her members the *catholic* or univerſal church. That in theſe widely diſtant countries the profeſſors of Chriſtianity are agreed in every minute article of belief, it would be raſh to aſſert; but there is certainly ſuch an agreement among them with reſpect both to faith and to diſcipline, that they mutually hold communion with each other, and are in fact but one church.

As the Greek church has no public or eſtabliſhed articles, like thoſe of the churches of England and Scotland, we can collect what is its doctrine only from its creed, from the councils whoſe decrees it receives (B),

(A) *King's Rites and Ceremonies of the Greek Church*—*Bruce's Travels to the Source of the Nile*—and *Lobo's Voyage to Abyſſinia.*

Church. (B), from the different offices in its liturgies, and from the catechisms which it authorises to be taught. "The doctrine of the Trinity, and the articles of the Nicene and Athanasian creeds, are received by the Greeks in common with other Christians. In one particular, indeed, they differ from the other churches of Europe, whether Romish or reformed. They believe, that the Holy Spirit proceeds from the Father only, and not from the Father and the Son; and in defence of this opinion they appeal to ecclesiastical history, the acts of councils, the writings of the fathers, ancient manuscripts, and especially to a copy of the creed of Constantinople, engraven on two tables of silver, and hung up in the church of St Peter at Rome by order of Leo III. Of the Nicene or Constantinopolitan creed, therefore, as it is received by them, the eighth article runs in these words; 'I believe in the Holy Ghost, the Lord and Giver of life, who proceedeth from the FATHER, and with the Father and the Son together is worshipped and glorified:' And the corresponding article of the Athanasian creed is of course, "The Holy Ghost is of the FATHER, neither made, nor created, nor begotten, but proceeding †."

2 The faith of that church.

Though the bishops and clergy of the Greek church abhor the use of images, which they pretend to be one cause of their separation from the see of Rome, they admit into their churches the pictures of saints to instruct, they say, the ignorant, and to animate the devotion of others. This practice they consider as by no means contrary to the second commandment of the decalogue, which, according to them, prohibits only the worshipping of such idols as the Gentiles believed to be gods; whereas their pictures, being used merely as remembrancers of Christ and the saints, have written on each of them the name of the person whom it is meant to represent. Dr King assures us that the more learned of the Russian clergy would willingly allow no representation whatever of God the Father; and that, during the reign of Peter the Great, the synod not only censured the use of such pictures in churches, but petitioned the emperor that they might be everywhere taken down. Peter, however, though he fully concurred in opinion with the synod, thought this a measure for which the minds of his subjects were not ripe, and dreaded, that if carried into execution it would occasion a general insurrection. Such pictures, therefore, though not more impious than absurd, are still in use; and in many churches, as well ancient as modern, the figure of Daniel's *Ancient of Days*, together with that of *Christ* and a *dove*, are painted in one group to signify the Holy Trinity. Nay, when our author was in St Petersburg, not thirty years ago, there was in the church of St Nicholas the picture of an old man holding a globe, and surrounded with angels, on which GOD THE FATHER was inscribed; and we have not heard that the picture has been since taken down.

† *Dallaway's Constantinople, Ancient and Modern*, and *King's Rites and Ceremonies, &c.*

3 It admits of pictures, but not of graven images.

In the Greek as well as in the Roman church, the invocation of saints is practised, but they are not invoked in either as deities, but merely as intercessors with the Supreme God, "it being more modest (say the Greeks), as well as more available, to apply to them to intercede with God, than to address ourselves immediately to the Almighty." Plausible as this reasoning may at first sight appear, it ascribes to the saints the divine attribute of ubiquity, and is likewise in direct contradiction to the doctrine of St Paul, who hath taught us, that as "there is one God, so there is but one mediator between God and man, the man Christ Jesus."

4 Invocation of saints.

The Greek church, at the celebration of the Lord's Supper, commemorates the faithful departed, and even prays for the remission of their sins; but she allows not of purgatory, nor pretends to determine dogmatically concerning the state or condition of departed souls. She must, however, believe that no final judgment is passed upon the great body of mankind (c) till the consummation of all things, otherwise such prayers could not be offered without absurdity; and in this part of her doctrine she is certainly countenanced by all the writers of the primitive church, if not by some passages of the sacred scriptures.* The practice of praying for the dead is loudly condemned in every Protestant country, and yet there is no Christian who does not in effect pray for his departed friends. This may appear a paradox, but it is an obvious and a certain truth; for where is the man who believes in a general judgment, and does not *wish* that his deceased wife, or parent, or child, or friend, "may find mercy of the Lord in that day?" Such a wish is the essence of a prayer; which consists not of the sounds in which our sentiments are cloathed, but in the aspirations of a devout heart.

5 Prayers for the dead.

* *Matth.* xxv. 19, 20, —31—34. 2 *Tim.* i. 18, iv. 8.

Supererogation, with its consequent indulgencies and dispensations, which were once so profitable, and afterwards so fatal to the interests of the court of Rome, are utterly disallowed in the Greek church, which likewise lays no claim to the character of infallibility. She is indeed like some other churches, very inconsistent on this last topic; for whilst she pretends not to an absolute exemption from error, her clergy seem to consider their own particular mode of worship as that which alone is acceptable to God.

6 Grants no indulgencies.

Predestination is a dogma of the Greek Church, and a very prevailing opinion amongst the people of Russia; "and I must do the justice (says Dr King) to those who have written upon it, especially the latest authors of that country, to say that they have treated it, as depending on the attribute of prescience in the divine nature, with a much better kind of logic than that with which such points are generally discussed." As our author has not given us the reasoning of the Russian doctors on this difficult subject, we cannot hazard any opinion of our own on the soundness of their logic; but from the state of science in that vast empire, as

7 Predestination.

(B) In the Greek church seven general councils are received, and nine provincial ones. The seven general councils are, 1. The council of Nice, held in the year 325, under Constantine. 2. The first council of Constantinople, held A. D. 381, under Theodosius the Great. 3. The council of Ephesus, A. D. 431, in the reign of Theodosius Minor. 4. The council of Calcedon, A. D. 451, in the reign of Marcian. 5. The second council of Constantinople, A. D. 553, in the reign of Justinian. 6. The third council of Constantinople in Trull, A. D. 680, in the reign of Constantine Pagonatus. 7. The second council of Nice, A. D. 787.

(C) We say the great body of mankind, because she doubtless believes that Enoch, Elias, and those saints who rose with our Saviour, have been already judged, and now enjoy their reward in heaven.

Church. as it was represented to us by an abler judge than he, we doubt of its being entitled to the praise which he
8 bestows on it. (See Russia, n° 104. *Encycl.*)

Seven sacraments. In the Greek church there are seven *sacraments*; or, as they are there termed, *mysteries*, viz. *baptism*; the *chrism*, or baptismal unction; the *eucharist*; *confession*; *ordination*; *marriage*; and the mystery of *the holy oil*, or *euchelaion*. By the Greeks a mystery is defined to be "a ceremony or act appointed by God, in which God giveth or signifieth his grace; and of the seven which they celebrate, four are to be received by all Christians, viz. *baptism*, the *baptismal unction*, the *eucharist*, and *confession*. Of these, *baptism* and the *eucharist* are deemed the chief; and of the other three none, not even the *euchelaion*, is considered as obligatory upon all.

With respect to baptism, we know not that they hold any peculiar opinions. They consider it indeed as so absolutely necessary to salvation, that in cases of extremity, when a priest or deacon cannot be had, it may be administered by a midwife or any other person, and is not to be repeated on any occasion whatever. In this opinion, as well as in the practice founded on it, they are in perfect harmony with the church of Rome, which, as every person knows, has for many ages allowed the validity of lay baptism in cases of necessity. The Portuguese Jesuits, who in the last century visited Abyssinia in the capacity of missionaries, have maintained that once every year, all grown people are in that country baptized: but Mr Bruce has shown, by the most incontrovertible evidence, that this was a mere fiction, invented to throw odium upon what the church of Rome calls the eastern schism, and abhors perhaps
9 more than paganism itself.

Daily service of the church, The daily service of the Greek Church is so long and so complicated, that it is impossible for us to give an adequate account of it, without swelling this article far
10 beyond its due proportion. Of this the reader will be
Intricate and tedious, convinced, when he is informed that the several books containing the church service for all the days in the year, amount to more than twenty volumes in folio, besides one large volume called *the regulation*, which contains the directions how the rest are to be used.

The four gospels make one volume by themselves; and whenever the gospel is read in any service, the deacon exclaims; "Wisdom, stand up. Let us hear the holy gospel." The priest then saith, "The lesson from the gospel according to St Matthew, St Mark, &c." The deacon says again, "Let us stand." The choir, at the beginning and end of the gospel, always says, "Glory be to thee, O Lord, glory be to thee." From the old testament and the epistles extracts only are used in the service, and when they are to be read, the deacon calls out, "Attend."

The service of this church, as it now stands, and was at first drawn up in writing, is calculated for the use of monasteries; and when it was afterwards applied to parochial churches, many of the offices or forms, which were composed for different hours of the day and night, were used as one service, without the slightest alteration being made to avoid repetitions. Something of this kind has taken place in the church of England, where the matins, the litany, and the communion, which were formerly three distinct services, read at different times of the day, are now run into one service; which by those not accustomed to it is therefore deemed long, as well as deformed by needless repetitions. Church, 11

The service of every day, whether it has a vigil or not, begins in the evening of what we would call the preceding day, as among the Jews; and for the same reason, because it is said in the Mosaic account of the creation, that "the evening and the morning were the first day." The several services, according to the original or monkish institution, are, 1. *The vespers*, which used to be celebrated a little before sun-set; 2. *The after vespers*, answering to the *completorum* of the Latin church, which used to be celebrated after the monks had supped, and before they went to bed; 3. *The mesonyecticon*, or midnight service; 4. *The matins* at break of day, answering to the *laudes* of the Romish church; 5. The *first hour* of prayer, or *prima*, at sun-rise; 6. The *third hour*, or *tertia*, at the third hour of the day; 7. The *sixth hour*, or *sexta*, at noon; 8. The *ninth hour*, or *nona*, in the afternoon at the ninth hour of the day. These are called the canonical hours; but it is to be observed, that the *after-vespers* were not added till a late period, before which the reason assigned for the number of services being seven, was, that David saith, "Seven times a day will I praise thee." When all the psalms and hymns were sung, these daily services could not possibly have been performed in less than twelve or fourteen hours. In the church of Russia, and probably in other branches of the Greek church, there are at present but three services in the day: the *ninth hour*, the *vespers*, and the *after vespers* making one; the *mesonyecticon*, the *matins*, and *prima*, another; and the *third* and *sixth hour*, with the *communion*, the last. In all the services, except the communion, prayers and praises are offered to some saint, and to the Virgin Mary, almost as often as to God; and in some of the services, after every short prayer uttered by the deacon or the priest, the choir chaunts, "Lord have mercy upon us," thirty, forty, or fifty times successively. Begins in the evening.

Though the number of services is the same every day, the services themselves are constantly varying in some particular or other, as there is not a day which, in the Greek Church, is not either a fast or a festival. Besides the saints, whose festivals are marked in the calendar, and who are so very numerous that there are more than one for every day in the year, there are other saints and festivals, to which some portion of the service for every day of the week is appropriated. Thus, Sunday is dedicated to the resurrection; Monday, to the angels; Tuesday, to St John Baptist; Wednesday, to the virgin and the cross; Thursday, to the apostles; Friday, to the passion of Christ; and Saturday, to the saints and martyrs. For these days there are particular hymns and services, in two volumes folio, to which there is a supplement, containing services for the saints and festivals, as they occur in the calendar throughout the year. These different services are mixed together, and adjusted by the directions contained in the book of *regulation*; and it is the difficulty of this adjustment which makes the public worship of the Greek Church so very intricate, that, as was said of the service of the English church before the Reformation, "there is more business to find out what should be read, than to read it when found out."

We have observed, that the Greeks have no peculiar opinions

Church.

12 Mode of administering baptism.

opinions respecting the nature of baptism; but the rites and ceremonies with which that ordinance is administered will appear to our unlearned readers very extraordinary. On the day that a woman is delivered, the priest goes to the house, and uses a form of prayer for her and for her child. On the eighth day the child should be regularly carried to the church, where the priest having signed it with the sign of the cross on the forehead, on the mouth, and on the breast, offers up for it a prayer, in which he first gives it a name, commonly the name of the saint for that day in the calendar; he then takes it from the midwife, and standing before the picture of the blessed virgin, he makes the sign of the cross with the infant, uttering a kind of hymn in honour of the Virgin, and of Simeon, who held in his bosom the Saviour of our souls. He then dismisses the company with an exhortation not to delay the baptizing of the infant should it appear in danger of death before the regular time for its baptism.

On the fortieth day after her delivery, the mother should attend the church to be purified, and carry the child again to be presented, the person who is to be sponsor being present. Upon their arrival at the church door, the priest utters some pious exclamations; and then, the mother holding the child in her arms and bowing down her head, he makes the sign of the cross upon her and the child, and laying his hand upon its head, he prays, that the woman may be cleansed from every sin, and from every defilement, and that the child may be sanctified and endued with understanding, with wisdom, and with gentleness of manners. He then signs it again, and again prays for it, for its parents, and for its sponsor; after which, if it has been privately baptized, he takes it in his arms, and makes with it the sign of the cross before the door of the church, saying, "N. N. the servant of God, enters into the church in the name of the Father, and of the Son, and of the Holy Ghost, now and forever, even unto ages of ages. Amen." He then carries the child into the church, saying, "He shall go into thine house, and shall worship toward thy holy temple;" and advancing into the middle of the church, he says, "In the midst of thy church shall he praise thee." Then if the child be a boy, he carries him within the rails of the altar; but if a girl, only to the door, and says, "*Nunc dimittis*(D);" after which he delivers it to the sponsor, who makes three reverences, and retires.

This is called the presentation of the child in the temple, and can only be performed after it has been baptized. In the detail we have given, we have supposed that it was baptized privately before the purification of the mother, which is now indeed commonly the case. Such baptism, however, is not regular, being allowed only in cases of necessity, and when it has not taken place, the mother and child are dismissed as soon as she is purified, and return at some other time, not fixed, in order that the child may be publicly baptized.

Previous to baptism, the child, though not two months old, must be solemnly initiated into the church as a catechumen (See CATECHUMEN *Encycl.*). By those whose religion is a reasonable service, such initiation of an infant will be considered as a very idle ceremony; and the rites with which it is performed are not well calculated to give it even a fictitious importance. At the door of the church the priest unties the girdle of the infant; takes off all his clothes but one loose garment; turns him towards the east with his head uncovered, his feet naked, and his hands held down; blows thrice in his face; signs him thrice with the sign of the cross on the forehead, and on the breast, and lays his hand upon his head, praying that his "*ancient* error may be put away from him, that his heart may be filled with faith, hope and charity; and that he may walk in the ways of God's commandments." The priest then four times exorcises the infant, commanding Satan in the first exorcism to "tremble, depart, and flee from Christ's creature, nor dare to return again, nor dare to lurk concealed within him, or to meet him or to meditate against him, either in the evening or the morning, at midnight, or at noon day." In the last exorcism he blows thrice upon the child's mouth, upon his forehead, and upon his breast; saying, each time, "Drive away from him every evil and unclean spirit that lurks in him, and hath made itself a nest in his heart." The child is now become a catechumen, and, being turned to the west uncovered, without shoes, and his hands lifted up, the priest repeatedly asks him, if he *renounces*, and *has* renounced the Devil and all his works? and receiving from the sponsor the proper answer, he says, "blow and spit upon him;" and having blown and spit upon the catechumen, he turns him to the east, and holding down his hands, asks him repeatedly if he be joined to Christ, and if he believes in him? The catechumen or his sponsor replies to each question, that he is, and has been, joined to Christ; and as a proof of his faith he repeats, from beginning to end, the Nicene creed. After a repetition of the formerly repeated questions and answers, the priest prays that the catechumen may be called to God's holy sanctification, and receive the grace of God's holy baptism.

Baptism may be celebrated immediately after the candidate has been made a catechumen, or on any subsequent day at no great distance. In the first part of the form there is not much that is singular, or with which every scholar is not acquainted. After praying that the water may be sanctified, in terms differing little from those which are used in the most respectable Protestant churches, the priest dips his fingers in it, signs it thrice with the sign of the cross; and then blowing upon it, says three times, "Let every adverse power be confounded under the sign of the cross." He then solemnly exorcises it of the dæmon of darkness and all evil spirits; and prays, that "the person to be baptized therein may put off the old man, which is corrupt after the lust of fraud, and may put on the new man after the image of Him that made him." After this, he blows thrice into a vessel of oil of olives held by the deacon, signs it thrice with the sign of the cross; and prays fervently, that it may "become to those who are anointed with faith, and are partakers thereof, the unction of incorruption, the armour of righteousness, the renewing of soul and body, for turning aside all machinations

(D) We quote the words of Dr King. Is it possible that in the Greek Church Latin hymns are used, or that Greek hymns have Latin designations?

Church.

nations of the devil, and for deliverance from all evil." He then fings allelujah thrice with the people, and pours the oil on the top of the water; and making three croffes with it, fays aloud, "Bleffed be God, who enlighteneth and fanctifieth every man that cometh into the world, now and forever, even unto ages of ages." The perfon to be baptized is then prefented; and the prieft, taking fome of the oil with two fingers, and making the fign of the crofs on his forehead, on his breaft, and betwixt his fhoulders, fays, "N the fervant of God is anointed with the oil of gladnefs, in the name of the Father, and of the Son, and of the Holy Ghoft, now and forever, even unto ages of ages. Amen." He then figns him on the breaft and the middle of the back, faying, "For the healing of his foul and body;" then on the ears, faying, "For hearing the faith;" then on the palms of the hands, faying, "Thy hands have made me and fafhioned me;" then on the feet, "That he may walk in the way of thy commandments." After the whole body is thus anointed, the prieft baptizes him, ufing the trine immerfion; which is unqueftionably the moft primitive manner. He takes the child in his arms, and holding him upright with his face towards the eaft, he fays, "N the fervant of God is baptized (*dipping him the firft time*), in the name of the Father, Amen; in the name of the Son (*dipping him again*), Amen; and of the Holy Ghoft (*dipping him the third time*), Amen, now and for ever, even unto ages of ages. Amen." After the baptifm, the prieft wipes his hands, and with the people fings thrice, from beginning to end, the 32d Pfalm; he then puts upon the baptized perfon a white garment; faying, "N the fervant of God is clothed with the garment of righteoufnefs, in the name of the Father, and of the Son, and of the Holy Ghoft, now and for ever, even unto ages of ages (E)." He then prays that he may be delivered from the evil one, and all his infidious fnares; that he may be confirmed in the true faith; and that he may preferve his foul in purity and righteoufnefs: and proceeds immediately to anoint him with the *Holy Chrifm*.

13
The baptifmal chrifm.

This chrifm is a very different thing from the oil with which he was anointed previous to baptifm, and which was ufed in the confecration of the baptifmal water. It can be prepared only by a bifhop, and only on one day in the year, *viz*. Thurfday in Paffion-week; and as the anointing with it is fubftituted in place of the apoftolical rite of laying on hands, called *confirmation* in the weftern churches, great quantities of it are of courfe prepared at once, and diftributed through the different churches of each diocefe. The chrifm confifts of the following ingredients, which in different proportions are all boiled together, and afterwards folemnly confecrated by the bifhop: Fine oil (we fuppofe of olives), white wine, ftyrax calamita (F), palm-dew, rofe-flowers, black palm-gum, Bafil-gum, marjoram, thick and thin oil of nutmegs in very different quantities, oil of cinnamon, oil of cloves, lignum Rhodii, oil of oranges, oil of marjoram, oil of lavender, oil of rofemary, effence of rofemary, cedar, black balfam of Peru, fandarac, whiteft maftic, and Venice turpentine. With this holy mixture the baptized perfon is anointed, the prieft making with it the fign of the crofs on his forehead, on his eyes, his noftrils, his mouth, both ears, his breaft, his hands, and his feet; faying at each part, "The feal of the gift of the Holy Ghoft. Amen." Then with the fponfor and the child he goes thrice round the font, turning from the right to the left; the choir, in the mean time, finging, "As many of you as are baptized unto Chrift have put on Chrift, allelujah."

Seven days after this ceremony is performed, the child is again brought to the church; when the prieft, after praying for him, unties his girdle and linen clothes, wafhes him with clean water, and, fprinkling him, fays, "Thou haft been juftified, enlightened, fanctified, in the name of our Lord Jefus Chrift, and with the Spirit of our God." Then taking a new fponge moiftened with water, he wafhes his face, breaft, &c.; faying, "Thou haft been baptized, enlightened, anointed, fanctified, wafhed, in the name of the Father, and of the Son, and of the Holy Ghoft, now and for ever, even unto ages of ages. Amen."

14
The tonfure.

The laft ceremony appended to baptifm is that of the tonfure, or fhaving the head of the child in the form of the crofs. At what time this rite crept into the church it would not be eafy to difcover. Some think it received its origin from the religious ceremonies of the Heathen, who certainly rounded the corners of their heads, and marred their beards at a very early period, in honor of their idols (See THEOLOGY, n° 155. *Encycl.*); and fome pious, but foolifh Chriftians, efteemed it highly commendable to transfer to the true God that worfhip, in a different form, which had been rendered by their anceftors to falfe deities. Others will have the tonfure to typify the dedication of the perfon to the fervice of God; the cutting off of the hair being always confidered as a mark of fervitude. Be thefe conjectures as they may, the prieft, after the child is baptized, offers up for him feveral prayers, all alluding to the rite to be performed; and then cuts his hair crofs-wife, faying, "N the fervant of God is fhorn, in the name of the Father, and of the Son, and of the Holy Ghoft, now and forever, even unto ages of ages. Amen."

We have given a full account of the manner in which the facrament of baptifm is celebrated among the Greeks, that the reader may have fome notion of the childifh fuperftition of that church, with which certain zealous Proteftants in England were very defirous, at the beginning of this century, to form a union. There is no occafion for dwelling fo long upon their other offices.

15
The Greeks have three communion-offices.

For the celebration of the Lord's Supper, they have three liturgies that are occafionally ufed, *viz*. that of St Chryfoftom, which is in ordinary daily ufe; that of St Bafil, ufed on particular days; and that of the *prefanctified*, as it is called, which is ufed on the Wednefdays and Fridays during the great faft before Eafter. Between the liturgies of St Chryfoftom and St Bafil there is no effential difference; and the office of the prefanctified

(E) The reader will perceive, that many of thefe rites and ceremonies are common to the Greek church and the church of Rome in the celebration of the facrament of baptifm.

(F) We quote the words of Dr King, taking it for granted that our readers will pardon our not giving ourfelves much trouble to difcover, on the prefent occafion, what particular fpecies or variety of the ftorax he means by this defignation. See STYRAX, *Encycl.*

sanctified is merely a form of dispensing the communion with elements which had been consecrated on the preceding Sunday. We would gladly insert the liturgy of St Chrysostom, or at least such an abstract of it as we have given of the form of administering baptism; but as our limits will not permit us to do so, we must refer such of our readers as have any curiosity respecting subjects of this nature to *Dr King's Rites and Ceremonies of the Greek Church*.

16 Strange ceremony at the offertory.

It is proper, however, to observe here, that many superstitious ceremonies have been added to the service since the age of St Chrysostom, and that no man can compare his genuine works with the liturgy which now goes under his name, and entertain the smallest doubt but that the latter has been greatly, though gradually, corrupted. In the offertory there is a strange ceremony, called *the slaying of the Holy Lamb*, when the priest, taking into his left hand one of the five loaves which are to be consecrated, thrusts a spear into the right side of it; saying, "He was led as a lamb to the slaughter;" then into the left side, adding, "And as a blameless lamb before his shearers is dumb, so he openeth not his mouth:" then into the upper part of the loaf; saying, "In his humiliation his judgment was taken away:" and into the lower part, adding, "And who shall declare his generation?" He then thrusts the spear obliquely into the loaf, lifting it up, and saying, "For his life was taken away from the earth." After this he lays down the loaf, and cutting it crosswise, says, "The Lamb of God, which taketh away the sins of the world, is slain for the life and salvation of the world."

17 The consecration of the elements.

All this, and more to the same purpose, is unquestionably modern; but we have no doubt but that the priest uses the words of Chrysostom himself, when, in the consecration of the elements, he says, "We offer unto thee this reasonable, this unbloody sacrifice; and we implore, we pray thee, we humbly beseech thee, to send down thy Holy Spirit upon us, and those oblations presented unto thee; and make this bread the precious body of thy Christ; and that which is in this cup the precious blood of thy Christ, changing them by thy Holy Spirit."

Dr King observes, that this invocation of the Holy Spirit upon the elements, which in the eastern church is always used after the words of Christ, "This is my body, this is my blood, &c." is inconsistent with the Popish doctrine of transubstantiation: and he is undoubtedly right; for the church of Rome teaches, that the change is made about the middle of the mass, when the priest, taking into his hand first the bread, and then the wine, pronounces over each separately the sacred words of consecration; *i. e.* the words of Christ. "It is the office of the priest, in this and in all other sacraments (says a dignitary of that church), only to perform the outward sensible part; but the inward invisible effect is the work of the great God, who accordingly changes the substance of the bread and wine into the body and blood of Christ the very instant that the sacred words of consecration are pronounced by the priest over them." But if this be so, it would be impious, and we believe that by the church of Rome it is deemed impious, to pray afterwards that God would send down his Holy Spirit to change into the body and blood of Christ elements which he had already changed into that body and blood, in consequence of the priest's pronouncing over them the all-powerful words of Christ. Yet is it certain, that in the present Greek church transubstantiation is as much an article of faith as in the church of Rome; for now every bishop, at his consecration declares, in the most solemn manner, that he believes and "understands that the transubstantiation of the body and blood of Christ, in the holy supper, is effected by the influence and operation of the Holy Ghost, when the bishop or priest invokes God the Father in these words, *and make this bread the precious body of thy Christ*, &c." This is indeed a different account from that of the Latin church of the time at which this portentous change is wrought; but such difference is a matter of very little importance (G). If the change itself be admitted, the consequences must be the same, whether it be supposed to take place when the priest pronounces the words of institution, or after he has invoked the descent of the Holy Ghost; in either case it leads to idolatry. It may be proper to mention, that in the Greek church it is deemed essential to the validity of this holy sacrament, that a little warm water be mixed with the wine; that the napkin, which is spread over the holy table, and answers to the *corporale* of the church of Rome, be consecrated by a bishop, and that it have some small particles of the reliques of a martyr mixed in the web, otherwise the eucharist cannot be administered. In this church children may receive the communion immediately after baptism; and the lay communicants, of whatever age, receive both the elements together, the bread being sopped in the cup: the clergy receive them separately.

18 Transubstantiation.

19 The laity communicate in both kinds.

20 Confession in the Greek Church.

We have observed, that one of the seven *mysteries*, or sacraments of the Greek church is *confession*; but among the Greeks it is a much more rational and edifying service than in the Church of Rome. In the Greek church the end of confession is the amendment of the penitent; in the church of Rome it is to magnify the glory of the priest. In the former church, the confessors pretend only to abate or remit the penance, declaring the pardon from God alone; in the latter, they take upon them to forgive the sin itself. The Greek church prescribes confession four times in the year to all her members; but the laity, for the most part, confess only once a year previous to receiving the holy communion; and to this they are in Russia obliged by the laws of the empire.

The

(G) Mr Bruce seems to doubt whether transubstantiation be the doctrine of the Abyssinian church, and relates a conversation which he had on the subject with a priest; who solemnly affirmed, that he never believed in the conversion of the substance of the bread and wine, into the substance of our Saviour's body and blood. It must be remembered, however, that the priest had at the time a powerful reason for wishing that doctrine not to be true. The Jesuits uniformly attest, that the Abyssinians believe in the real presence; though it must not be forgotten, that Ludolf was of a different opinion, and that no man had studied the language of Abyssinia more successfully than he.

21 Matrimony.

The ceremonies with which matrimony is performed in the Greek church confift of three diftinct offices, formerly celebrated at different times, after certain intervals, which now make but one fervice. Firft there was a folemn fervice when the parties betrothed themfelves to each other, by giving and receiving rings or other prefents as pledges of their mutual fidelity and attachment. The ancient ufage was for the man to receive a gold ring, and the woman a filver one, which is ftill alluded to in the rubric, though in the prefent practice, the rings are generally both of gold. At this time the dowry was paid, and certain obligations were entered into, to forfeit fums in proportion to it, if either of the parties fhould refufe to ratify the engagement. At this ceremony, called the *μνηστρον*, or *recording of the pledges before witneffes*, the prieft gives lighted tapers to the parties to be contracted, making the fign of the crofs on the forehead of each with the end of the taper before he deliver it.

The fecond ceremony, which is properly the marriage, is called the office of *matrimonial coronation*, from a fingular circumftance in it, that of *crowning* the parties. This is done in token of the triumph of continence; and therefore it has, in fome places, been omitted at fecond marriages. Formerly thefe crowns were garlands made of flowers or fhrubs; but now there are kept, in moft churches, crowns of filver or fome other metal for the celebration of matrimony. At the putting of them on, the prieft fays, "N, the fervant of God, is crowned for the handmaid of God;" and "N, handmaid of God, is crowned for the fervant of God, in the name of the Father, and of the Son, and of the Holy Ghoft;" adding thrice, "O Lord our God, crown them with glory and honour."

The third ceremony is that of diffolving the crowns on the eighth day; after which the bride is conducted to the bridegroom's houfe, immediately to enter on the cares of his family.

22 Regular and fecular clergy.

With refpect to difcipline and government, the Greek church bears a ftriking refemblance to that of Rome. In both there is the fame divifion of the clergy into regular and fecular; the fame fpiritual jurifdiction of bifhops and their officials, and the fame diftinction of ranks and offices. In fome points the difcipline of the Greeks differs from that of the Romans. All orders of fecular clergy in the Greek church inferior to bifhops are permitted to marry; but celibacy, and the affumption of the monaftic habits, are indifpenfably requifite in thofe who are candidates for the mitre. The regular clergy, fays Mr Dallaway, are generally men of a certain education; whereas the feculars are of the meaner fort, and illiterate in the extreme.

23 Five orders of clergy.

In the Greek church there are five orders of clergy promoted by the impofition of hands; but it does not appear that the ordination of the reader, or of the fubdeacon, is confidered as a facrament. The forms ufed in the ordination of deacons, prefbyters, and bifhops, are ferious and fignificant (H), bearing in themfelves evidence of great antiquity. The candidate for the deaconate or priefthood kneels before the holy table, and the bifhop, laying his right hand on his head, faith,

24 Form of ordination.

"The divine grace, which healeth our infirmities, and fupplieth our defects, promoteth N, the moft pious *fubdeacon*, to the order of *deacon*;" or, in the cafe of the priefthood, "The moft pious *deacon* to the order of a *prefbyter*; let us pray for him, that the grace of the Holy Spirit may come upon him." It does not appear from Dr King's account of thefe offices, that in the Greek church the attending prefbyters lay on their hands together with the bifhop at the ordination of a prefbyter, as is practifed in the church of England; but feveral bifhops lay on their hands together with the archbifhop at the confecration of a bifhop.

25 Solemn confecration of bifhops.

This is indeed a very folemn ceremony. The candidate for the epifcopate, who is always an *archimandrite* or *hieromonachus*, *i. e.* an abbot or chief monk in fome monaftery, being named to the vacant fee, and the election being confirmed, repairs at the time appointed, to the church where the confecration is to be performed. Being arrived, he is introduced by the proto-pope (I) and proto-deacon to the archbifhop and bifhops, who are arranged in proper order on a temporary theatre or platform, erected in the church for the occafion. He there gives an account of his faith; declares folemnly that he has neither given nor promifed money, or any bribe-worthy fervice, for his dignity; and promifes to adhere fteadily to the traditions and canons of the eaftern church, to vifit his diocefe regularly, and to oppofe ftrenuoufly all innovations and herefies, particularly the errors of the Latin church. This being done, the archbifhop fays, "The grace of the Holy Spirit, through my humility, exalts thee N. archimandrite or hieromonachus, beloved of God, to be bifhop of the cities N. N. which God preferve." With much ceremony the bifhop-elect is then conducted from the theatre, within the rails of the holy altar, where he kneels down with the other bifhops, who hold open over his head the holy gofpel with the letters inverted, the archbifhop faying aloud, "The divine grace, which always healeth our infirmities, and fupplieth our defects, by

(H) We muft except thofe ufed in the church of Abyffinia, which, according to Mr Bruce, are fhamefully indecent. "A number of men and children prefent themfelves at a diftance, and there ftand, from humility, not daring to approach the *abuna* or bifhop. He then afks who thefe are? and they tell him that they want to be deacons. On this, with a fmall iron crofs in his hand, after making two or three figns, he blows with his mouth twice or thrice upon them; faying, *Let them be deacons*. I faw once (fays our author) all the army of Begemder made deacons juft returned from fhedding the blood of 10,000 men. With thofe were mingled about 1000 women, who confequently having part of the fame blaft and brandifhment of the crofs, were as good deacons as the reft. In the ordination of priefts a little more ceremony is ufed; for they muft be able to read a chapter of St Mark, which they do in a language of which the abuna underftands not one word. They then give him a brick of falt, to the value perhaps of fixpence, for their ordination; which, on account of this prefent, the Jefuits maintained to be Simoniacal." There is but one bifhop or abuna in Abyffinia, and he is always a foreigner, fubordinate in his jurifdiction to the patriarch of Alexandria.

(I) In the Greek church all parifh priefts are called *papas* or popes; and the proto-pope is an archprefbyter.

Church.

by my hand conducteth thee N. archimandrite or hieromonachus, beloved of God, bifhop elect of the cities of N. N. which God preferve !—Let us pray therefore for him, that the grace of the moft Holy Spirit may come upon him." Then the priefts fay thrice, Lord have mercy upon us;" and while the bifhops continue to hold the gofpel, the archbifhop figns the newly confecrated bifhop thrice with the fign of the crofs, faying, "In the name of the Father, and of the Son, and of the Holy Ghoft, now and forever, even unto ages of ages. Amen." Then all the bifhops putting their right hands on his head, the archbifhop prays that he may be confirmed in the office of which they have judged him worthy, that his priefthood may be rendered irreproachable, and that he himfelf may be made holy and worthy to be heard of God. After this, one of the affifting bifhops reads a fhort litany in a low voice, to be heard only by thofe within the altar, and the other bifhops make the refponfes. At the end of the litany the archbifhop, laying his hand again upon the head of the newly confecrated bifhop, prays in very decent and devout terms, that Chrift will render him an imitator of himfelf, the true fhepherd; that he will make him a leader of the blind, a light to thofe who walk in darknefs, and a teacher of infants; that he may fhine in the world, and receive at laft the great reward prepared for thofe who contend boldly for the preaching of the gofpel. After this the paftoral ftaff is delivered to the new bifhop, with a very proper and folemn exhortation from the archbifhop, to feed the flock of Chrift committed to his care.

The laft facrament of the Greek church is that of the holy oil or euchelaion, which is not confined to perfons *periculofe ægrotantibus, et mortis periculo imminente*, like the extreme unction of the Romifh church; but is adminiftered, if required, to devout perfons upon the flighteft malady. Though this ordinance is derived from St James, chap. v. ver. 14, 15. it is by no means deemed neceffary to falvation, or obligatory upon all Chriftians; and it is well that it is not, for feven priefts are required to adminifter it regularly, and it cannot be adminiftered at all by lefs than three. The oil is confecrated with much folemnity; after which each prieft, in his turn, takes a twig, and dipping it in the oil now made holy, anoints the fick perfon crofs-wife, on the forehead, on the noftrils, on the paps, the mouth, the breaft, and both fides of the hands, praying that he may be delivered from the bodily infirmity under which he labours, and raifed up by the grace of Jefus Chrift.

26 The lavipedium.

In the Greek, as well as in the Latin church, there is a fervice called the divine *lavipedium*, obferved on the Thurfday of paffion-week, in imitation of our Saviour's humility. At Conftantinople, Jefus Chrift is, on this occafion, perfonified by the Patriarch, and everywhere elfe by the bifhop of the diocefe, and the twelve apoftles by twelve regular priefts, when a ludicrous conteft arifes who fhall reprefent Judas; for the name attaches for life. This office is performed at the weft end of the church, where an arm chair is fet at the bottom, facing the eaft, for the bifhop; and on each fide are placed twelve chairs for the twelve priefts, who are to reprefent the twelve apoftles. The prayers and hymns ufed on this occafion are extremely beautiful and appropriate; and when the firft gofpel, relating our Saviour's wafhing of his difciples feet, begins to be read, the bifhop or patriarch rifes up, and takes off his pontifical veftments, by himfelf without affiftance. He then girds himfelf with a towel, and taking a bafon of water in his hand, kneels down and wathes one foot of each prieft, beginning with the youngeft; and after having wafhed it he kiffes it. All this is done as the feveral circumftances are read; and when he comes to the laft prieft, who is fuppofed to reprefent Peter, that prieft rifes up and faith, "Lord, doft thou wafh my feet?" &c. The bifhop anfwers in the words of our Saviour; and having finifhed the whole, puts on his garments again, and fits down; and as the fecond gofpel is read (K), repeats the words of our Saviour, "Know ye what I have done unto you?" &c. The office is certainly ancient, and if decently performed muft be affecting.

27 The privileges of the patriarch of Conftantinople.

Under the word PATRIARCHS (*Encycl.*) we have given a fufficient account of the rife of the patriarchates, as well as of the various degrees of rank and authority claimed by the bifhops of feveral other fees in the Greek church. It may be proper to add here, that after the taking of Conftantinople by Mohammed II. he continued to the patriarch of that city the fame prefent which the Greek emperors had been accuftomed to make, a paftoral ftaff, a white horfe, and four hundred ducates in gold. To the Greek church and the maintenance of its clergy he left indeed ample revenues, which they have gradually facrificed to their inconftancy, their ambition, and their private jealoufy. Still, however, the patriarch of Conftantinople fills a very lucrative and high office. "Befides the power of nominating the other three patriarchs, and all epifcopal dignitaries (fays Mr Dallaway), he enjoys a moft extenfive jurifdiction, comprifing the churches of Anatolia, Greece, Wallachia, Moldavia, and the iflands of the Archipelago. Since the clofe of the fixteenth century, the Ruffian church has claimed a jurifdiction independent of the fee of Conftantinople; though appeals have been made to that fee in cafes of extraordinary importance. The influence of the patriarch with the Porte is very extenfive, as far as his own nation is concerned. His memorials are never denied; and he can, in fact, command the death, the exile, imprifonment for life, depofition from offices, or pecuniary fine, of any Greek whom he may be inclined to punifh with rigour, or who has treated his authority with contempt. On the death of the patriarch the moft eager competition is exerted to fill the vacant throne; which, as it is obtained by bribery and intrigue, is of courfe a very unftable feat to the fuccefsful candidate, fhould another offer to accept the appointment at a lower falary." For a fuller account of the doctrines, difcipline, and worfhip of the Greek church at prefent, we refer the reader to *King's Rites and Ceremonies of the Greek Church in Ruffia*, and to *Dallaway's Conftantinople ancient and modern* (publifhed in 1797); from which two works this abftract has been moftly taken.

CHURCH *Creek Town*, in Dorchefter co. Maryland, lies at the head of Church creek, a branch of Hudfon river, 7 miles S. wefterly from Cambridge. —*Morfe.*

CHURCH

(K) The firft gofpel is John xiii. 3—12. The fecond gofpel is John xiii. 12—18.

CHURCH HILL, a village in Queen Anne's co. Maryland, at the head of S. E. Creek, a branch of Chester river; N. W. of Bridgetown, and N. E. of Centreville 8 miles, and 85 S. W. from Philadelphia. N. lat. 40. 9. W. long. 75. 53.—*ib.*

Church Hill, Fort, in New N. Wales, ſtands at the mouth of Seal river on the E. ſide of Hudſon bay; 120 miles N. N. E. of York fort. N. lat. 48. 58. W. long. 94. 13.—*ib.*

CHURCHILL *River* in New South Wales, runs N. eaſterly into the W. ſide of Hudſon bay, at Church Hill fort, in lat. 58. 57. 32. N. long. 94. 12. 30. W.—*ib.*

CHURCHTOWN, a village, ſo called, in the N. E. part of Lancaſter co. Pennſylvania, about 20 miles E. N. E. of Lancaſter, and 50 W. N. W. of Philadelphia. It has 12 houſes, and an Epiſcopal church; and in the environs are two forges, which manufacture about 450 tons of bar iron annually.—*ib.*

CHUSAN-Islands, a cluſter of ſmall iſlands on the eaſt coaſt of China, which were viſited by Lord Macartney in his courſe to Pekin. Moſt of theſe iſlands ſeem to be hills riſing regularly out of the ſea, and rounded at top, as if any points or angles exiſting in their original formation had been gradually worn off into a globular and uniform ſhape. Many of them, though cloſe to each other, are divided by channels of great depth. They reſt upon a foundation of grey or red granite, ſome part reſembling porphyry, except in hardneſs. They were, certainly, not formed by the ſucceſſive alluvion from the earth brought into the ſea by the great river at whoſe mouth they are ſituated, like the numerous low and muddy iſlands at the mouth of the Po, and many others; but ſhould rather be conſidered as the remains of part of the continent thus ſcooped and furrowed, as it were, into iſlands, by the force of violent torrents carrying off, further into the ſea, whatever was leſs reſiſtible than the rocks juſt mentioned. Some of them wore a very inviting aſpect; one in particular, called Poo-too, is deſcribed as a perfect paradiſe. This ſpot was choſen, no doubt, for its natural beauties, and afterwards embelliſhed, by a ſet of religious men, who, to the number of three thouſand, poſſeſs the whole of it, living there in a ſtate of celibacy. It contains four hundred temples, to each of which are annexed dwelling houſes and gardens for the accommodation of thoſe monks. This large monaſtery, as it may be called, is richly endowed, and its fame is ſpread throughout the empire.

The Engliſh Eaſt India Company had once a factory at Chuſan, the principal of theſe iſlands, from which they were many years ago interdicted. This, according to the account of a Chineſe merchant who remembered the factory, was not occaſioned by any offence given by the Engliſh, but by the avarice of the officers governing at Canton, who draw large ſums from the accumulation of foreign trade in that port. Perhaps, too, the exceſſive jealouſy of the Chineſe government might fancy danger in the unreſtrained communication between foreigners and the ſubjects of that empire in ſeveral of its ports at the ſame time.

Ting-hai, the chief town of Chuſan, reſembles Venice, but on a ſmaller ſcale. It is ſurrounded, as well as interſected, by canals, over which are thrown ſteep bridges, aſcended by ſteps like the Rialto. The ſtreets are narrow and paved with ſquare flat ſtones; but the houſes, unlike the Venetian buildings, are low and moſtly of one ſtory. The ornaments of theſe buildings are confined chiefly to the roofs, on the ridges of which are uncouth figures of animals in clay, ſtone, or iron. The town is full of ſhops, containing chiefly articles of clothing, food, and furniture, diſplayed to full advantage. Even coffins are painted in a variety of lively and contraſting colours. The ſmaller quadrupeds, including dogs, intended for food, are expoſed alive for ſale, as well as poultry, and fiſh in tubs of water with eels in ſand. When the gentlemen belonging to the embaſſy were at Ting-hai, they were ſtruck with the number of places where tin-leaf and ſticks of odoriferous wood were ſold for burning in the temples, which indicated no ſlight degree of ſuperſtition in the people. Superſtition, however, made them not idle; for throughout the whole place there was a quick and active induſtry. Men paſſed buſily through the ſtreets, while not an individual was ſeen aſking alms; and the women were employed in the ſhops. At Chuſan, the number of valuable harbours, or places of perfect ſecurity for ſhips of any burden, is almoſt equal to the number of iſlands. This advantage, together with that of their central ſituation, in reſpect to the eaſtern coaſt of China, and the vicinity of Corea, Japan, Leoo-keoo, and Formoſa, attract conſiderable commerce, eſpecially to Ning-poo, a city of great trade in the adjoining province of Che-chiang, to which all the Chuſan iſlands are annexed. From one port in that province twelve veſſels ſail annually for copper to Japan.

According to Brooks, Chuſan is in N. Lat. 30. 0. and E. Long. 124. 0.

CIACICA, a juriſdiction in S. America, in Peru, ſubject to the archbiſhop of Plata, and 90 leagues diſtant from that city; abounding in cocoa, cattle, and ſome ſilver mines.—*Morse.*

CIBOLA, or *Civola*, the name of a town in, and alſo the ancient name of, New-Granada, in Terra Firma, South-America. The country here, though not mountainous, is very cool; and the Indians are ſaid to be the whiteſt, wittieſt, moſt ſincere and orderly of all the aboriginal Americans. When the country was diſcovered, they had each but one wife, and were exceſſively jealous. They worſhipped water, and an old woman that was a magician; and believed ſhe lay hid under one of their lakes.—*ib.*

CICERO, a military townſhip in New-York, on the S. W. ſide of Oneida lake; and between it, the Salt lake, and the Salt ſprings.—*ib.*

CINALOA, called by ſome *Cinoleo*, a province in the audience of Galicia, in Old-Mexico, or New-Spain. It has the gulf of California on the W. the province of Culiacan on the S. and the kingdom of New-Mexico on the N. and E. From S. E. to N. E. it is about 100 leagues; and not above 40 where broadeſt. On the E. ſide it is bounded by the high craggy mountains, called Tepecſuan, 30 or 40 leagues from the ſea. It is well watered, its rivers abound with fiſh, and the air is ſerene and healthful. It abounds with all ſorts of fruit, and grain, and cotton. The natives are hardy and induſtrious, and manufacture cotton cloth, with which they clothe themſelves.—*ib.*

CINARA, or Cynara, which we tranſlate *artichoke*, is, according to Profeſſor Beckmann, the name which was given by the ancients to a plant very different from the artichoke of our kitchen gardens, though he admits that they belong to the same genus. The proofs which he adduces for the truth of his opinion are too tedious to be introduced into this Work, especially as they appear not to us to be absolutely conclusive. We must therefore refer the reader to his History of Inventions. The *cinara*, *carduus*, and *scolymus* (see Scolymus in this Supplement), were in his opinion species of the *thistle*, of which the *roots* and young *shoots*, as well as the bottom of the *calyx* of the last, were eaten. He has proved indeed, he thinks, that the Greeks and Romans used the pulpy bottom of the calyx, and the tenderest stalks and young shoots of many plants belonging to the thistle kind, in the same manner as we use artichokes and cardoons, but that these latter were unknown to them.

"It appears probable (says he) that the use of these thistles, at least in Italy and Europe in general, was in the course of time laid aside and forgotten, and that the artichoke, when it was first brought to Italy from the Levant, was considered as a new species of food. It is undoubtedly certain that our artichoke was first known in that country in the 15th century. Hermolaus Barbarus, who died in 1494, relates that this plant was first seen at Venice in a garden in 1473, at which time it was very scarce. About the year 1466, one of the family of Strozza brought the first artichokes to Florence from Naples. Politian, in a letter in which he describes the dishes he found at a grand entertainment in Italy in 1488, among these mentions artichokes. They were introduced into France in the beginning of the 16th century, and into England in the reign of Henry VIII."

The original country of the artichoke is unknown. Linnæus says that it grew wild in Narbonne, Italy, and Sicily, as the cardoon did in Crete; but our author has proved very sufficiently, that with respect to both these facts the great botanist was misinformed. The artichoke is certainly known in Persia; but Tavernier says expressly, that it was carried thither, like asparagus and other European vegetables of the kitchen garden, by the Carmelite and other monks: and that it was only in latter times that it became common.

CINCINNATI, a flourishing town in the territory of the U. S. N. W. of the Ohio, and the present seat of government. It stands on the N. bank of the Ohio, opposite the mouth of Licking river 2½ miles S. W. of Fort Washington, and about 8 miles westerly of Columbia. Both these towns lie between Great and Little Miami rivers. Cincinnati contains about 200 houses; and is 82 miles N. by E. of Frankfort; 90 N. W. of Lexington, and 779 W. by S. of Philadelphia. N. lat. 39. 22. W. long. 85. 44.—*Morse.*

CINCINNATUS, is the S. easternmost of the military townships of New-York state. It has Virgil on the W. and Salem, in Herkemer co. on the E. and lies on two branches of Tioughnioga river, a N. western branch of the Chenango. The centre of the town lies 53 miles S. W. by W. of Cooperstown, and 39 S. E. by S. of the S. E. end of Salt Lake. N. lat. 42. 30.

CINNABAR. See Chemistry in this Supplement, n° 91.

CIRCLE of Curvature, or circle of equicurvature, is that circle which has the same curvature with a given curve at a certain point; or that circle whose radius is equal to the radius of curvature of the given curve at that point.

Circles of Declination are great circles intersecting each other in the poles of the world.

Circle of Dissipation, in optics. See Optics, *Encycl.* n° 253.

Circle Equant, in the Ptolemic astronomy, is a circle described on the centre of the equant. Its chief use is to find the variation of the first inequality.

Circles of Excursion are little circles parallel to the ecliptic, and at such a distance from it, as that the excursions of the planets towards the poles of the ecliptic may be included within them; being usually fixed at about 10 degrees.

Circles of Position, are circles passing through the common intersections of the horizon and meridian, and through any degree of the ecliptic, or the centre of any star, or other point in the heavens; and are used for finding out the situation or position of any star. These are usually six in number, cutting the equinoctial into 12 equal parts, which the astrologers call the *celestial houses*, and hence they are sometimes called *circles of the celestial houses*.

CIRCULAR Lines, a name given by some authors to such straight lines as are divided by means of the divisions made in the arch of a circle; such as the sines, tangents, secants, &c.

Circular Parts, called, from the use which he first made of them, *Napier's* circular parts, are the five parts of a right-angled or a quadrantal spherical triangle; they are the two legs, the complement of the hypothenuse, and the complements of the two oblique angles.

Concerning these circular parts, Napier gave a general rule in his *Logarithmorum Canonis Descriptio*, which is this; "The rectangle under the radius and the sine of the middle part is equal to the rectangle under the tangents of the adjacent parts, and to the rectangle under the cosines of the opposite parts. The right angle or quadrantal side being neglected, the two sides and the complements of the other three natural parts are called the *circular parts*, as they follow each other as it were in a circular order. Of these, any one being fixed upon as the middle part, those next it are the adjacent, and those farthest from it the opposite parts."

This rule contains within itself all the particular rules for the solution of right-angled spherical triangles, and they were thus brought into one general comprehensive theorem, for the sake of the memory; as thus, by charging the memory with this one rule alone: All the cases of right angled spherical triangles may be resolved, and those of oblique ones also, by letting fall a perpendicular, excepting the two cases in which there are given either the three sides, or the three angles. And for these a similar expedient has been devised by Lord Buchan and Dr Minto, which may be thus expressed: "Of the circular parts of an oblique spherical triangle, the rectangle under the tangents of half the sum and half the difference of the segments at the middle part (formed by a perpendicular drawn from an angle to the opposite side), is equal to the rectangle under the tangents of half the sum and half the difference of the opposite parts." By the circular parts of an oblique spherical triangle are meant its three sides and the supplements of its three angles. Any of these six being assumed as a middle part, the opposite parts are those two of the fame denomination with it, that is, if the middle part is one of the fides, the oppofite parts are the other two, and, if the middle part is the fupplement of one of the angles, the oppofite parts are the fupplements of the other two. Since every plane triangle may be confidered as defcribed on the furface of a fphere of an infinite radius, thefe two rules may be applied to plane triangles, provided the middle part be reftricted to a fide.

Thus it appears that two fimple rules fuffice for the folution of all the poffible cafes of plane and fpherical triangles. Thefe rules, from their neatnefs, and the manner in which they are expreffed, cannot fail of engraving themfelves deeply on the memory of every one who is a little verfed in trigonometry. It is a circumftance worthy of notice, that a perfon of a very weak memory may carry the whole art of trigonometry in his head.

CIRCULATING Decimals. See Decimals in this Supplement.

CIVIDAD REAL, the capital city of Chiapa, in New-Spain. Chilton, an Englifhman, fays the Indians called it Sacatlan, and that, in 1570, it contained about 100 Spanifh inhabitants.—*Morse.*

Cividad Real, is the capital of the province of Guaira, in the E. divifion of Paraguay.—*ib.*

CLAIR, St, a county in the territory N. W. of the Ohio; was laid off 27th April, 1790. Its boundaries are thus officially defcribed: "Beginning at the mouth of the Little Michillimackinack river; running thence foutherly in a direct line to the mouth of the Little river above fort Maffac, upon the Ohio river; thence with the Ohio to its junction with the Miffiffippi; thence up the Miffiffippi to the mouth of the Illinois river; and up the Illinois to the place of beginning, with all the adjacent iflands of the faid rivers Illinois and Miffiffippi."—*ib.*

Clair, St, a fort in the territory N. W. of the Ohio, is fituated 25 miles N. of fort Hamilton, on a fmall creek which falls into the Great Miami; and 21 miles S. of fort Jefferfon.—*ib.*

Clair, St, *Lake*, lies about half way between lake Huron and lake Erie, in North America, and is about 90 miles in circumference. It receives the waters of the three great lakes, Superior, Michigan, and Huron, and difcharges them through the river or ftrait, called D'Etroit (which is in French, the Strait) into lake Erie. Its channel, as alfo that of the lake, is fufficiently deep for veffels of very confiderable burden.—*ib.*

CLARE, a townfhip on St Mary's bay, in Annapolis co. Nova-Scotia. It has about 50 families, and is compofed of woodland and falt marfh.—*ib.*

CLAREMONT, a townfhip in Chefhire co. New-Hampfhire, on the E. fide of Connecticut river, oppofite Afcutney mountain, in Vermont, and on the N. fide of Sugar river; 24 miles S. of Dartmouth college, and 82 S. W. by W. of Portfmouth. It was incorporated in 1764, and contains 1435 inhabitants.—*ib.*

Claremont *Co.* in Camden diftrict, S. Carolina, contains 2479 white inhabitants, and 2110 flaves. Statefburg is the county town.—*ib.*

CLARENDON *Co.* the fouthernmoft in Camden diftrict, S. Carolina, is about 30 miles long and 30 broad, and contains 1790 whites and 602 flaves.—*ib.*

Clarendon, a townfhip near the centre of Rutland co. Vermont, watered by Otter Creek and its tributary

ftreams; 14 or 15 miles E. of Fairhaven, and 44 N. E. of Bennington. It contains 1478 inhabitants. On the S. E. fide of a mountain in the wefterly part of Clarendon, or in the edge of Tinmouth, is a curious cave, the mouth of which is not more than 2½ feet in diameter. In its defcent, the paffage makes an angle with the horizon of 35 or 40 degrees; but continues of nearly the fame diameter through its whole length, which is 31½ feet. At that diftance from the mouth, it opens into a fpacious room, 20 feet long, 12½ wide, and 18 or 20 feet high. Every part of the floor, fides and roof of this room appear to be a folid rock, but very rough and uneven. The water is continually percolating through the top, and has formed ftalactites of various forms; many of which are conical, and fome have the appearance of maffive columns. From this room there is a communication by a narrow paffage to others equally curious.—*ib.*

CLARKE, a new county of Kentucky between the head waters of Kentucky and Licking rivers. Its chief town is Winchefter.—*ib.*

CLARKSBURG, the chief town of Harrifon co. Virginia. It contains about 40 houfes, a court-houfe, and gaol; and ftands on the E. fide of Monongahela river, 40 miles S. W. of Morgantown.—*ib.*

CLARKSTOWN, in Orange co. New-York, lies on the W. fide of the Tappan Sea, 2 miles diftant; northerly from Tappan townfhip, 6 miles, and from New-York city, 29 miles. By the ftate cenfus of 1796, 224 of its inhabitants are electors.—*ib.*

CLARKSVILLE, the chief town of what was till lately called Tenneffee co. in the ftate of Tenneffee, is pleafantly fituated on the E. bank of Cumberland river, and at the mouth of Red river, oppofite the mouth of Muddy Creek. It contains about 30 houfes, a court-houfe and gaol, 45 miles N. W. of Nafhville; 220 N. W. by W. of Knoxville, and 940 W. by S. of Philadelphia. N. lat. 36. 25. W. long. 88. 57.—*ib.*

Clarksville, a fmall fettlement in the N. W. territory, which contained, in 1791, about 60 fouls. It is fituated on the northern bank of the Ohio, oppofite Louifville, a mile below the Rapids, and 100 miles S. E. of Poft Vincent. It is frequently flooded, when the river is high, and inhabited by people who cannot, at prefent, find a better fituation.—*ib.*

CLAVERACK, a poft town in Columbia co. New-York, pleafantly fituated on a large plain, about 2¼ miles E. of Hudfon city, near a creek of its own name. It contains about 60 houfes, a Dutch Church, a court-houfe, and a gaol. The townfhip, by the cenfus of 1791, contained 3262 inhabitants, including 340 flaves. By the ftate cenfus of 1796, there appears to be 412 electors. It is 231 miles from Philadelphia.—*ib.*

CLERK's *Ifles*, lie S. W. from, and at the entrance of Behring's ftraits, which feparate Afia from America. They rather belong to Afia, being very near, and S. S. W. from the head land which lies between, the ftraits and the gulf of Anadir, in Afia. They have their name in honor of that able navigator, Capt. Clerk, the companion of Capt. Cook. In other maps they are called St Andrea Ifles.—*ib.*

CLERMONT, a poft town in Columbia co. New-York, 6 miles from Red Hook, 15 from Hudfon, 117 miles N. of New-York, and 212 from Philadelphia. The townfhip contains 867 inhabitants, inclufive of 113 flaves.—*ib.*

Clermont, a village 13 miles from Camden, South-Carolina. In the late war, here was a block-houfe encompaffed by an abbatis. It was taken from col. Rugely, of the Britifh militia, in Dec. 1781, by an ingenious ftratagem of lieut. col. Wafhington.—*ib.*

CLIE, LAKE LE, in Upper Canada, about 38 miles long, and 30 broad; its waters communicate with thofe of Lake Huron.—*ib.*

CLINCH *Mountain*, divides the waters of Holfton and Clinch rivers, in the ftate of Tenneffee. In this mountain, Burk's Garden, and Morris's Nob, might be defcribed as curiofities.—*ib.*

Clinch, or *Pelefon*, a navigable branch of Tenneffee river, which is equal in length to Holfton river its chief branch, but lefs in width. It rifes in Virginia, and after it enters into the ftate of Tenneffee, it receives Powel's, and Poplar's creek, and Emery's river, befides other ftreams. The courfe of the Clinch is S. W. and S. W. by W. Its mouth, 150 yards wide, lies 35 miles below Knoxville, and 60 above the mouth of the Hiwaffee. It is boatable for upwards of 200 miles; and Powel's river, nearly as large as the main river, is navigable for boats 100 miles.—*ib.*

CLINTON, the moft northern county of the ftate of New York, is bounded N. by Canada, E. by the deepeft waters of Lake Champlain, which line feparates it from Vermont; and S. by the county of Wafhington. By the cenfus of 1791, it contained 1614 inhabitants, including 17 flaves. It is divided into 5 townfhips, viz. Plattfburgh, the capital, Crown Point, Willfborough, Champlain, and Peru. The length from N. to S. is about 96 miles, and the breadth from E. to W. including the line upon the lake, is 36 miles. The number of fouls is now (1796,) eftimated to be 6,000. By the ftate cenfus, in Jan. 1796, there were 624 perfons entitled to be electors. A great proportion of the lands are of an excellent quality, and produce abundance of the various kinds of grain cultivated in other parts of the ftate. The people manufacture earthen ware, pot and pearl afhes, in large quantities, which they export to New-York or Quebec. Their wool is excellent; their beef and pork fecond to none; and the price of ftall-fed beef in Montreal, 60 miles from Plattfburg, is fuch as to encourage the farmers to drive their cattle to that market. Their forefts fupply them with fugar and molaffes, and the foil is well adapted to the culture of hemp. The land carriage from any part of the country, in tranfporting their produce to New-York, does not exceed 18 miles. The carrying place at Ticonderoga is 1½ miles; and from Fort George, at the S. end of the lake of that name, to Fort Edward, is but 14 miles. The fmall obftructions after that are to be removed by the proprietors of the northern canal. From this country to Quebec, are annually fent large rafts; the rapids at St John's and Chamblee, being the only interruptions in the navigation, and thofe not fo great, but that at fome feafons, batteaux with fixty bufhels of falt can afcend them. Salt is fold here at half a dollar a bufhel. Saranac, Sable, and Boquet rivers water Clinton co. The firft is remarkable for the quantity of falmon it produces.—*ib.*

Clinton, a townfhip in Dutchefs co. New-York, above Poughkeepfie. It is large and thriving, and contains 4607 inhabitants, including 176 flaves. 666 of its inhabitants are electors.—*ib.*

Clinton, a fettlement in Tioga co. New-York, bounded by Fayette on the N. Warren on the S. Greene on the W. and Franklin in Otfego co. on the E. Unadilla river joins the Sufquehanna at the N. E. corner, and the confluent ftream runs S. W. to Warren.—*ib.*

Clinton, a plantation in Lincoln co. diftrict of Maine, lies 27 miles from Hallowell.—*ib.*

Clinton, parifh, in the townfhip of Paris, 7 miles from Whiteftown, is a wealthy, pleafant, flourifhing fettlement, containing feveral handfome houfes, a newly erected Prefbyterian meeting-houfe, a convenient fchool houfe, and an edifice for an academy delightfully fituated, but not yet finifhed. Between this fettlement and the Indian fettlements at Oneida, a diftance of 12 miles, (in June 1796) was wildernefs, without any inhabitants, excepting a few Indians at the Old Oneida village.—*ib.*

Clinton's *Harbor*, on the N. W. coaft of N. America, has its entrance in N. lat. 52. 12. W. long. 136. Capt. Gray named it after gov. Clinton of New-York. —*ib.*

CLISTINOS, a fierce nation of Indians who inhabit round Hudfon bay.—*ib.*

CLOCK, a machine for meafuring time, of which a defcription is given in the Encyclopædia. For the fcientific principles of *clock* and *watch making*, as well as for a fhort account of the moft valuable conftructions, fee Watch-*Making* in this Supplement.

CLOSTER, a village in Bergen co. New-Jerfey, nearly 7 miles S. E. of Peramus, and 16 N. of New-York city.—*Morse.*

CLYOQUOT, a found or bay on the N. W. coaft of America, wefterly from Berkley's Sound.—*ib.*

COACH, as we have obferved in the Encyclopædia, is a very modern invention, if by that word be meant a covered carriage fufpended on fprings. We learn, indeed, from the laborious refearches of Profeffor Beckmann, that coaches of fome kind were known in the beginning of the 16th century; but they were ufed only by women of the firft rank, for the men thought it difgraceful to ride in them. At that period, when the electors and princes did not choofe to be prefent at the meetings of the ftates, they excufed themfelves by informing the emperor that their health would not permit them to ride on horfeback, and it was confidered as a point eftablifhed, that it was unbecoming for them to ride like women. It is certain, however, that, about the end of the 15th century, the emperor, kings, and princes, began to employ covered carriages on journeys, and afterwards on public folemnities.

The wedding carriage of the firft wife of the emperor Leopold, who was a Spanifh princefs, coft, together with the harnefs, 38,000 florins. The coaches ufed by that emperor, are thus defcribed by Kink: "In the imperial coaches no great magnificence was to be feen; they were covered over with red cloth and black nails. The harnefs was black, and in the whole work there was no gold. The pannels were of glafs, and on this account they were called the *Imperial glafs coaches.* On feftivals, the harnefs was ornamented with red filk fringes. The imperial coaches were diftinguifhed only by their having leather traces; but the ladies in the imperial fuite were obliged to be contented with carriages, the traces of which were made of ropes." At the magnificent court of Duke Erneft Auguftus of Hanover, there were in the year 1681 fifty gilt coaches with fix horfes each. So early did Hanover begin to furpafs other cities in the number of its carriages. The firft time

time that ambassadors appeared in coaches on a public solemnity was at the imperial commission held at Erfurth in 1613, respecting the affair of Juliers.

In the history of France we find many proofs that at Paris, in the 14th, 15th, and even 16th centuries, the French monarchs rode commonly on horses, the servants of the court on mules, and the princesses, together with the principal ladies, sometimes on asses. Persons of the first rank often sat behind their equerry, and the horse was often led by servants. Carriages, however, of some kind appear to have been used very early in France. An ordinance of Philip the Fair, issued in 1294 for suppressing luxury, and in which the citizens wives are forbid to use carriages *(cars)*, is still preserved. Under Francis I. or rather about 1550, somewhat later, there were in Paris for the first time only three coaches.

The oldest carriages used by the ladies in England were known under the now forgotten name of *whirlicotes*. When Richard II. towards the end of the 14th century, was obliged to fly before his rebellious subjects, he and all his followers were on horseback; his mother only, who was indisposed, rode in a carriage. This, however, became afterwards somewhat unfashionable, when that monarch's queen, Anne, the daughter of the Emperor Charles IV. shewed the English ladies how gracefully and conveniently she could ride on a side-saddle. Whirlicotes were laid aside, therefore, except at coronations and other public solemnities. Coaches were first known in England about the year 1580, and, as Stow says, were introduced from Germany by Fitzallen, earl of Arundel. In the year 1598, when the English ambassador came to Scotland, he had a coach with him. Anderson places the period when coaches began to be in common use about the year 1605. The celebrated duke of Buckingham, the unworthy favourite of two kings, was the first person who rode with a coach and six horses, in 1619. To ridicule this new pomp, the earl of Northumberland put eight horses to his carriage.

Respecting the progress of luxury with regard to coaches, the reader will find much curious information in the first volume of Professor Beckmann's History of Inventions. It is perhaps one of the most entertaining articles in that very learned work. The author, however, with all his labour, has not been able to ascertain the country in which coaches hung on springs were first used; but he seems inclined to give the credit of the invention to Hungary.

COATZACUALCO, a navigable river of Mexico, or New Spain, which empties into the gulf of Mexico, near the country of Onohualco.—*Morse*.

COBALT (see Chemistry-*Index*, in this Supplement), is a valuable article to potters and dyers. To fit it for their use, it is first roasted, and freed from the foreign mineral bodies with which it is united: it is then well calcined, and sold either mixed or unmixed with fine sand under the name of zaffer *(zaffera)*; or it is melted with siliceous earth and pot ashes to a kind of blue glass called *smalt*, which when ground very fine is known in commerce by the name of *powder blue*. All these articles, because they are most durable pigments, and those which best withstand fire, and because one can produce with them every shade of blue, are employed above all for tinging crystal and for enamelling: for counterfeiting opaque and transparent precious stones, and for painting and varnishing real porcelain and earthen and potters ware. This colour is indispensably necessary to the painter, when he is desirous of imitating the fine azure colour of many butterflies and other natural objects; and the cheaper kind is employed to give a bluish tinge to new-washed linen, which so readily changes to a disagreeable yellow, though not without injury to the health, as well as to the linen.

Professor Beckmann, in his *History of Inventions*, gives the following account of the paint prepared from cobalt. "About the end of the 15th century cobalt appears to have been dug up in great quantity in the mines on the borders of Saxony and Bohemia, discovered not long before that period. As it was not known at first to what use it could be applied, it was thrown aside as a useless mineral. The miners had an aversion to it, not only because it gave them much fruitless labour, but because it often proved prejudicial to their health by the arsenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then first took its rise. At any rate I have never met with it before the beginning of the 16th century; and Mathesius and Agricola seem to have first used it in their writings. Frisch derives it from the Bohemian word *kow* which signifies *metal*; but the conjecture that it was formed from *cobalus*, which was the name of a spirit that, according to the superstitious notions of the times, haunted mines, destroyed the labours of the miners, and often gave them a great deal of unnecessary trouble, is more probable; and there is reason to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes and rendering their labour often fruitless. It was once customary, therefore, to introduce into the church-service a prayer that God would preserve miners and their works from *kobolts* and spirits.

"Respecting the invention of making an useful kind of blue glass from cobalt, we have no better information than that which Klotzsch has published from the papers of Christian Lehmann. The former author of an historical work respecting the upper district of the mines in Misnia, and a clergyman at Scheibenberg, collected with great diligence every information that respected the history of the neighbouring country, and died at a great age, in 1688. According to his account, the colour-mills at the time when he wrote were about a hundred years old; and as he began first to write towards the end of the thirty years war, the invention seems to fall about 1540 or 1560. He relates the circumstance as follows, 'Christopher Schurer, a glass-maker at Platten, a place which belongs still to Bohemia, retired to Neudeck, where he established his business. Being once at Schneeberg, he collected some of the beautiful coloured pieces of cobalt which were found there, tried them in his furnace; and finding that they melted, he mixed some cobalt with glass metal, and obtained fine blue glass. At first he prepared it only for the use of the potters; but in the course of time it was carried as an article of merchandize to Nuremberg, and thence to Holland. As painting on glass was then much cultivated in Holland, the artists there knew better how to appreciate this invention. Some Dutchmen therefore repaired to Neudeck, in order that they might learn the process procefs ufed in preparing this new paint. By great promifes they perfuaded the inventor to remove to Magdeburg, where he alfo made glafs from the cobalt of Schneeberg; but he again returned to his former refidence, where he conftructed a handmill to grind his glafs, and afterwards erected one driven by water. At that period the colour was worth 7½ dollars per cwt. and in Holland from 50 to 60 florins. Eight colour-mills of the fame kind, for which roafted cobalt was procured in cafks from Schneeberg, were foon conftructed in Holland; and it appears that the Dutch muft have been much better acquainted with the art of preparing, and particularly with that of grinding it, than the Saxons; for the Elector, John George fent for two colour-makers from Holland, and gave a thoufand florins towards the enabling them to improve the art. He was induced to make this advance chiefly by a remark of the people of Schneeberg, that the part of the cobalt which dropped down while it was roafting contained more colour than the roafted cobalt itfelf. In a little time more colour-mills were erected around Schneeberg. Hans Burghard, a merchant, and chamberlain of Schneeberg, built one, by which the eleven mills at Platten were much injured. Paul Nordhoff, a Frieflander, a man of great ingenuity, who lived at the Zwittermill, made a great many experiments in order to improve the colour; by which he was reduced to fo much poverty that he was at length forced to abandon that place, where he had been employed for ten years in the colour-manufactory. He retired to Annaberg, eftablifhed there in 1649, by the affiftance of a merchant at Leipfic, a colour-manufactory, of which he was appointed the director; and by thefe means rendered the Annaberg cobalt of utility. The confumption of this article, however, muft have decreafed in the courfe of time; for in the year 1659, when there were mills of the fame kind at more of the towns in the neighbourhood of mines, he had on hand above 8000 quintals.' Thus far Lehmann."

Kofsler fays, that the Bohemian cobalt is not fo good as that of Mifnia, and that its colour is more like that of afhes. We truft, however, that the qualities of foreign cobalt fhall foon be a matter of little importance to the Britifh artift, as a rich mine of this mineral has lately been difcovered near Penzance in Cornwal.

COBBESECONTE, or *Copfecook*, which in the Indian language fignifies the land where fturgeon are taken, is a fmall river which rifes from ponds in the town of Winthrop, in the diftrict of Maine; and falls into the Kennebeck within 5 miles of Nahunkeag Ifland, and 15 from Moofe Ifland.—*Morse.*

COBEQUIT, or *Colchefter River*, in Nova-Scotia, rifes within 20 miles of Tatamogouche, on the N. E. coaft of Nova-Scotia; from thence it runs foutherly, then S. W. and W. into the E. end of the Bafin of Minas. At its mouth there is a fhort bank, but there is a good channel on each fide, which veffels of 60 tons burden may pafs, and go 40 miles up the river. There are fome fcattered fettlements on its banks.—*ib.*

COBEZA, or *Colija*, an obfcure port and village in the audience of Los Charcos, in Peru, S. America. The place is inhabited by about 50 Indian families, and is the moft barren fpot on the coaft. This is, however, the neareft port to Lipes, where there are filver mines, and alfo to Potofi, which is yet above 100 leagues diftant, and that through a defart country.—*ib.*

COBHAM, a fmall town in Virginia, on the S. bank of James river oppofite Jameftown; 20 miles N. W. of Suffolk, and 8 or 9 S. W. of Williamfburgh.—*ib.*

COBHAM *Ifle*, mentioned by Captain Middleton, in the journal of his voyage for finding a N. E. paffage. Its two extremities bear N. by E. and E. by N. in N. lat. 63. E. long. from Churchill, 3. 40. which he takes to be the *Brook Cobham* of Fox.—*ib.*

COBLESKILL, a new town, in the co. of Schoharie, New-York, incorporated March 1797.

COCALICO, a townfhip in Lancafter co. Pennfylvania.—*ib.*

COCHECO, a N. W. branch of Pifcataqua river in New-Hampfhire. It rifes in the Blue Hills in Strafford co. and its mouth is 5 miles above Hilton's Point.—*ib.*

COCHABAMBA, a province and jurifdiction in Peru, 50 leagues from Plata, and 56 from Potofi. Its capital of the fame name is one of the richeft, largeft, and moft populous in Peru, as it is the granary of the archbifhoprick of Plata; and in fome fpots filver mines have been difcovered.—*ib.*

COCKBURNE, a townfhip in the northern part of New-Hampfhire, Grafton co. on the E. Bank of Connecticut river, S. of Colebrooke.—*ib.*

COCKERMOUTH, a town in Grafton co. New-Hampfhire, about 15 miles N. E. of Dartmouth College. It was incorporated in 1766, and in 1775, contained 118 inhabitants; and in 1790, 373.—*ib.*

CODORUS, a townfhip in York co. Pennfylvania.—*ib.*

COEYMANS, a townfhip in Albany co. New-York, 12 miles below Albany. By the ftate cenfus of 1796, 389 of its inhabitants are electors.—*ib.*

COFFEA, the COFFEE-TREE, is a plant which has been botanically defcribed in the Encyclopædia Britannica, where fome account is likewife given of the modes of cultivating it, as well as of the qualities of its fruit. Since that account, however, was publifhed, two works have fallen into our hands, from which we deem it our duty to make fuch extracts as may not only correct fome miftakes which we had committed, but alfo communicate ufeful information to the public.

In our former article we adopted the common opinion, that the coffee produced in Arabia is fo greatly fuperior to that which is raifed everywhere elfe, that it is vain to think of cultivating the plant to any extent in the Weft India iflands. We are happy to find that this is a vulgar error. In the year 1783, when the cultivation of coffee was not fo well underftood in Jamaica as at prefent, fome famples from that ifland were produced in London, and pronounced by the dealers to be equal to the very beft brought from the Eaft. "Two of the famples were equal to the beft Mocha coffee, and two more of them fuperior to any coffee to be had at the grocers fhops in London, unlefs you will pay the price of *picked* coffee for it, which is two fhillings per pound more than for that which they call the *beft* coffee. All the reft of the famples were far from bad coffee, and very little inferior, if at all, to what the grocers call *beft* coffee*."

* *Mofeley's Treatife on Coffee.*

If this be fo, it furely becomes the legiflature of Great Britain to encourage the cultivation of coffee in the Weft Indies, efpecially as it thrives beft in foil which is not fit for the fugar-cane, and may be raifed in confiderable

Coffea.

ſiderable quantities by thoſe who are not able to ſtock a ſugar plantation. The encouraging every article which increaſes the intercourſe with our colonies is increaſing our commerce. The payment for all the ſtaples of the Weſt Indies is made in our manufactures; the ſale of which muſt increaſe in proportion to the numbers that are employed in the cultivation of what is bartered for them. Our Weſt India iſlands, without draining us of ſpecie or bullion, can ſupply us with many of thoſe very articles for which we are drained in other parts of the world, and particularly with coffee.

To give a detailed account of the introduction of the coffee-tree into the Weſt Indies, would ſwell this article to very little purpoſe. According to Boerhaave, a Dutch governor was the firſt perſon who procured freſh berries from Mocha, and planted them in Batavia; and in the year 1690 ſent a plant from thence to Amſterdam, which came to maturity, and produced thoſe berries which have ſince furniſhed all that is now cultivated in the Weſt Indies.

In 1714 a plant from the garden of Amſterdam was ſent by Mr Pancras, a burgomaſter, and director of the botanic garden, as a preſent to Louis XIV. which was placed in the garden at Marly. In 1718 the Dutch began to cultivate coffee in Surinam; in 1721 the French began to cultivate it at Cayenne; in 1727 at Martinico; and in 1728 the Engliſh began to cultivate it in Jamaica.

As it has been more cultivated in the French Weſt-India iſlands than in the Britiſh, it may be of importance to our coloniſts to be made acquainted with the practice of the French planters. Accordingly Dr Laborie, a royaliſt of St. Domingo, has lately publiſhed a volume for their inſtruction on this ſubject; in which are many judicious obſervations, the reſult of long experience, reſpecting the ſoil fit for a coffee-plantation; the various eſtabliſhments neceſſary; the cultivation of the coffee-tree through the ſeveral ſtages of its growth and duration; and the management and uſe of the negroes and cattle.

With reſpect to ſoil, it is a fact, ſays he, beyond contradiction, that low lands, and even the mountains near the champaign country, are leſs proper for the production of coffee, than lands which are high and at a diſtance from the ſea. The coffee-tree delights in a comparatively cool climate, and in an open and permeable virgin ſoil; and is hurt by the parching deſtructive air of the ſea. The ſoil on the mountains of St Domingo conſiſts generally of a bed of mould more or leſs deep; but which, for the production of coffee-trees, ought not to be leſs than four or five feet. If the declivity be gentle, the ſofteſt and moſt friable earth is preferable to all others; but in ſteep grounds a firm though not clayey ſoil, mixed with a proportion of gravel or ſmall ſtones, through which the water may find an eaſy way, is the moſt deſirable. The colour of the ground is of little conſequence, though ſuch as is ſomewhat reddiſh is generally to be preferred. With regard to expoſure, the north and weſt are the moſt eligible in low and hot ſituations, becauſe theſe expoſures are the cooleſt; and on the higheſt mountains the ſouth and eaſt are to be choſen, becauſe they are the hotteſt. On the whole, neither the higheſt nor the loweſt ſituations are the beſt, but thoſe which are conſiderably above the middle of the mountains.

Whatever be the planter's circumſtances in point of fortune, and our author thinks that he ought not to undertake a ſettlement without the command of 3000 or 4000 pounds ſterling, he ought not to ſet out with a great number of negroes. If he cannot command a plentiful ſupply of victuals from ſome contiguous plantation, ſix, or at the moſt twelve, male negroes, with one or two women, will be found ſufficient to make the firſt eſſay. After building two huts, one for the maſter or overſeer and the other for the ſlaves, they are to commence their operations by cutting away the underwood and creeping plants with the bill, and felling the trees. The trees are to be cut as low as poſſible, but the roots are to be left in the ground, becauſe they preſerve the ſoil during the firſt period of culture; and in burning this maſs of wood and ſhrubs, the only way ſometimes of clearing the ground, care muſt be taken that the fire be nowhere ſo violent as to convert the ſoil into the conſiſtence of brick, which it is very apt to do if the ſoil be clayey. Amid the coffee-trees, after they are planted may be ſown beans, maize, and all kinds of eſculent plants, pot herbs, and roots; but particular care muſt be taken to remove from theſe plantations all creeping plants, ſuch as melons, yams, potatoes, gourds, and more eſpecially tobacco, which multiplies to a vaſt extent, and exhauſts the ground.

In St Domingo the moſt approved method of planting the coffee-tree is in ſtraight rows croſſing each other at right angles, and the diſtance between the plants is regulated by the quality and expoſure of the ground. The richer the ſoil, the expoſures being the ſame, and the cooler the expoſure, the quality of the ſoil being the ſame, the farther muſt the trees be planted aſunder. If on the north and weſt the ground be good, plant ſtill farther; but, on the contrary, if to the eaſt or ſouth it be light (which it generally is), plant ſtill nearer. Thus if it be proper on a ſouth or eaſt expoſure to plant at the diſtance of ſix feet, it will be neceſſary to plant at the diſtance of ſeven on a weſt or north expoſure, if the ground be of the ſame quality as in the other ſituations.

Though coffee, like all other vegetables, grows from the ſeed, Dr Laborie adviſes, in the forming of large plantations, to make uſe of ſaplings reared in nurſeries; and the ſituation fitteſt for a nurſery is a plain, or at leaſt a ground of gentle aſcent, where the mould is crumbly. In forming a nurſery, ſome plant the whole berry; but our author recommends the taking off the ſkin, and waſhing the ſeparated ſeeds; in which we ſuſpect that he is miſtaken, as his practice is certainly a deviation from nature. The nurſery muſt be kept very clear of weeds, and neither corn nor any thing elſe ſown in it.

The beſt ſeaſon for tranſplanting the ſaplings is during the genial rains of April and May, when great attention is required, as the treaſures of future harveſts are at ſtake. Thoſe plants are the fitteſt for being removed which, in the language of our author, are *crowned*, or have each four little boughs; and, if the ſeeds were freſh and ſown in furrows about an inch from each other, this perfection is generally attained in the courſe of a year. The ſaplings muſt not be pulled up by force, but carefully raiſed by means of a flat, ſharp, iron ſhovel, thruſt deep under their roots; and the ſooner they are planted, after being taken up, the better.

In

In planting, the firſt thing to be done is to thruſt into the ground a dibble, or ſharp pointed ſtick, round which a hole is dug from nine to twelve inches in diameter, and from fifteen to eighteen in depth. Then a quantity of the mould taken out of the hole is thrown back into it, till its depth be diminiſhed about four or ſix inches; and the plant being ſupported with the left hand, in the middle of the hole, while the end of its ſtraight root, which our author calls its pivot, touches lightly the new bed, the ſurrounding mould is with the right hand thrown in, to the height of ſix inches. This being lightly preſſed down with both hands, more earth is thrown in and preſſed in the ſame manner, care being taken not to hurt, or bend, or diſplace the ſapling, which muſt be ſet ſo deep that its two inferior branches be rather below the level of the ground. On this account three or four inches of the hole are left open, which, by the time that theſe branches riſe above its margin, are filled up by the ſurrounding earth. The buſineſs is finiſhed by ſinking the ſharp-pointed ſtick at the upper margin of the hole, where it ſerves as a ſmall fence to the infant tree. In hot ſituations plantain trees are intermingled with the coffee-trees for the purpoſe of ſhade and coolneſs. They are uſually placed in every fourth or ſixth row, as the trees are more or leſs diſtant, and the expoſure more or leſs hot.

To the buſineſs of planting very ſoon ſucceeds that of weeding; for there is hardly any plant to which weeds are ſo pernicious as the coffee-tree: they cauſe it to grow yellow, fade, wither, and periſh. Where the ground ſlopes much, eſpecially if the ſoil be ſoft and friable, the weeds muſt be taken up by the hand; for if they be rooted out by the hoe, the ſoil will be ſo looſened that the rains will ſweep it away. Some weeds, however, from the depth of their roots muſt be dug up; and when that is the caſe the earth muſt be carefully returned and preſſed down. If, in weeding, any ſaplings be found withered, others of the ſame ſize muſt be brought from the nurſery and planted in their ſtead, with what our author calls their clod, *i. e.* with the earth of the nurſery adhering to their roots. If any ſapling be found broken or twiſted, it muſt be cut cloſe by the ground in a ſloping direction, the cut ſurface facing the north, and it will ſoon put forth ſuckers, of which the beſt only need be preſerved. In plantations of eighteen or twenty months old trees are often found with yellow, withered leaves, of which the cauſe is ſometimes a premature load of fruit, which muſt therefore be inſtantly removed or the tree will periſh. If, after this, it begin not in a few days to recover, it is probably eaten at the roots by a large white worm reſembling a ſlug. In that caſe the tree muſt be removed, the worm taken out, and before another tree be planted in its ſtead, a large hole muſt be made in the ground, expoſed to the influence of the ſun at leaſt for a fortnight.

The natural height of the coffee tree is from 15 to 18 feet; and if left to itſelf it would have the form of moſt other trees, *i. e.* a naked trunk and a branchy head. This is prevented by what the planters call *ſtopping;* which is performed by cutting off the top of the tree when it has arrived at the proper height, which varies according to circumſtances. In the beſt ſoil and moſt genial expoſure, it is ſuffered to grow to the height of five feet, and in the worſt ſtopped at two; but under the ſame aſpect, and on ground of the ſame quality, all the trees ought to be ſtopped at the ſame height. This operation of ſtopping is very apt to make the trees put forth ſuperfluous branches, which renders them inacceſſible to the genial warmth of the ſun, and, of courſe, deficient in the powers of fructification. Theſe muſt be *plucked* away while yet tender; for if they be ſuffered to grow till it become neceſſary to cut them, a number of ſprouts ſucceed; whereas, when they are plucked, the wound ſoon cicatrizes, and nothing follows.

The ſaw and the knife, however, muſt ſometimes be uſed; for when trees grow old their heads are apt to ſpoil; ſuperfluous branches may have been left upon them through neglect; a bough may have been broken by accident; or branches may be ſpent by too great a load of fruit. In all theſe caſes recourſe muſt be had to pruning, which ſhould be performed immediately after crop, and in ſuch a manner as that the tree, when it puts forth its new branches, may ſtill have as much as poſſible its natural or former appearance. This will be accompliſhed by cutting the withered bough immediately above a knot, whence a good ſecondary branch is put forth, which may be eaſily trained into the proper ſhape. Our author directs the cut to be always made ſo as that the ſloping ſurface ſhall face the north; by which expoſure it will eſcape the injury which it would otherwiſe receive from the exceſſive heat of the ſun. This is a good advice; but it would ſtill be an improvement on it to treat the wound with Forſyth's or Hit's plaſter, which we have deſcribed elſewhere (See *Encycl.* Vol. XVIII. page 562). When the tree is completely pruned, the moſs and other excreſcences muſt be ſcraped from the trunk with a wooden knife, great care being taken not to injure the bark.

After pruning follows what is called *nipping*. This is nothing more than the removal of thoſe ſuperfluous ſmall twigs which are ſent forth from every cut ſurface in ſuch numbers as would ſoon exhauſt the tree; and it is called nipping, becauſe they are plucked away by the hand, and not cut by the knife. It is needleſs to add, that when the ground begins to be impoveriſhed, it muſt be enriched by proper manure. This is known to every huſbandman both in Europe and in the Weſt Indies; but it is not perhaps ſo generally known that the weedings, and chiefly the red ſkins of coffee, when gathered into pits, are, in proceſs of time, converted into a black mould, which our author ſays makes the very beſt manure.

"The fruit of the coffee, when perfectly ripe, appears like a ſmall oval cherry. Under a red and ſhining ſkin a whitiſh clammy luſcious pulp preſents itſelf, which generally incloſes two ſeeds. Theſe ſeeds have one ſide flat, the other hemiſpherical. The firſt is marked with a longitudinal fiſſure, and the flat ſides are applied to each other. When the ſeeds are opened, they are found covered with a white, ligneous, brittle membrane, denominated *parchment;* on the inſide of which is another ſilver-coloured membrane, exceedingly thin, and ſeeming to originate from the fiſſure of the ſeeds. Sometimes the cherry has but one ſeed or grain, which then is in the form of a ſmall egg. This is peculiar to old decayed trees, or to the extremities of ſome ſmall branches."

The buſineſs of preparation conſiſts in taking the ſeed from its covering, in drying, and in cleaning it ſo

Coffea. as to have every advantage at market. Our author thinks that the beſt method of preparing the coffee is to ſtrip the ſeed of its outer ſkin immediately on its being pulled, and to dry it in its parchment. The proceſs has been already deſcribed in the Encyclopædia; but we believe it to be an injudicious one. We have the authority of a very eminent botaniſt*, well acquainted with all the vegetable productions of the Weſt Indies, to ſay, that the improvement which we have there mentioned, as propoſed by Mr Miller, is greatly preferable to Dr Laborie's practice. Indeed he himſelf admits, that coffee dried in the berry is more heavy than when dried in parchment, and that it generally has a higher flavour. Nay, he ſays expreſsly, that "if a planter wants to have coffee of the firſt quality, either for himſelf or for his friends, he muſt ſet apart a number of his oldeſt trees, and not gather the fruit till it is ripened into *dryneſs*. It is in that manner, he believes, that the Arabians in Yemen make their little harveſts; and he declares, that coffee thus nouriſhed on the tree to the laſt moment, muſt have every perfection of which it is capable." His only plauſible objection is, that the trees are ſoon exhauſted when the fruit is left ſo long upon them; but doubtleſs this exhauſtion might be retarded by proper manure.

* Dr Wright.

The chemical analyſis of coffee evinces that it poſſeſſes a great portion of mildly bitter and lightly aſtringent gummous and reſinous extract; a conſiderable quantity of oil; a fixed ſalt; and a volatile ſalt.—Theſe are its medicinal conſtituent principles. The intention of torrefaction is not only to make it deliver thoſe principles, and make them ſoluble in water, but to give it a property it does not poſſeſs in the natural ſtate of the berry. By the action of fire, its leguminous taſte and the aqueous part of its mucilage are deſtroyed; its ſaline properties are created and diſengaged, and its oil is rendered empyreumatic.—From thence ariſes the pungent ſmell, and exhilarating flavour, not found in its natural ſtate.

The roaſting of the berry to a proper degree requires great nicety: Du Four juſtly remarks, that the virtue and agreeableneſs of the drink depend on it, and that both are often injured in the ordinary method. Bernier ſays, when he was at Cairo, where it is ſo much uſed, he was aſſured by the beſt judges, that there were only two people in that great city, in the public way, who underſtood the preparing it in perfection. If it be under-done, its virtues will not be imparted, and in uſe it will load and oppreſs the ſtomach:—If it be overdone, it will yield a flat, burnt, and bitter taſte, its virtues will be deſtroyed, and in uſe it will heat the body, and act as an aſtringent.

Fourteen pounds weight of raw coffee is generally reduced, at the public roaſting houſes in London, to eleven pounds by the roaſting; for which the dealer pays ſeven pence half-penny, at the rate of five ſhillings for every hundred weight. In Paris, the ſame quantity is reduced to ten pounds and an half. But the roaſting ought to be regulated by the age and quality of the coffee, and by nicer rules than the appearance of the fumes, and ſuch as are uſually practiſed: therefore the reduction muſt conſequently vary, and no exact ſtandard can be aſcertained. Beſides, by mixing different ſorts of coffee together, that require different degrees of heat and roaſting, coffee has ſeldom all the advantages it is capable of receiving to make it delicate, grateful, and pleaſant. This indeed can be effected no way ſo well as by people who have it roaſted in their own houſes, to their own taſte, and freſh as they want it for uſe. The cloſer it is confined at the time of roaſting, and till uſed, the better will its volatile pungency, flavour, and virtues, be preſerved.

The mode of preparing this beverage for common uſe differs in different countries, principally as to the additions made to it.—But though that is generally underſtood, and that taſte, conſtitution, the quality of the coffee, and the quantity intended to be drunk, muſt be conſulted, in regard to the proportion of coffee to the water in making it—yet there is one material point, the importance of which is not well underſtood, and which admits of no deviation.

The preſervation of the virtues of coffee, particularly when it is of a fine quality, and exempt from rankneſs, as has been ſaid, depends on carefully confining it after it has been roaſted; and not powdering it until the time of uſing it, that the volatile and æthereal principles, generated by the fire, may not eſcape. But all this will ſignify nothing, and the beſt materials will be uſeleſs, unleſs the following important admonition is ſtrictly attended to; which is, that after the liquor is made,—it ſhould be bright and clear, and entirely exempt from the leaſt cloudineſs or foul appearance, from a ſuſpenſion of any of the particles of the ſubſtance of the coffee.

There is ſcarcely any vegetable infuſion or decoction whoſe effects differ from its groſs origin more than that of which we are ſpeaking. Coffee taken in ſubſtance cauſes oppreſſion at the ſtomach, heat, nauſea, and indigeſtion: conſequently a continued uſe of a preparation of it, in which any quantity of its ſubſtance is contained, beſides being diſguſting to the palate, muſt tend to produce the ſame indiſpoſitions. The reſiduum of the roaſted berry, after its virtues are extracted from it, is little more than an earthy calx, and muſt therefore be injurious.

The want of attention to this circumſtance has been the cauſe of many of the complaints againſt coffee, and of the averſion which ſome people have to it; and it is from this conſideration that coffee ſhould not be prepared with milk inſtead of water, nor ſhould the milk be added to it on the fire, as is ſometimes the caſe, for economical dietetic purpoſes, where only a ſmall quantity of coffee is uſed, as the tenacity of the milk impedes the precipitation of the grounds, which is neceſſary for the purity of the liquor, and therefore neither the milk not the ſugar ſhould be added until after it is made with water in the uſual way, and the clarification of it is completed (A).—The milk ſhould be hot when

(A) It is not to coffee alone that this reflection is confined; every article we uſe as a diluter demands the ſame attention. Malt liquors, particularly ſmall beer, which in this reſpect is much neglected, ought always to be carefully fined. The fæculent matter entangled by the mucilage of the malt is hurtful to digeſtion, and detrimental to health.

when added to the liquor of the coffee, which ſhould alſo be hot, or both ſhould be heated together, in this mode of uſing coffee as an article of ſuſtenance.

If a knowledge of the principles of coffee, founded on examination and various experiments, added to obſervations made on the extenſive and indiſcriminate uſe of it, cannot authoriſe us to attribute to it any particular quality unfriendly to the human frame;—if the unerring teſt of experience has confirmed its utility, in many countries, not excluſively productive of thoſe inconveniences, habits, and diſeaſes, for which its peculiar properties ſeem moſt applicable—let thoſe properties be duly conſidered; and let us reflect on the ſtate of our atmoſphere, the food and modes of life of the inhabitants,—and the chronical infirmities which derive their origin from theſe ſources, and it will be evident what ſalutary effects might be expected from the general dietetic uſe of coffee in Great Britain.

COFFER DAMS, or *Batardeaux*, in bridge-building, are incloſures formed for laying the foundation of piers, and for other works in water, to exclude the ſurrounding water, and ſo prevent it from interrupting the workmen.

COHANZY, or *Cæſaria*, a ſmall river, which riſes in Salem co. New-Jerſey, and running through Cumberland co. empties into Delaware river oppoſite the upper end of Bombay Hook. It is about 30 miles in length, and is navigable for veſſels of 100 tons to Bridgetown, 20 miles from its mouth.—*Morſe.*

COHASSET, a townſhip in Norfolk co Maſſachuſetts, which was incorporated in 1770, and contains 817 inhabitants. It has a congregational church, and 126 houſes, ſcattered on different farms. Cohaſſet rocks, which have been ſo fatal to many veſſels, lie off this town, about a league from the ſhore. It lies 25 miles S. E. of Boſton; but in a ſtraight line not above half the diſtance.—*ib.*

COHGNAWAGA, a pariſh in the townſhip of Johnſtown, Montgomery co. New York, on the W. ſide of Mohawk river, 26 miles W. of Schenectady. This place which had been ſettled nearly 80 years, and which was the ſeat of Sir William Johnſon, was moſtly deſtroyed by the Britiſh and Indians, under the command of Sir William, in the year 1780. In this action, Johnſon evinced a want of feeling which would have diſgraced a ſavage. The people deſtroyed in this expedition, were his old neighbours, with whom he had formerly lived in the habits of friendſhip. His eſtate was among them, and the inhabitants had always conſidered him as their friend and neighbour. Theſe unfortunate people, after ſeeing their houſes and property conſumed to aſhes, were hurried, ſuch as could walk, into cruel captivity; thoſe who could not walk, fell victims to the tomahawk and ſcalping knife.—*ib.*

COHOEZ, or the *Falls* in Mohawk river between 2 and 3 miles from its mouth, and 10 miles northward of Albany, are a very great natural curioſity. The river above the falls, is about 300 yards wide, and approaches them from the N. W. in a rapid current, between high banks on each ſide, and pours the whole body of its water over a perpendicular rock of about 40 (ſome ſay more) feet in height, which extends quite acroſs the river, like a mill dam. The banks of the river, immediately below the falls, are about 100 feet high. A bridge 1100 feet long, and 24 feet wide, reſting on 13 piers, was erected, at the expenſe of 12,000 dollars, in 1794, a mile below the falls, from which a ſpectator may have a grand view of them: but they appear moſt romantically from Lanſinburg hill, 5 miles E. of them.—*ib.*

COHONGORONTO, is the name of Potowmac river before it breaks through the Blue Ridge, in N. lat. 39. 45. Its whole length to the Blue Ridge, may be about 160 miles; from thence it aſſumes the name of *Potowmack.*—*ib.*

COHUIXCAS, a country in New-Spain, in which there is a conſiderable mountain of loadſtone, between Tcoiltylan and Chilapan.—*ib.*

COKESBURY COLLEGE, in the town of Abington, in Harford co. Maryland, is an inſtitution which bids fair to promote the improvement of ſcience, and the cultivation of virtue. It was founded by the Methodiſts, in 1785, and has its name in honor of Thomas Coke, and Francis Aſbury, the American biſhops of the Methodiſt Epiſcopal church. The edifice is of brick, handſomely built, on a healthy ſpot, enjoying a fine air, and a very extenſive proſpect. The college was erected, and is wholly ſupported by ſubſcription and voluntary donations. The ſtudents, who are to conſiſt of the ſons of travelling preachers, annual ſubſcribers, members of the ſociety, and orphans, are inſtructed in Engliſh, Latin, Greek, logic, rhetoric, hiſtory, geography, natural philoſophy, and aſtronomy; and when the finances of the college will admit, they are to be taught the Hebrew, French and German languages. The rules for the private conduct of the ſtudents extend to their amuſements; and all tend to promote regularity, encourage induſtry, and to nip the buds of idleneſs and vice. Their recreations without doors are, walking, gardening, riding, and bathing; within doors they have tools and accommodations for the carpenter's, joiner's, cabinet maker's, or turner's buſineſs. Theſe they are taught to conſider as pleaſing and healthful recreations, both for the body and mind.—*ib.*

COLAN, a ſmall Indian town, ſituated near the South Sea, 2 or 3 leagues to the northward of Payta, inhabited by fiſhermen. Here they make large rafts of logs, which will carry 60 or 70 tons of goods; with theſe they make long voyages, even to Panama, 5 or 600 leagues diſtant. They have a maſt with a ſail faſtened to it. They always go before the wind, being unable to ply againſt it; and therefore only fit for theſe ſeas, where the wind is always in a manner the ſame, not varying above a point or two all the way from Lima, till they come into the bay of Panama; and there they muſt ſometimes wait for a change. Their cargo is uſually wine, oil, ſugar, Quito cloth, ſoap, and dreſſed goat ſkins. The float is uſually navigated by 3 or 4 men, who ſell their float where they diſpoſe of their cargo; and return as paſſengers to the port they came from. The Indians go out at night by the help of the land-wind, with fiſhing floats, more manageable than the others, though theſe have maſts and ſails too, and return again in the day-time with the ſea wind.—*ib.*

COLCHESTER, the chief town in Eſſex, is deſcribed in the Encyclopædia; but the deſcription is in many reſpects erroneous. The following account of

Colchester. || Colebrook.

it was sent to us by an obliging correspondent, who is desirous that the place of his nativity may be accurately described in this Supplement.

Colchester is pleasantly situated upon an eminence, gradually rising on the south side of the river Colne. It is the ancient *Colonia Camulodunum*, from which word Colonia, both the town and the river Colne, received their names. The Saxons called it *Colneceaster*. That it flourished under the Romans, several buildings full of their bricks, and innumerable quantities of coin dug up in and about it, fully evince. In the year 1763, a curious tessellated or mosaic pavement was found in the garden of the late Mr Barnard, surgeon in the High Street, now the property of Mr John Wallis, about three feet under the surface of the earth. The emperor Constantine the Great was born here, his mother Helen being daughter of Cool, governor or king of this district under the Romans. She is said to have found out the cross of Christ at Jerusalem; and on that account the arms of this town are a cross regulee between three ducal coronets, two in chief and one in base, the coronet in base passing through the cross.

The walls wherewith the town was encompassed are still tolerably entire on the south, east, and west sides, but much decayed on the north side: they are generally about nine feet thick. By a statute of King Henry VIII. this town was made the see of a suffragan bishop.

This town is the most noted in England for making of baize; it is also of special note for candying the eringo roots, and for oysters.

In the conclusion of the civil war 1648, this town suffered a severe siege of ten weeks; and the besieged making a very resolute defence, the siege was turned into a blockade, wherein the garrison and inhabitants suffered the utmost extremity of hunger, being reduced to eat horse-flesh, dogs, and cats, and were at last obliged to surrender at discretion, when their two valiant chief officers, Sir Charles Lucas and Sir George Lisle, were shot under the castle walls in cold blood. Colchester is a borough by prescription, and under that right sends two members to parliament, all their charters being silent upon that head. The Charter was renewed in 1763. The town is now governed by a mayor, recorder, 12 aldermen, 18 assistants, and 18 common council men. Quarter sessions are held here four times in the year.

The famous abbey gate of St John is still standing, and allowed to be a surprising, curious, and beautiful piece of Gothic architecture, great numbers of persons coming from remote parts to see it. It was built, together with the abbey, in 1097, and Gudo, steward to King William Rufus, laid the first stone.

St Ann's chapel, standing at the east end of the town, is valuable in the esteem of antiquarians as a building of great note in the early days of Christianity, and made no small figure in history many centuries past. It is now pretty entire.

St Botoph's priory was founded by Ernulphus in the reign of Henry I. in the year 1110. It was demolished in the wars of Charles I. by the parliament army under Sir Thomas Fairfax. The ruins still exhibit a beautiful sketch of ancient masonry, much admired by the lovers of antiquities. The castle is still pretty entire, and is a magnificent structure, in which great improvements have of late been made. Here is an excellent and valuable library.

The markets, which are on Wednesday and Saturday, are very well supplied with all kinds of provisions. There are no less than six dissenting meeting houses in this town. Colchester is 51 miles from London. It had 16 parish churches, in and out of the walls, but now only 12 are used, the rest being damaged at the siege in 1648.

Colchester, a township in Ulster co. N. York, on the Popachton branch of Delaware river, S. W. of Middletown; and about 50 miles S. W. by S. of Cooperstown. By the state census of 1796, 193 of its inhabitants are electors.—*Morse*.

Colchester, a large township in New-London co. Connecticut, settled in 1701; about 15 miles westward of Norwich, 25 S. E. of Hartford, and 20 N. W. of New-London city. It is in contemplation to have a post office established in this town.—*ib.*

Colchester, the chief town in Chittenden co. Vermont, is on the E. bank of lake Champlain, at the mouth of Onion river, and N. of Burlington, on Colchester bay, which spreads N. of the town.—*ib.*

Colchester, a post town in Fairfax co. Virginia, situated on the N. E. bank of Ocquoquam creek, 3 or 4 miles from its confluence with the Potowmack; and is here about 100 yards wide, and navigable for boats. It contains about 40 houses, and lies 16 miles S. W. of Alexandria, 106 N. by E. of Richmond, and 172 from Philadelphia.—*ib.*

Cold *Spring*, in the island of Jamaica, is a villa, 6 miles from the highlands of Liguania. The grounds are in a high state of improvement. Cold spring is 4200 feet above the level of the sea; and few or none of the tropical fruits will flourish in so cold a climate. The general state of the thermometer is from 55. to 65.; and even sometimes so low as 44.: so that a fire there, even at noon-day, is not only comfortable, but necessary a great part of the year. Many of the English fruits, as the apple, the peach, and the strawberry, flourish there in great perfection, with several other valuable exotics, as the tea-tree and other oriental productions.—*ib.*

Cold *Spring Cove*, near Burlington, New-Jersey, is remarkable for its sand and clay, used in the manufacture of glass; from whence the glass works at Hamilton, 10 miles W. of Albany, are supplied with these articles.—*ib.*

Colebrook, in the northern part of New-Hampshire, in Grafton co. lies on the E. bank of Connecticut river, opposite the Great Monadnock, in Canaan, state of Vermont; joining Cockburne on the southward and Stuartstown on the northward; 126 miles N. W. by N. from Portsmouth.—*ib.*

Colebrook, a rough, hilly township on the N. line of Connecticut, in Litchfield co.; 30 miles N. W. of Hartford city. It was settled in 1756. Here are 2 iron works, and several mills, on Still river, a N. W. water of Farmington river. In digging a cellar in this town, at the close of the year 1796, belonging to Mr John Hulburt, the workmen, at the depth of about 9 or 10 feet, found three large tusks and two thigh bones of an animal, the latter of which measured each about 4 feet, 4 inches in length, and 12¼ inches in circumference. When first discovered they were entire, but

 as

as ſoon as they were expoſed to the air they mouldered to duſt. This adds another to the many facts, which prove that a race of enormous animals, now extinct, once inhabited the United States.—*ib.*

COLERAIN, a townſhip in Lancaſter co. Pennſyl. vania.—*ib.*

Colerain, a town on the N. bank of St Mary's river, Camden co. Georgia, 40 or 50 miles from its mouth. On the 29th of June, 1796, a treaty of peace and friendſhip was made and concluded at this place, between the Preſident of the United States, on the one part, in behalf of the United States, and the kings chiefs and warriors of the Creek nation of Indians, on the other. By this treaty, the line between the white people and the Indians, was eſtabliſhed to run "from the Currahee mountain to the head or ſource of the main ſouth branch of the Oconee river, called, by the white people, Appalatohee, and by the Indians, Tulapoeka, and down the middle of the ſame." Liberty was alſo given by the Indians to the Preſident of the United States, to "eſtabliſh a trading or military poſt on the S. ſide of Alatamaha, about 1 mile above Beard's bluff, or any where from thence down the river, on the lands of the Indians;" and the Indians agreed to "annex to ſaid poſt a tract of land of five miles ſquare; and in return for this, and other tokens of friendſhip on the part of the Indians, the United States ſtipulated to give them goods to the value of 6000 dollars, and to furniſh them with two blackſmiths with tools.—*ib.*

COLRAINE, a townſhip in Hampſhire co. Maſſachuſetts, which contains 229 houſes, and 1417 inhabitants.—*ib.*

COLIMA, a large and rich town of Mechoacan and New-Spain, on the S. Sea, near the borders of Xaliſca, and in the moſt pleaſant and fruitful valley in all Mexico, producing cocoa, caſſia, and other things of value, beſides ſome gold. Dampier takes notice of a volcano near it, with two ſharp peaks, from which ſmoke and flame iſſue continually. The famous plant oleacazan grows in the neighbourhood, which is reckoned a catholicon for reſtoring decayed ſtrength, and a ſpecific againſt all ſorts of poiſon. The natives apply the leaves to the parts affected, and judge of the ſucceſs of the operation by their ſticking or falling off.—*ib.*

COLOURS. See Pigments in this Supplement.

Accidental Colours, a name given to a very curious optical phenomenon, which was firſt, we believe, attended to by Buffon. That philoſopher wrote a ſhort paper on it, which was publiſhed in the Memoirs of the Academy of Sciences for the year 1743.

If a perſon look ſtedfaſtly and for a conſiderable time at a ſmall *red* ſquare painted upon *white* paper, he will at laſt obſerve a kind of green-coloured border ſurround the red ſquare. If he now turn his eyes to ſome other part of the paper, he will ſee an imaginary ſquare of a delicate green bordering on blue, and correſponding exactly in point of ſize with the red ſquare. This imaginary ſquare continues viſible for ſome time, and indeed does not diſappear till the eye has viewed ſucceſſively a number of new objects. It is to this imaginary ſquare that the improper name of *accidental colour* has been given. If the ſmall ſquare be *yellow*, the imaginary ſquare or accidental colour is blue: the accidental colour of green is red; of blue, yellow; of white, black; and on the contrary, that of black is white.

The firſt perſon, as far as we know, who gave a ſatisfactory explanation of theſe phenomena was Profeſſor Scherffer of Vienna, whoſe diſſertation, tranſlated by Mr Bernouilli, has been pubiſhed in the 26th volume of the Journal de Phyſique.

In order to underſtand theſe phenomena, let us recollect, in the firſt place, that light conſiſts of ſeven rays, namely, red, orange, yellow, green, blue, indigo, violet; that whiteneſs conſiſts in a mixture of all theſe rays; and that thoſe bodies which reflect but very little light are black. Thoſe bodies that are of any particular colour, reflect a much greater quantity of the rays which conſtitute that particular colour than of any other rays. Thus red bodies reflect moſt red rays; green bodies, moſt green rays, and ſo on.

Let us recollect, in the ſecond place, that when two impreſſions are made at the ſame time upon any of our organs of ſenſation, one of which is ſtrong and the other weak, we only perceive the former. Thus if we examine by the priſm the rays reflected by a red roſe, we ſhall find that they are of four kinds, namely, red, yellow, green, and blue. In this caſe, the impreſſion made by the red rays makes that made by the others quite inſenſible. For the ſame reaſon, when a perſon goes from broad day light into an ill-lighted room, it appears to him at firſt perfectly dark, the preceding ſtrong impreſſion rendering him for ſome time incapable of feeling the weaker impreſſion.

With the aſſiſtance of theſe two remarks, it will not be difficult to explain the phenomena of accidental colours. When a perſon conſiders attentively for ſome time a white ſquare lying on any black ſubſtance (paper for inſtance), it is evident that the part of the retina on which the white ſquare is painted, receives a ſtronger impreſſion than any other part; at leaſt the greateſt number of rays ſtrike upon it. A weaker impreſſion, therefore, will act on it with much leſs force than upon the reſt of the retina. Conſequently, when the eye is turned from the white ſquare to ſome other part of the black paper, a ſquare is perceived of the ſame ſize with the white ſquare, and much blacker than any other part of the paper; this is evidently in conſequence of the weaker impreſſion made by the rays reflected by the black paper upon that part of the eye previouſly fatigued by the copious reflection from the white ſquare. For the very ſame reaſon, if, after looking for a ſufficient time at a white ſquare lying on a black ground, we turn our eyes upon a ſheet of white paper, we perceive a very well defined black ſquare. In this caſe, the part of the retina already fatigued is not ſo ſenſible to the rays reflected by the white paper as the other parts of it which have not been fatigued. The reaſon then that *black* is the accidental colour of white is ſufficiently evident.

On the contrary, when we look a ſufficient time at a black ſquare lying upon a white ground, if we turn our eyes to any other part of the white paper, or even upon black paper, we ſhall perceive a ſmall ſquare anſwering to the black ſquare, and much brighter than any other part of the paper: evidently becauſe that part of the retina on which the black ſquare was painted being leſs fatigued, is more ſuſceptible of impreſſions than any other part of the eye. Thus we ſee why the accidental colour of black is white, and why that of white on the contrary is black. Theſe facts, indeed, have been long known, Colours. known, and they have been generally explained in this manner.

When a person has looked for a sufficient time at a red square placed on a sheet of white paper, and then turns his eyes to another part of the paper, that part of the retina on which the red was painted being fatigued, the red rays reflected from the white paper cease to make any sensible impression on it, and consequently there will be seen upon the white paper a square similar to the red square, and the colour of which is that which would result from the mixture of all the rays of light except the red. In general, therefore, the *accidental colour* is the colour which results from the mixture of all the rays of light, those rays excepted which are the same with the primitive colour.

Now in order to discover these accidental colours, let us recollect the manner which Newton employed to determine the colour which results from the mixture of several others, the species and quantity of which are known. He did it by dividing the circumference of a circle, so that the arches are to one another in the proportion of a string shortened by degrees, in order to sound, one after another, the notes of an octave; which is nearly the proportion that the different rays occupy when light is decomposed by means of the prism. Or suppose the circumference of the circle, as usual, divided into 360 degrees, the different rays, according to Benvenut, should occupy the following arches:

Red, - - - -	45°.
Orange, - - -	27.
Yellow, - - -	48.
Green, - - -	60.
Blue, - - -	60.
Indigo, - - -	40.
Violet, - - -	80.

Let us now compare the action of colours on one another with that of different weights; and for that purpose let us suppose each colour concentrated in the centre of gravity of its arch. In order to find the colour resulting from any mixture, we have only to find the common centre of gravity of the arches which represent the different colours: The colour resulting from the mixture will be that of the arch to which the common centre of gravity approaches nearest. And if that common centre of gravity is not in the straight line which joins the centre of the circle, and the centre of gravity of the arch to which it is most contiguous, the resulting colour will approach more or less to the colour of the contiguous arch, towards which the line, passing through the centre of the circle, and the common centre of gravity of the arches, falls. And farther, the resulting colour will be more or less deep according to the distance of the common centre of gravity from the centre of the circle.

In the case under consideration at present, namely, to determine the different accidental colours, the application of this method is remarkably easy; because only one of the seven primitive colours is excluded, and consequently the six colours from the mixture of which we wish to know the resulting colour are all contiguous. For it is evident, that the sum of the six arches, representing these six colours, will be divided into two equal parts by the line which passes through the centre of the circle and their common centre of gravity; and that if the same line be produced till it reaches the circumference of the circle on the other side, it will also divide the arch representing the seventh or omitted colour into two equal parts. Let us suppose, for instance, that the violet is omitted, and that we wanted to know the colour resulting from the mixture of the other six colours, we have only to bisect the arch representing the violet, and from the point of section to draw a diameter to the circle, the arch of the circle opposite to the violet through which the diameter passes will indicate the colour of the mixture. The arch representing the violet being 80°, let us take the half of it which is 40°, and let us add to it 45° for the red, 27° for the orange, and 48° for the yellow, we shall have 160°, which wants 20° of half the circumference of the circle. If now we add the 60° for the green, the sum total will be 220°, considerably more than half the circumference. Consequently the common centre of gravity is nearest the green arch; but it falls 10° nearer the yellow than the straight line which joins the centre of the circle and the centre of gravity of the green arch. Hence we see that the resulting colour will be green, but that it will have a shade of yellow.

It is evident, then, that the accidental colour of violet must be green with a shade of yellow; and this is actually the case, as any one may convince himself by making the experiment.

Suppose, now, we wanted to know the accidental colour of *green*, or which is the same thing, the colour resulting from the mixture of all the primitive rays except the green. The green arch is 60°, the half of which is 30°; if to this we add 60° for the blue arch, and 40° for the indigo arch, we shall have 130°, or 50° degrees less than a semicircle. If to this we add the violet arch, which is 80°, we shall have 30° more than the semicircle; consequently the common centre of gravity falls nearest the violet, and it is 10° nearer the red arch than is the centre of gravity of the violet arch. Hence we know that the accidental colour of green will be violet or purple, with a shade of red: And experiment confirms this.

Buffon observed, that the accidental colour of blue was reddish and pale. Let us see whether we shall obtain the same result from our method. Let us suppose that Buffon employed a light blue. In that case, if to 30, the half of the blue arch, we add 60 for the green, 48 for the yellow, and 27 for the orange, we shall have 165°, or 15° less than half the circumference of the circle: Consequently the common centre will fall nearest the red arch, but within 15° of the orange. The accidental colour must therefore be red, with a shade of orange; or, which is the same thing, it must be a pale red.

In the same manner we may discover, that the accidental colour of indigo is yellow, inclining a good deal to orange, and that the accidental colour of indigo and blue together is orange, with a strong shade of red. Both of which correspond accurately with experiment.

It would be easy to indicate in the same manner, the accidental colour of any primitive colour, if what has been said were not sufficient to explain the cause of accidental colours, and to show that their phenomena correspond exactly, both with the Newtonian theory of optics, and with what we know to be laws of our sensations in other particulars.

From the theory above given, which is that of Professor Scherffer, the following consequences may be deduced;

1. The

1. The accidental colour of a red ſquare lying upon a white or black ground, ought to be blackiſh, if we caſt our eyes upon a red coloured ſurface. 2. If the ſurface upon which we look at a red ſquare be itſelf coloured, if it be yellow, for inſtance, the white paper upon which we afterwards caſt our eyes, will appear blue, with a green ſquare in it correſponding to the original red ſquare. And, in general, we ought to perceive the accidental colour of the ground on which the ſquare is placed as well as the ſquare itſelf. 3. If while we are looking at the little ſquare we change the ſituation of the eye, ſo that its image ſhall occupy a different place on the retina, when we turn our eyes to the white paper, we ſhall ſee two ſquares, or at leaſt one unlike the figure of the original one. 4. If the white paper on which we look be farther diſtant than the little ſquare was, the imaginary ſquare will appear conſiderably larger than the true one. 5. If while we are looking at the little ſquare we gradually make the eye approach to it without altering its ſituation, the imaginary ſquare will appear with a pale border. Theſe and many other conſequences that might eaſily be deduced, will be found to take place conſtantly and accurately, if any one chooſes to put them to the teſt of experiment; and therefore may be conſidered as a complete confirmation of the theory given above of the cauſe of accidental colours.

There is another circumſtance reſpecting accidental colours which deſerves attention. If we continue looking ſtedfaſtly at the little ſquare longer than is neceſſary, in order to perceive its accidental colour, we ſhall at laſt ſee its border tinged with the accidental colour of the ground on which the ſquare is lying. For inſtance, if a white ſquare be placed upon blue paper, its border becomes yellow; if upon red paper it becomes green; and it becomes reddiſh upon green. In like manner the border of a yellow ſquare becomes greeniſh upon a red ground, and that of a red ſquare on a green ground becomes purple.

The cauſe of this phenomenon ſeems to depend upon the contraction and extenſion of the image of the ſquare painted on the retina. We know for certain, that the diameter of the pupil changes during our inſpecting the ſquare; at firſt it becomes leſs, and afterwards increaſes. And though we cannot ſee what paſſes in the bottom of the eye, we can ſcarcely doubt that ſimilar movements are going on there, if we attend to the changes they are continually taking place in the border of our little ſquare; ſometimes it is large, ſometimes ſmall; at one time it diſappears altogether, and the next moment makes its appearance again.

There is another phenomenon connected with accidental colours, which is not ſo eaſy to explain, namely, that if we look at theſe little ſquares for a very long time, till the eye is very much fatigued, their accidental colours will appear even after we ſhut our eyes. The very ſame thing takes place if we attempt to look at a very luminous object, as the ſun, for inſtance. Profeſſor Scherffer thinks that this may be partly owing to the light which ſtill paſſes through the eye-lids. That ſome light paſſes through the eye-lids, is evident, becauſe when we look towards a ſtrong light with our eye-lids ſhut, we ſee diſtinctly their colour, derived from the blood-veſſels with which they are filled; and if we paſs our finger before our eyes, we ſee the ſhadow of the finger though our eye-lids be ſhut, provided our eyes be turned towards the window. But that this light is not ſufficient to explain the phenomenon in queſtion is evident from this circumſtance, that the ſame accidental colours make their appearance, though we go immediately into the darkeſt place. Perhaps we have accounted for the phenomenon elſewhere (See METAPHYSICS, *Encycl.* n° 54.). We paſs over the other conjectures of Profeſſor Scherffer, which are exceedingly ingenious, but not ſufficiently ſupported by facts to be admitted.

COLUMBA NOACHI, *Noah's dove*, a ſmall conſtellation in the ſouthern hemiſphere, conſiſting of 10 ſtars.

COLUMBIA, a townſhip in Waſhington co. diſtrict of Maine, on Pleaſant river, adjoining Machias on the N. E. and was formerly called Plantations No. 12 and 13. It was incorporated in 1796. The town of Machias lies 15 miles to the eaſtward. It is 9 miles from Steuben.—*Morse.*

COLUMBIA *County*, in New-York, is bounded N. by Renſſelaer, S. by Ducheſs, E. by the ſtate of Maſſachuſetts, and W. by Hudſon river, which divides it from Albany co. It is 32 miles in length and 21 in breadth, and is divided into eight towns; of which Hudſon, Claverack, and Kinderhook are the chief. It contained, in 1790, 27,732 inhabitants, and in 1796, 3560 electors.—*ib.*

COLUMBIA, a poſt town, the capital of Kerſhaw co. and the ſeat of government of South-Carolina. It is ſituated in Camden diſtrict, on the E. ſide of the Congaree, juſt below the confluence of Saluda and Broad rivers. The ſtreets are regular, and the town contains upwards of 70 houſes. The public offices have, in ſome meaſure, been divided, for the accommodation of the inhabitants of the lower counties, and a branch of each retained in Charleſton. It lies 115 miles N. N. W. of Charleſton, 35 S. W. of Camden, 85 from Auguſta, in Georgia, and 678 S. W. of Philadelphia. N. lat. 34. 1. W. long. 80. 57.—*ib.*

COLUMBIA, a flouriſhing poſt town in Goochland co. Virginia, on the N. ſide of James river, at the mouth of the Rivanna. It contains about 40 houſes, and a warehouſe for the inſpection of tobacco. It lies 45 miles above Richmond, 35 from Charlotteſville, and 328 S. W. of Philadelphia.—*ib.*

COLUMBIA, a town newly laid out, in Lancaſter co. Pennſylvania, on the N. E. bank of Suſquehanna river, at Wright's ferry; 10 miles W. of Lancaſter, and 76 W. by N. of Philadelphia.—*ib.*

COLUMBIA *Co.* in the Upper diſtrict of Georgia, is bounded by Savannah river on the N. E. and E. which ſeparates it from the ſtate of S. Carolina, N. W. of Richmond co. Its ſhape is very irregular.—*ib.*

COLUMBIA, a town in the N. W. territory, on the N. bank of Ohio river, and on the W. ſide of the mouth of Little Miami river; about 6 miles S. E. by E. of Fort Waſhington, 8 E. by S. of Cincinnati, and 87 N. by W. of Lexington, in Kentucky. N. lat. 39. 20. —*ib.*

COMANA, a town and province in the northern diviſion of Terra Firma, S. America. It lies on the N. eaſternmoſt part of the ſea coaſt.—*ib.*

COMAR, or KHOMAR, a Zemindar's demeſne of land.

COMARGO, a town of New-Leon, in N. America, ca, fituated on the S. fide of Rio Bravo, which empties into the gulf of Mexico on the W. fide.—*Morse*.

COMBAHEE, a confiderable river of South-Carolina, which enters St Helena found between Coofa and Afhepoo rivers.—*ib.*

Combahee *Ferry*, on the above river, is 17 miles from Jackfonfborough, 15 from Pocotaligo and 52 from Charlefton.—*ib.*

COMBUSTION. See Chemistry in this Supplement, n° 293.

COMFORT, POINT, is the S. eafternmoft part of Elizabeth city co. in Virginia, formed by James river at its mouth in Chefapeak bay. Point Comfort lies 19 miles W. by N. of Cape Henry.—*Morse*.

COMMANOES, one of the fmall Virgin ifles, in the Weft-Indies, fituated to the N. N. E. of Tortula. N. lat. 18. 25. W. long. 63.—*ib.*

COMPASS, or Mariner's Steering Compass, is an inftrument of fo great value, that every improvement of it, propofed by men of fcience or of experience, is intitled to notice. We fhall therefore lay before our readers fome obfervations on the defects of the compafs in common ufe which have fallen into our hands fince the article in the Encyclopædia was publifhed. The firft is by Captain O'Brien Drury of the royal Navy, and relates entirely to the needle.

" Experience (fays this officer) fhews us, that the needle of a compafs, as well as all other magnets, whether artificial or real, perpetually lofes fomething of its magnetic powers, which often produces a difference exceeding a point; and I am well convinced that the great errors in fhip-reckonings proceed more frequently from the incorrectnefs of the compafs than from any other caufe.

" Steele cannot be too highly tempered for the needle of a fea compafs, as the more it is hardened the more permanent is the magnetifm it receives; but to preferve the magnetifm, and confequently the polarity of the needle, I recommend to have the needle cafed with thin, well-polifhed, foft iron; or elfe to have it armed at the poles with a bit of foft iron. I have found, from many experiments, that the cafed needle preferved its magnetifm in a much more perfect degree than the needle not cafed; and I have fometimes thought that the magnetic power of the cafed needle had increafed, while the magnetic power of the uncafed and unarmed needle always lofes of its polarity."

This is not an opinion taken up at random, but is the refult of what appears to have been a fair and judicious experiment; for our author placed a cafed needle, an armed needle, and one without either cafe or armour, in a room for three months; each having at that time precifely the fame direction, and nearly the fame degree of force. At the expiration of the three months, he found that the cafed needle and the armed needle had not in the leaft changed their direction; but the other had changed two degrees, and had loft very confiderable of its magnetic power. If there was any change in either of the other needles, it was too inconfiderable to be perceived.

Thefe obfervations feem to be new, and may tend to the improvement of the compafs. But it is not with refpect to the needle only that this inftrument is defective. Mr Bernard Romans of Penfacola well obferves, that, on another account, the heavieft brafs compaffes now in ufe are by no means to be relied on in a hollow or high fea. This is owing to the box hanging in two brafs rings, confining it to only two motions, both vertical and at right angles with each other; by which confinement of the box, upon any fucceffion, more efpecially fudden ones, the card is always put into too much agitation, and before it can well recover itfelf, another jerk prevents its pointing to the pole; nor is it an extraordinary thing to fee the card unfhipped by the violence of the fhip's pitching.

All thefe inconveniences are remedied to the full by giving the box a vertical motion at every degree and minute of the circle, and compounding thefe motions with a horizontal one of the box as well as of the card. By this unconfined difpofition of the box, the effects of the jerks on the card are avoided, and it will always very fteadily point to the pole. " Experience (fays our author) has taught me, that the card not only is not in the fmalleft degree affected by the hollow fea, but that, in all the violent fhocks and whirlings the box can receive, the card lies as ftill as if in a room unaffected by the leaft motion.

" Lately a compafs was invented and made in Holland, which has all thefe motions. It is of the fize of the common brafs compaffes; the bottom of the brafs box, inftead of being like a bowl, muft be raifed into a hollow cone like the bottom of a common glafs bottle; the vertex of the cone muft be raifed fo high as to leave but one inch between the card and the glafs; the box muft be of the ordinary depth, and a quantity of lead muft be poured in the bottom of the box, round the bafe of the cone; this fecures it on the ftile whereon it traverfes.

" This ftile is firmly fixed in the centre of a fquare wooden box, like the common compafs, except that it requires a thicker bottom. The ftile muft be of brafs, about fix inches long, round, and of the thicknefs of one-third of an inch; its head blunt, like the head of a fewing-thimble, but of a good polifh: the ftile muft ftand perpendicular. The inner vertex of the cone muft alfo be well polifhed; the vertical part of the cone ought to be thick enough to allow of a well-polifhed cavity, fufficient to admit a fhort ftile, proceeding from the centre of the card whereon it traverfes. The compafs I faw was fo conftructed; but I fee no reafon why the ftile might not proceed from the centre of the vertex of the cone, and fo be received by the card the common way. The needle muft be a magnetic bar, blunt at each end; the glafs and cover are put on in the common way."

A compafs of this kind was fubmitted to our author's examination by the captain of a floop of war, who affured him, that in a hard gale, which lafted fome days, there was no other compafs of the fmalleft fervice. Mr Romans was fatisfied that the officer did not praife the apparatus more than it deferved: and we feel ourfelves ftrongly inclined to be of the fame opinion.

It muft not be concealed, however, that the ingenious Mr Nicholfon feems to think very differently of all fuch contrivances. In a paper publifhed in the ninth number of his valuable Journal, he labours to prove, that the compafs is very little difturbed by tilting the box on one fide, but very much by fudden horizontal changes of place; that a fcientific provifion againft the latter is therefore the chief requifite in a well made inftrument

ftrument of this kind; and that no other provifion is requifite, or can eafily be obtained, than good workmanfhip according to the common conftruction, and a proper adjuftment of the weight with regard to the centres or axes of fufpenfion. The fame author is of opinion, that it would greatly improve the compafs to make the needle flat and thin, and to fufpend it, not, as is moft commonly done, with its flat fide, but with its edge uppermoft; for it being a well-known fact, that foft fteel lofes its magnetifm fooner than hard, it is obvious, that unlefs both fides of a needle be equally hard (which is almoft impoffible if they be diftant from each other), the magnetic power will, in procefs of time, deviate towards the harder fide.

The Chinefe Compass has fome advantages over the European compafs, from which it differs with refpect to the length of the needle, and the manner in which it is fufpended. In the compafs of China, the magnetic needle is feldom above an inch in length, and is lefs than a line in thicknefs. It is poifed with great nicety, and is remarkably fenfible, or, in other words, points fteadily towards the fame portion of the heavens. This fteadinefs is accomplifhed by the following contrivance: "A piece of thin copper is ftrapped round the centre of the needle. This copper is rivetted by its edges to the upper part of a fmall hemifpherical cup, of the fame metal, turned downwards. The cup fo inverted ferves as a focket to receive a fteel pivot rifing from a cavity made into a round piece of light wood or cork, which thus forms the compafs-box. The furfaces of the focket and pivot, intended to meet each other, are perfectly polifhed, to avoid, as much as poffible, all friction. The cup has a proportionably broad margin, which, befide adding to its weight, tends, from its horizontal pofition, to keep the centre of gravity, in all fituations of the compafs, nearly in coincidence with the centre of fufpenfion. The cavity, in which the needle is thus fufpended, is in form circular, and is little more than fufficient to remove the needle, cup, and pivot. Over this cavity is placed a thin piece of tranfparent talc, which prevents the needle from being affected by any motion of the external air; but permits the apparent motion of the former to be eafily obferved. The fmall and fhort needle of the Chinefe has a material advantage over thofe of the ufual fize in Europe, with regard to the inclination or dip towards the horizon; which, in the latter, requires that one extremity of the needle fhould be made fo much heavier than the other as will counteract the magnetic attraction. This being different in different parts of the world, the needle can only be accurately true at the place for which it had been conftructed. But in fhort and light needles, fufpended after the Chinefe manner, the weight below the point of fufpenfion is more than fufficient to overcome the magnetic power of the dip or inclination in all fituations of the globe; and therefore fuch needles will never deviate from their horizontal pofition.

COMPLEMENT, in general, is what is wanting, or neceffary, to complete fome certain quantity or thing.

Arithmetical Complement, is what a number or logarithm wants of unity or 1 with fome number of cyphers. It is beft found by beginning at the left-hand fide, and fubtracting every figure from 9, except the laft, or right hand figure, which muft be fubtracted from 10. So, the arithmetical comp. of the log. 9·5329714, by fubtracting from 9's, &c. is 0·4670286.

The arithmetical complements are much ufed in operations by logarithms, to change fubtractions into additions, which are more conveniently performed, efpecially when there are more than one of them in the operation.

Complement, in aftronomy, is ufed for the diftance of a ftar from the zenith; or the arc contained between the zenith and the place of a ftar which is above the horizon. It is the fame as the complement of the altitude, or co-altitude, or the zenith diftance.

Complement of the Courfe, in navigation, is the quantity which the courfe wants of 90°, or 8 points, *viz.* a quarter of the compafs.

Complement of the Curtain, in fortification, is that part of the anterior fide of the curtain which makes the demigorge.

Complement of the Line of Defence, is the remainder of that line, after the angle of the flank is taken away.

Complements of a Parallelogram, or *in a Parallelogram*, are the two leffer parallelograms, made by drawing two right lines parallel to each fide of the given parallelogram, through the fame point in the diagonal.

Complement of Life, a term much ufed, in the doctrine of life annuities, by De Moivre; and, according to him, it denotes the number of years which a given life wants of 86, this being the age which he confidered as the utmoft probable extent of life. So 56 is the complement of 30, and 30 is the complement of 56.

COMPOSITION of proportion, according to the 15th definition of the 5th book of Euclid's Elements, is when, of four proportionals, the fum of the 1ft and 2d is to the 2d, as the fum of the 3d and 4th is to the 4th.

Composition of Ratios, is the adding of ratios together; which is performed by multiplying together their correfponding terms, viz. the antecedents together, and the confequents together, for the antecedent and confequent of the compound ratio; like as the addition of logarithms is the fame thing as the multiplication of their correfponding numbers. Or, if the terms of the ratio be placed fraction-wife, then the addition or compofition of the ratios is performed by multiplying the fractions together.

COMPOSTELLA, a very rich town in New-Spain, and province of Xalifco, built in 1531, fituated near the S. Sea, 400 miles N. W. of Mexico. The foil is barren and the air unhealthful; but it has feveral mines of filver at St Pecaque, in its neighborhood. N. lat. 21. 20. W. long. 109. 42.—*Morse.*

COMPOUND Interest. See Algebra, *Encycl.* and *Compound Interest* in this *Supplement.*

CANAJOHARY, a poft town, on the S. fide of Mohawk river, New-York, very large, 36 miles above Schenectady, and 318 from Philadelphia.—*Morse.*

CONAWANGO, a northern branch of Alleghany river, in Pennfylvania, which rifes from Chataughque lake.—*ib.*

CONCEPTION, a city of Chili in South America, was vifited in 1786 by the celebrated, though unfortunate, navigator La Peroufe, who gives an account of fome particulars relating to it very different from what we have given of it under the article Conception, *Encycl.*

Conception.

cycl. So far are the Spaniards from living in ſecurity with reſpect to the Indians, that, according to him, they are under continual alarms of being attacked by thoſe bold and enterpriſing ſavages. "The Indians of Chili (ſays he) are no longer thoſe Americans who were inſpired with terror by European arms. The increaſe of horſes, which are diſperſed through the interior of the immenſe deſerts of America, and that of oxen and ſheep, which has alſo been very great, have converted theſe people into a nation of Arabs, in every thing reſembling thoſe who inhabit the deſerts of Arabia. Conſtantly on horſeback, they conſider an excurſion of two hundred leagues as a very ſhort journey. They march accompanied by their flocks; feed upon their fleſh and milk, and ſometimes upon their blood; and cover themſelves with their ſkins, of which they make helmets, cuiraſſes, and bucklers. All their old cuſtoms are laid aſide. They no longer feed upon the ſame fruits, nor wear the ſame dreſs; but have a more ſtriking reſemblance to the Tartars, or to the inhabitants of the banks of the Red Sea, than to their anceſtors, who lived two centuries ago. So deciſive an influence has the introduction of two domeſtic animals had upon the manners of that once timid people. It is eaſy to conceive what formidable enemies they muſt now be to the Spaniards; for ſuppoſing them defeated in battle, How is it poſſible to follow them in ſuch long excurſions? How is it poſſible to prevent aſſemblages, which bring together in a ſingle point nations ſcattered over 400 leagues of country, and thus form armies of 30,000 men?"

Of theſe people M. Rollin, ſurgeon major of the frigate *la Buſſole*, gives the following phyſiological particulars: "They are, in general (ſays he), of lower ſtature, and leſs robuſt, than Frenchmen, though they endure with great courage the fatigues of war and all its attendant privations. There is a great ſameneſs in the phyſiognomy of moſt individuals. The face is larger and rounder than that of Europeans. The features are more ſtrongly marked. The eyes are ſmall, dull, black, and deeply ſeated. The forehead is low; the eyebrows black and ſhaggy; the noſe ſhort and flattened; the cheek-bones high; the lips thick; the mouth wide; and the chin diminutive. The women are ſhort, ill-made, and with diſguſting countenances. Both men and women bore their noſe and ears, which they adorn with glaſs or mother-of-pearl trinkets. The colour of their ſkin is a reddiſh brown: That of their nails is ſimilar, but not ſo deep. The hair of both is black, coarſe, and very thick. The men have little beard; but their arm-pits and parts of ſex are well furniſhed with hair, which parts, in moſt of the women, have none."

The military governor of Conception, who was an Iriſhman, returned, while M. de la Perouſe was there, from the frontiers of the Spaniſh ſettlements, where he had juſt concluded a glorious peace with the Indians. This peace was highly neceſſary to the people of his government, whoſe diſtant habitations were expoſed to the inroads of ſavage cavalry, whoſe practice it is to maſſacre the men and children, and to make the women priſoners. This amiable man, whoſe name was *Higguins* (probably *Higgins*), had ſucceeded in gaining the good will of theſe ſavages, and thereby rendered the moſt ſignal ſervice to the nation that had adopted him. For while the Indians and Spaniards are at variance, an alliance with the former by any of the maritime powers of Europe would become ſo formidable to the latter, as to induce them, for fear of their lives, to abandon their ſettlements in Chili, and retire to Peru. This was clearly ſeen by *Monneron* the engineer on the expedition, who, with the true ſpirit of a Frenchman, pointed out to his government the method of wreſting from its moſt faithful ally, one of the moſt valuable provinces in the Spaniſh empire.

La Perouſe deſcribes the common people of Conception as much addicted to thieving, and the women as exceedingly eaſy of acceſs. "They are a degenerated and mongrel race (ſays he); but the inhabitants of the firſt claſs, the true bred Spaniards, are polite and obliging in the extreme. The biſhop was a man of great ſenſe, of agreeable manners, and of a charity of which the Spaniſh prelates afford frequent examples." He was a Creole, and had never been in Europe. Of the monks, our author gives a very different character. "The misfortune (ſays he) of having nothing to do, the want of family ties, the profeſſion of celibacy, without being ſeparated from the world, and their living in the convenient retirement of their cells, has rendered, and could not fail to render, them the greateſt profligates in America. Their effrontery is inconceivable. I have ſeen ſome of them ſtay till midnight at a ball; aloof, indeed, from the good company, and ſeated among the ſervants. Theſe ſame monks gave our young men more exact information than they could get elſewhere, concerning places with which prieſts ought to have been acquainted only in order to interdict the entrance."

M. de la Perouſe repreſents that part of Chili, which is called *the Biſhoprick of Conception*, as one of the moſt fertile countries in the univerſe. Corn yields ſixty to one; the vineyards are equally productive; and the plains are covered with innumerable flocks, which, tho' left to themſelves, multiply beyond all imagination. Yet this colony is far from making the progreſs that might be expected from a ſituation ſo favorable to an increaſe of population. The influence of the government inceſſantly counteracts the climate and the ſoil. Prohibitory regulations exiſt from one end of Chili to the other; and this kingdom, of which the productions, if carried to the higheſt pitch, would feed the half of Europe; of which the wool would ſuffice for the manufactures of Great Britain and France, even when manufactures flouriſhed in the latter country; and of which the cattle, if ſalted down, would produce an immenſe revenue—is entirely deſtitute of commerce, and its inhabitants ſunk in ſloth and indolence. Unleſs, therefore, Spain change its ſyſtem entirely, Chili will never reach that pitch of proſperity which might be expected from its ſituation and fertility. For the latitude and longitude of Conception, ſee *Encycl.*

Conception, a large bay on the E. ſide of Newfoundland iſland, whoſe entrance is between Cape St Francis on the ſouthward, and Flamborough-head on the northward. It runs a great way into the land in a ſouthern direction, having numerous bays on the W. ſide, on which are two ſettlements, Carboniere and Havre de Grace. Settlements were made here in 1610, by about 40 planters, under governor John Guy, to whom king James had granted a patent of incorporation.—*Morse.*

Conception *of Salaya* a small town of N. America, in the province of Mechoacan, in Mexico or New-Spain, was built by the Spaniards, as well as the stations of St Michael and St Philip, to secure the road from Mechoacan to the silver mines of Zacateca. They have also given this name to several boroughs of America; as to that in Hispaniola island, and to a sea-port of California, &c.—*ib.*

Conception, by the Indians called *Penco*, a city in Chili, S. America, situated on the edge of the sea, at the mouth of a river, and at the bottom of a bay of its own name. It lies in about 37. S. lat. It was several times destroyed by the powerful confederacy of the Indians, and as often repaired. In 1730 it was destroyed by an earthquake, and since that, rebuilt. It is within the audience and jurisdiction of St Jago, and is governed by a correlidore. The Spanish inhabitants here, are the most warlike and hardy of any in S. America; they are all trained to arms from their childhood, to be ready to resist the attack of the Chilese Indians, whom they have reason to consider as a formidable enemy.

The inhabitants, and even the women, excel in horsemanship; they are very dexterous in managing the lance or noose; and it is very rare to see them miss their aim, though at full speed, with the noose, which they throw 40 or 50 yards, and so halter the object of their diversion or revenge. This noose is made of throngs of cow-hide; these they twist with oil, till rendered supple and pliant to command; and so strong that, when twisted, they will, it is said, hold a wild bull, which would break a halter of hemp of twice the thickness.

The soil here is fruitful, abounding with corn and excellent wine. The fruit trees bear so luxuriantly here, that they are forced to thin the fruit, otherwise the branches would break, nor could the fruit come to maturity. This city has a church and six very famous monasteries; but the dwelling houses make no great appearance. Here the women go out in the night to the shops, to buy such necessaries as they want for their families, it being contrary to the custom of this country for women of any character, to go abroad in the daytime on such affairs. It is an open town; and the few batteries it has, are kept in very indifferent order. —*ib.*

CONCHUCOS, a jurisdiction in the empire of Peru, in S. America, under the archbishop of Lima; it begins 40 leagues N. N. E. of the metropolis, and runs along the center of the Cordillera. It produces fruits, grain, &c. and affords extensive pasture for cattle of all kinds. Several branches of the woollen manufactory are carried on here, which constitute its greatest commerce with the other provinces.—*ib.*

CONCORD, a post town of New-Hampshire, very flourishing, and pleasantly situated on the W. bank of Merrimack river, in Rockingham co. 8 miles above Hookset falls. The legislature, of late, have commonly held their sessions here; and from its central situation, and a thriving back country, it will probably become the permanent seat of government. Much of the trade of the upper country centers here. A handsome toll bridge across the Merrimack, connects this town with Pembroke. It has 1747 inhabitants, and was incorporated in 1765. The Indian name was *Penacook*. It was granted by Massachusetts, and called *Rumford*. The compact part of the town contains about 170 houses, a congregational church, and an academy, which was incorporated in 1790. It is 55 miles W. N. W. of Portsmouth, 58 S. W. of Dartmouth college, and 70 northward from Boston. N. lat. 43. 12. W. long. 71. 29.—*ib.*

Concord, in Essex co. Vermont, lies on Connecticut river, opposite a part of the 15 mile falls—*ib.*

Concord, in Massachusetts, a post town, one of the most considerable towns in Middlesex co. situated on Concord river, in a healthy and pleasant spot, nearly in the center of the county, and 18 miles N. W. of Boston, and 17 E. of Lancaster. Its Indian name was Musquetequid; and it owes its present name to the peaceable manner in which it was obtained from the natives. The first settlers, among whom were the Rev. Messrs Buckley and Jones, having settled the purchase, obtained an act of incorporation, Sept. 3, 1635; and this was the most distant settlement from the seashore of New-England at that time. The settlers never had any contest with the Indians; and only three persons were ever killed by them within the limits of the town. In 1791, there were in this township 225 dwelling houses, and 1590 inhabitants; of the latter there were 80 persons upwards of 70 years old. For 13 years previous to 1791, the average number of deaths was 17; one in four of whom were 70 years old and upwards. The public buildings are, a Congregational church, a spacious stone gaol, the best in New-England, and a very handsome county court-house. The town is accommodated with three convenient bridges over the river; one of which is 208 feet long, and 18 feet wide, supported by 12 piers, built after the manner of Charles river bridge. This town is famous in the history of the revolution, having been the seat of the provincial congress in 1774, and the spot where the first opposition was made to the British troops, on the memorable 19th of April, 1775. The general court have frequently held their sessions here when contagious diseases have prevailed in the capital. N. lat. 42. 25. —*ib.*

Concord, a small river of Massachusetts, formed of two branches, which unite near the center of the town of Concord, whence it takes its course in N. E. and N. direction through Bedford and Billerica, and empties itself into Merrimack river at Tewksbury. Concord river is remarkable for the gentleness of its current, which is scarcely perceivable by the eye. At low water mark it is from 100 to 200 feet wide, and from 3 to 12 feet deep. During floods, Concord river is near a mile in breadth; and when viewed from the town of Concord, makes a fine appearance.—*ib.*

Concord, a township in Delaware co. Pennsylvania. —*ib.*

Concord, a settlement in Georgia, on the E. bank of the Mississippi, about a mile from the S. line of Tennessee, 108 miles N. from the mouth of Yazoo river and 218 below the Ohio. N. lat. 33. 55. W. long. 91. 25.—*ib.*

Conde, Fort, or *Mobile city*, is situated on the W. side of Mobile bay, in West-Florida, about 40 miles above its mouth in the gulf of Mexico. N. lat. 30. 42. W. long 87. 57.—*ib.*

CONDECEDO, a cape or promontory of N. America,

rica, in the province of Yucatan, 100 miles W. of Merida. N. lat. 20. 50. W. long. 91. 27.—*ib.*

CONDESUYOS DE AREQUIPA, a jurifdiction under the bifhop of Arequipa, 30 leagues N. of that city, in Peru. Here is cultivated the wild cochineal: the Indians carry on a great trade with this article; they grind it, and mix four ounces of it with 12 ounces of violet-maize, of which they form cakes of 4 ounces each, and fell it for a dollar a pound. Thefe cakes they call magnos. This place abounds alfo with gold and filver mines, which are not fo carefully worked as formerly.—*ib.*

CONDORCET (Jean-Antoine Nicholas Caritat de), was born at Ribemont in Picardy, the 17th of September 1743, of a noble and very ancient family. At the age of 15 he was fent to ftudy philofophy at the college of Navarre, and had the good fortune to fall into the hands of an able profeffor, who has fince diftinguifhed himfelf by his geometrical works. The young Condorcet had no relifh for the bufinefs of the firft courfe, for the quibbles of ontology and pneumatology, and all the wretched appendages of fchool metaphyfics; but in the following year, his ftudies, being directed to the mathematical and phyfical fciences, were entirely congenial to his tafte; and though there were upwards of 120 fcholars, he diftinguifhed himfelf above them all. At Eafter he held a public thefis, at which Clairaut, D'Alembert, and Fontaine affifted. He now returned home, but continued to cultivate geometry. To enjoy more opportunities of improvement, he removed in 1762 to Paris; where he attended the chemical courfe of Maquer, and Beaumé, and frequented the literary focieties which D'Alembert had formed at the houfe of Mademoifelle de Lefpinaffe.

In 1765, when only 22 years old, he publifhed a work on the integral Calculus, which difcovered vaft extent and originality of views. Condorcet was already numbered with the foremoft mathematicians in Europe. "There was not (fays La Lande) above ten of that clafs; one at Peterfburg, one at Berlin, one at Bafle, one at Milan, and five or fix at Paris; England, which had fet fuch an illuftrious example, no longer produced a fingle geometer that could rank with the former." It is mortifying to us to confefs that this remark is but too much founded in truth. We doubt not but there are in Great-Britain at prefent mathematicians equal in profundity and addrefs to any who have exifted fince the illuftrious Newton; but thefe men are not known to the learned of Europe, becaufe they keep their fcience to themfelves. They have no encouragement, from the tafte of the nation, to publifh any thing in thofe higher departments of geometry which have fo long occupied the attention of the mathematicians on the continent.

In 1767 Condorcet publifhed his folution of the problem of three bodies; and in the following year, the firft part of his Analytical Effays; in which he entered very profoundly into thofe arduous queftions. He was received into the academy on the 8th of March, 1769; and from that time till 1773 he enriched their annual volumes with memoirs on infinite feries, on partial and finite differences, on equations of condition, and on other objects of importance in the higher calculus. It muft be regretted, that he indulged fpeculation perhaps to excefs; the methods that he propofes for integration are fometimes of a nature fo extremely general, as to refufe to be accommodated to practice. Profecuting thofe refearches for feveral years longer, he compofed an ample Treatife on the Integral Calculus, in five parts, comprizing the doctrines and their application. It was afterwards copied out for the prefs in 1785 by Keralio, formerly governour to the Infant of Parma. Only 128 pages were printed; but the manufcript ftill exifts; as does that of an elementary Treatife on Arithmetic. It is to be hoped that both of thefe will yet be given to the public.

His attention was not, however, entirely abforbed in thofe recondite ftudies. He publifhed about this time an anonymous pamphlet, intitled *a Letter to a Theologian*; in which he replied with keen fatire to the attacks made by the author of the *Three Centuries of Literature* againft the philofophical fect. "But (fubjoins the prudent La Lande) he pufhed the matter fomewhat too far; for, admitting the juftnefs of his fyftem, it was more prudent to confine within the circle of the initiated, thofe truths which are dangerous for the multitude, who cannot replace, by found principles what they would lofe of fear, of confolation, and of hope." Condorcet was now leagued with the atheifts; and *La Lande*, who wifhes well to the fame fect, cenfures not his principles, but only regrets his rafhnefs. He was indeed, as Mr Burk obferved, a fanatic atheift and furious democratic republican.

On the 10th of June 1773 he was made fecretary of the academy of fciences; and that important truft he difcharged through the reft of his life with great ability and uncommon reputation. The duties of his office required him to write the lives of the deceafed academicians, which he performed with diligence, judgment, and univerfal applaufe: And what fpecies of compofition is capable of being rendered fo extenfively ufeful as biography? In the moft infinuating form it conveys inftruction; and beftowing vitality and action on the rules of conduct and on the leffons of virtue, it fires the breaft with the nobleft emulation. The life of a philofopher muft alfo include a portion of the hiftory of fcience. We there trace the fucceffive fteps which led to difcoveries, and learn to eftimate the value of thofe acquifitions by the efforts that were made, and the obftacles that were furmounted. The literati of France have long excelled in the compofition of *Eloges*: but thofe of Condorcet are of a very fuperior caft. Replete with information and genuine fcience, they maintain a dignified impartiality, and difplay vigour of imagination with boldnefs and energy of ftyle. The intrepidity (fay his Panegyrifts) with which he uttered the fentiments of truth and of freedom, could not have been expected from the mouth of an academician under an abfolute monarchy. It could not, indeed, till the prefent eventful age, have been expected under any government whatever; for what he called the fentiments of truth were the dogmas of debafing irreligion which would not have been permitted in the far-famed republics of Greece and Rome; and what he dignified with the appellation of the principles of freedom, experience has fhown to have been the immediate fource of anarchy, out of which has fprung a defpotifm, the heavieft under which any people have groaned fince the creation of the world.

Befides the eloges, which properly belonged to his province, Condorcet publifhed in a feparate volume the lives

Condorcet. lives of those *savants*, who, having died before the renewal of the academy in 1699, did not fall in with the plan of Fontenelle. The suppression of the history of the academy, or the regular abstracts of the printed memoirs which he effected in 1783, afforded him more leisure. In 1787 appeared, yet without a name, his account of Turgot; an inestimable piece, which, in developing the beneficial views of a virtuous and enlightened minister, exhibits the neatest abstract of the principles of political economy that is extant in any language. Nearly about the same time, he composed that elegant life which is prefixed to the splendid edition of the works of Voltaire. Condorcet had been elected member of the *academie Françaife* in 1782; and his reputation as a fine writer was so well established, that booksellers were solicitous to cover their undertakings with the sanction of his name. He promised an additional volume to the translation of Euler's Letters to a German princess; but it was never finished. The part which was printed, amounting to only 112 pages, contains the elements of the calculation of probabilities, and a curious plan of a dictionary, in which objects should be arranged by their qualities merely. A new translation of Smith's celebrated *Wealth of Nations* was likewise announced with the notes of Condorcet, tho' he was never heartily engaged about it. On equally slight grounds his name was lent to the *Bibliotheque de l' Homme Public*; and the facility of his temper laid him but too open, at this period, to such disingenuous arts. Indeed disingenuous arts seem to be the natural offspring of the present philosophy of France; for the tricks played by Voltaire to his booksellers, which are well known, would in this country have sunk into disgrace the greatest genius that ever lived; and the attempt of Diderot to cheat the late empress of Russia, by selling to her, at an immense price, a library, which he pretended to be one of the most valuable in Europe, when he possessed not perhaps one hundred volumes, was disingenuity ingrafted on impudence. But to return from this short digression,

These literary pursuits did not entirely seduce Condorcet from more profound studies. At the instigation of Turgot, he sought to apply analysis to questions of politics and morality. His first Memoir on Probabilities was read to the academy in 1781. He afterward extended his researches to the consideration of elections, sales, and successions; and digesting those remarks and calculations into a systematic shape, he published in 1785 a quarto volume, containing the elements of a new and important science.

It is easy to conceive the interest that Condorcet would take in the success of the revolution. Aware of the prodigious influence of newspapers, he contributed largely to the *Journal de Paris*, and the *Chronique*, which acquired great celebrity from the elegance of his pen; and not very long before his death, he began, in concert with the famous Sieyes, a Journal of Social Instruction. In 1791 he wrote a pamphlet in favour of republican government, which procured him a seat in the Legislative Assembly, and the academy permitted him still to retain the office of secretary. He drew up a manifesto on the subject of the war menaced by the crowned heads; and a very ample report on public instruction, which has in part been lately adopted by the councils of France. He was an early member of the Jacobin club, that active instrument of the revolution: Condorcet. but perceiving the progressive ferocity of its measures, he forsook it in March, 1792.

On the 13th of August, when the king was conducted to the temple, Condorcet was named by the Assembly to draw up a justificatory memorial addressed to all Europe. At the dissolution of that Assembly, he was chosen deputy to the National Convention, and for some time acted a distinguished part in its deliberations. He was at the head of the committee appointed to prepare the plan of a republican constitution. But, in the meanwhile, the faction of the Mountain, with a peculiar energy of character, was rapidly acquiring strength. The report of the committee was coldly received—was even treated with contempt; and on the 31st of May, 1793, Robespierre completely triumphed. The Brissotins were arrested, outlawed, dispersed; and Condorcet, having voted against the death of the king, was involved in the proscription. For some months he obtained an asylum at Paris in the house of a woman, who was ignorant of his person, but commiserated his lot. Nothing, however, could elude the vigilance of the tyrant. Menaces of a strict domiciliary visit compelled him at last, in March 1794, to quit his concealment. He escaped the barriers, and passed the first night in the plain of Montrouge. On the next morning, he repaired to the house of an old friend at Fontenai, who most unfortunately had gone to Paris, and was not expected to return for two days. In this deplorable state of suspense did Condorcet pass one night in a quarry, and another under a tree in the fields. On the third day he hastened to meet his friend; but the meeting was short and unsatisfactory. After a hasty refreshment, it was agreed that he should depart in the meanwhile, to return again at night after all the servants were retired to rest. He was therefore obliged to wander about the neighbourhood of Clamar. Exhausted with hunger and fatigue, and his feet terribly bruised, nature could hold out no longer. He entered an alehouse, where his long beard and haggard looks exposed him to suspicion. A member of the revolutionary committee of Clamar demanded his passport, led him away to the committee, and thence transferred him to the district of Bourg-la-Reine. Having arrived too late for interrogation, he was shut up in prison under the name of Pierre Simon, with the intention of being sent to Paris. On the 28th of March he was found dead.

Thus miserably perished a most able philosopher, and one of the finest writers of those that have adorned the present century. His private character is described by La Lande as easy, quiet, kind, and obliging; but his behaviour to Diderot when dying, displayed, instead of the milk of human kindness, the malignity of a fiend. Neither his conversation nor his external deportment bespoke the fire of his genius. D'Alembert used to compare him to a volcano covered with snow. He had a latent weakness, however, of constitution, which often made him the dupe of men altogether unworthy of his regard.

It was during the period of his concealment at Paris, uncertain of a day's existence, that he wrote his Sketch of the Progress of the Human Mind; a production which undoubtedly displays genius, though it contains some of the most extravagant paradoxes that ever fell from the pen of a philosopher. Among other

wonderful

wonderful things, the author inculcates the poffibility, if not the probability, that the nature of man may be improved to abfolute perfection in body and mind, and his exiftence in this world protracted to immortality. So firmly does he feem to have been perfuaded of the truth of this unphilofophical opinion, that he fet himfelf ferioufly to confider how men fhould conduct themfelves when the population fhould become too great for the quantity of food which the earth can produce; and the only way which he could find for counteracting this evil was, to check population by promifcuous concubinage and other practices, with an account of which we will not fully our pages. Yet we are told by La Lande, that this fketch is "only the outline of a great work, which, had the author lived to complete it, would have been confidered as a monument erected to the *honour* of human nature!!!" La Lande, indeed, fpeaks of the author in terms of high refpect: and his abilities are certainly unqueftionable: but what fhall we think of the morals of that man, who firft purfued with malicious reports, and afterwards hired ruffians to affaffinate,* the old Duke of Rochefoucalt, in whofe houfe he had been brought up; by whom he had been treated as a fon; and at whofe folicitation Turgot created for him a lucrative office; and by the power of the court raifed him to all his eminence? There is a living Englifh writer, who has laboured hard to prove that gratitude is a crime. Condorcet muft furely have held the fame opinion; and therefore could not blame thofe low born tyrants who put him to death by what we would call *an unjuft fentence;* for it was in fome degree to his writings that thofe tyrants were indebted for their power.

* *Jour. de Phyf.* Nov. 1792.

About the end of the year 1786, Condorcet married Marie-Louife Sophie de Grouchy, whofe youth, wit, and beauty, were lefs attractive in the eyes of a philofopher than the tender and courageous anxiety with which fhe watched the couch, and affuaged the fufferings, of the fon of the prefident du Paty, who had been bitten by a mad dog. This union, however, we are told, was fatal to his repofe; it tempted him into the dangerous road of ambition; and the idea of providing for a wife and daughter induced him to feek for offices which once he would have defpifed.

CONDUSKEEG, a fettlement in the diftrict of Maine, in Hancock co. containing 567 inhabitants. —*Morse.*

CONEGOCHEAGUE *Creek*, rifes near Mercerfburg, Franklin co. Pennfylvania, runs foutherly in a winding courfe, and after fupplying a number of mills, empties into the Potowmack, at William port, in Wafhington co. Maryland; 19 miles S. E. of Hancock, and 8 miles S. of the Pennfylvania line.—*ib.*

CONEMAUGH *River*, and Little Conemaugh, are the head waters of Kifkemanitas, in Pennfylvania: after paffing through Laurel hill and Chefnut ridge, Conemaugh takes that name and empties into the Alleghany, 29 miles N. E. of Pittfburg. It is navigable for boats, and there is a portage of 18 miles between it and the Frankftown branch of Juniata river.—*ib.*

CONENTES, LAS, a city of La Plata or Paraguay, in S. America, in the diocefe of Buenos Ayres.

CONESTEO, a N. weftern branch of Tioga river, in New-York.—*ib.*

CONESTOGA, a townfhip in Lancafter co. Pennfylvania.—*ib.*

CONESUS, a fmall lake in the Geneffee country, N. York, which fends its waters N. W. to Geneffee river.—*ib.*

CONFERVA Jugalis (fee Conferva *Encycl.)* is introduced here merely on account of a curious circumftance refpecting it, which was communicated, not long ago, to the Philomatic Society at Paris. Citizens Charles and Romain Coquebert having collected fome of this *Conferva* in the neighbourhood of Paris, afcertained, by means of an excellent microfcope, conftructed by Nairne and Blunt, that, in this fpecies there are male and female filaments, which unite by an actual copulation; that certain globules contained in the male filaments pafs into the interior part of the female filaments; and that by this union there are formed in the latter feeds, or, if we may ufe the expreffion, fmall *ova*, which reproduce the fpecies. This is the firft inftance, in the vegetable kingdom, of a reproduction abfolutely analogous to that which we find among animals. *Philofophical Magazine*, n° 3.

May this fact be depended on? We queftion not, in the flighteft degree, the veracity of the editor of the very refpectable mifcellany from which we have copied it; but we confefs ourfelves inclined to admit the phyfiological difcoveries of citizen philofophers with great hefitation. The fact, if real, is certainly curious, and may lead to important conclufions; and we therefore recommend an inveftigation of its truth to our botanical readers.

CONGAREE, a confiderable river of S. Carolina, formed by the confluence of Saluda and Broad rivers. The union of the waters of Congaree and Wateree, from the Santee.—*Morse.*

CONGELATION, fee Chemistry in this Supplement, n° 284.

CONHOCTON *Creek*, in New-York, is the northern head water of Tioga river. Near its mouth is the fettlement called Bath.—*Morse.*

CONNECTICUT, a ftream in Long Ifland, N. York, which falls into a bay at the S. fide of the ifland. It lies 2 miles to the fouthward of Rockonkama pond.—*ib.*

CONTAGION (fee *Encycl.)* is a fubject on which much has been written to very little purpofe. Of all the attempts which have been made to account for it, there is not one that can be thought fatisfactory. This, however, is not perhaps a matter of great importance, if a method could only be difcovered to ftop the progrefs of contagion where it is known to have place. Among the many benefits which may be reaped from the late difcoveries in Chemiftry, even this defideratum promifes to be one; and we furely need not add one of the greateft. Dr James Carmichael Smyth, phyfician extraordinary to his Majefty, fuggefted, in the year 1795 or 1796, a procefs for determining the effect of the nitric acid in deftroying contagion; and experiments, according to his directions, were made on board the *Union* and other fhips at Sheernefs.

The Union was an hofpital fhip, and the experiment on board her was conducted by Mr Menzies, late furgeon to his Majefty's floop Difcovery, and by Mr Baffan, furgeon of the Union; and when it is confidered, that

Contagion.

that fresh contagion was daily pouring into the hospital from the Russian vessels, which were at that time lying in the Downs, and which had brought with them a species of fever that might in every sense of the word be termed an epidemy, it will be allowed, that the success which attended it was such that it cannot be too generally known.

The wards were extremely crowded, and the sick of every description lay in cradles, promiscuously arranged, to the number of nearly two hundred; of which, about one hundred and fifty were in different stages of the above malignant fever, which was extremely contagious, as appeared evident from its rapid progress and fatal effects among the attendants on the sick and the ship's company.

The utensils and materials provided for the process were the following: A quantity of fine sand, about two dozen quart earthen pipkins, as many common tea-cups, some long slips of glass to be used as spatulas, a quantity of concentrated vitriolic (sulphuric) acid, and a quantity of pure nitre (nitrat of potash).

The process was conducted in the following manner: 1*st*, All the ports and scuttles were shut up; the sand, which had been previously heated in iron pots, was then scooped out into the pipkins by means of an iron ladle; and in this heated sand, in each pipkin, a small tea-cup was immersed, containing about half an ounce of the sulphuric acid, to which, after it had acquired a proper degree of heat, an equal quantity of nitrat of potash in powder was gradually added, and the mixture stirred with a glass spatula till the vapour arose from it in considerable quantity (A). The pipkins were then carried through the wards by the nurses and convalescents, who kept walking about with them in their hands, occasionally putting them under the cradles of the sick, and in every corner where any foul air was suspected to lodge. In this manner they continued fumigating, until the whole space between decks was fore and aft filled with the vapour, which appeared like a thick haze.

The vapour at first excited a good deal of coughing among the patients, which gradually ceased as it became more generally diffused through the wards: part of this effect, however, was to be attributed to the inattention of those who carried the pipkins, in putting them too near the faces of the sick; which caused them to inhale the strong vapour as it immediately issued from the cups.

The body-clothes and bed-clothes of the sick were, as much as possible, exposed to the nitrous vapour during the fumigation; and all the foul linen removed from them was immediately immersed in a tub of cold water, afterwards carried on deck, rinsed out, and hung up till nearly dry, and then fumigated before it was taken to the wash-house: a precaution extremely necessary in every case of infectious disorder. Due attention was also paid to cleanliness and ventilation.

It took about three hours to fumigate the ship. In about an hour after, the vapour having entirely subsided, the ports and scuttles were thrown open for the admission of fresh air. It could plainly be perceived that the air of the hospital was greatly sweetened even by this first fumigation. The process was repeated again next morning; and the people employed, being now better acquainted with it, were more expert, and finished the whole in about an hour's time. In an hour afterwards, the vapour having entirely subsided, the fresh air was freely admitted into the hospital as before. Fewer pipkins were employed for the evening fumigations than for those of the mornings, as the fresh air could not be admitted so freely after the former as the latter.

Contagion.

The pleasing and immediate effect of the fumigation in destroying the offensive and disagreeable smell, arising from so many sick crowded together, was now very perceptible, even to the nurses and attendants; the consequence of which was, that they began to place some degree of confidence in its efficacy, and approached the cradles of the infected with less dread of being attacked with the disorder: so that the sick were better attended, and the duty of the hospital was more regularly and more cheerfully performed. In short, a pleasing gleam of hope seemed now to cast its cheering influence over that general despondency, which was before evidently pictured in every countenance, from the dread and horror each individual naturally entertained of being, perhaps, the next victim to the malignant powers of a virulent contagion.

It is a remarkable fact, that from the 26th of November 1795, when the fumigation was first resorted to, till the 25th of December, not a person on board was attacked with the fever, though, in the three months preceding, more than one-third of all the people in the ship had been seized with the distemper, and of these more than one in four were carried off by it; and the probability is, that the sickness and mortality would have gone on, increasing in proportion to the diffusion of the contagion, and to the increasing despondency of the people, who considered themselves as so many devoted victims.

The advantage of the fumigation was not felt by the ship's company and attendants alone, whom it preserved from the baneful effects of the fever: the sick and convalescents derived almost an equal benefit from it. The symptoms of the disease were meliorated, and lost much of their malignant appearance; and the advantage of a pure air, and free from stench, to convalescents, may be readily conceived.

Great confidence is always dangerous. It proved so on the present occasion. On the 17th of December they imagined themselves so secure, that they discontinued the custom of fumigating morning and evening, thinking that once a day was sufficient. On the 25th, one of the nurses suffered a slight attack; and on the 26th, a marine, who, for a week before, had been in a state of intoxication, was seized with the fever, of which he died. These two accidents gave immediate alarm: they returned again to the practice of fumigating twice a day; and from that time to the extermination of the disorder,

(A) That the fumes of the mineral acids possessed the property of stopping contagion was proved by Morveau as far back as the year 1773, who, by means of the fumes of muriatic acid extricated from the muriat of soda (sea salt) by the sulphuric acid, purified the air of the cathedral of Dijon, which had been so much infected by exhumations that they were obliged to abandon the building. See CHEMISTRY, n°. 428, in this *Supplement*.

disorder, there was not an inftance of a perfon fuffering from contagion on board the fhip.

The fuccefs of the experiment was not confined to the Union: the power of the nitrous vapour to deftroy contagion was equally difplayed on board the Ruffian fhips in which it was employed. The fafety, too, with which it may be employed, in any fituation, without inconvenience or rifk of fire, is another great recommendation in its favour.

From the defcription that has been given of the procefs, no perfon can be at any lofs in reforting to the fame kind of fumigation. It is only neceffary to obferve, for the fake of thofe who may not be verfant in chemical purfuits, that the ingredients ought to be pure, and that metal veffels or rods muft not be employed. Any kind of metal getting among the ingredients would caufe the vapour to be very noxious inftead of falutary. The fumes that rife fhould be white; if they are of a red colour, there is reafon to fufpect the purity of the ingredients.

The importance of this difcovery need not be infifted on: it is equally applicable to every fpecies of putrid contagion, even to the plague itfelf. It fhould therefore be ufed in all hofpitals and parifh workhoufes; and fhould be conftantly reforted to by the proprietors of all large works, on the firft appearance of infectious difeafe among the people employed in them;—indeed, it fhould be employed even as a preventive in all fituations where a number of people, from the nature of their bufinefs, are obliged to be crowded together, or where, from local circumftances, there are reafons for fufpecting that the purity of the air is injured by noxious exhalations or other caufes. If there be any circumftances in which its utility may be called in queftion, it can only be in cafes of inflammatory difeafes; for, in fuch, fuperoxygenation has been found hurtful.

CONTINENTAL *Village*, was fituated on North river in New-York ftate. Before its deftruction by Sir Henry Clinton, in Oct. 1777, there were here barracks for 2,000 men.—*Morse*.

CONTRA-HARMONICAL *Proportion*, that relation of three terms, in which the difference of the firft and fecond is to the difference of the fecond and third, as the third is to the firft. Thus, for inftance, 3, 5, and 6, are numbers contra-harmonically proportional; for 2 : 1 : : 6 : 3.

CONTRA-Mure, in fortification, is a little wall built before another partition wall, to ftrengthen it, fo that it may receive no damage from the adjacent buildings.

CONVERSATION *Point*, a head land on the S. fide of a bay on the coaft of California. N. lat. 32. 30. W. long. 119.—*Morse*.

CONWAY, a townfhip in the province of New-Brunfwick, Sudbury co. on the weftern bank of St John's river. It has the bay of Fundy on the S. and at the wefternmoft point of the townfhip there is a pretty good harbor called Mufquafh cove.—*ib*

CONWAY, a townfhip in the N. E. corner of Strafford co. New-Hampfhire, on a bend in Saco river, incorporated in 1765, and contains 574 inhabitants. It was called *Pigwacket* by the Indians.—*ib*.

CONWAY, a thriving townfhip in Hampfhire co. Maffachufetts, incorporated in 1767, and contains 2092 inhabitants. It lies 13 miles N W. of Northampton, and 115 N. W. by W. of Bofton.—*ib*.

CONYA, a river in Surinam, or Dutch Guiana, S. America.—*ib*.

COOLOOME, an Indian town fituated on the W. fide of Talapoofe river, a branch of the Mobile.—*ib*.

COOK's *River*, in the N. W. coaft of N. America, lies N. W. of Prince William's found, and 1000 miles N. W. of Nootka found. N. lat. 59. 30. W. long. 153. 12. and promifes to vie with the moft confiderable ones already known. It was traced by Capt. Cook for 210 miles from the mouth, as high as N. lat. 61. 30. and fo far as is difcovered, opens a very confiderable inland navigation by its various branches. The inhabitants feemed to be of the fame race with thofe of Prince William's found; and like them had glafs beads and knives, and were alfo clothed in fine furs.—*ib*.

COOKHOUSE, on the Cookquago branch of Delaware river is fituated in the townfhip of Colchefter, New-York, 18 miles S. of the mouth of Unadilla river.—*ib*.

COOPER, an artificer who makes coops, cafks, tubs, or barrels, *i. e.* all kinds of wooden veffels bound together by hoops. See *Encycl.*

The art of the cooper appears to be of great antiquity, and to have very foon attained to all the perfection which it poffeffes at prefent. This being the cafe, it is obvious that we can communicate no inftruction to the cooper himfelf, and, on the fubject of his art, very little that could be interefting to our other readers. In the *Encyclopedie Methodique* there is a long and verbofe account of the tools or inftruments employed by the cooper; of the kinds of timber proper for the different kinds of cafks; of the methods of preparing the wood for his various purpofes; of the manner in which he ought to *hold the plane* when dreffing the ftaves; and of the time when it is proper to put the ftaves together, or, in other words, to mount the cafk. From this detail we fhall extract fuch particulars as appear to us to be leaft generally known, though perhaps of no great importance in themfelves.

Notwithftanding the antiquity of the art of *cafk-building*, there are fome countries in which even now it is wholly unknown; and others where, though it is fufficiently known, yet, from the fcarcity of wood or fome other caufe, earthen veffels, and fkins lined with pitch, are preferred to wooden barrels for the holding and tranfporting of liquors. The Latin word *dolium*, which we tranflate "a cafk," was employed by the Romans to denote earthen veffels ufed for this purpofe; though the word *dolare*, from which it is derived, applies very well to our cafks, which are compofed of feveral pieces of wood hewn from the fame tree, and fitted by planes before they be joined together. We are indeed certain that cafks of the fame kind with our own were in ufe among the Romans before the Chriftian era: for both Varro and Columella, in treating of the rural economy of their days, fpeak of veffels formed of feveral ftaves of wood bound together by circles or hoops. The merit of having invented fuch veffels is given by Pliny to certain people who lived at the foot of the Alps, and who in his days lined their cafks with pitch.

At what period the fabrication of cafks was introduced into Britain is unknown to us, though it is probable that we derived the art from the French, who might have it from the Romans.

We

We need hardly inform any of our readers, that a caſk has the appearance of two truncated cones joined at their baſes, or that the part where the junction appears to be made being the moſt capacious, or that of which the diameter is the largeſt, is vulgarly called the belly of the caſk. Theſe cones, however, were they completed, would not be regular, but rather *conoids*, being formed of pieces of timber, or ſtaves, which are not ſtraight lines as in the cone, but are curved from the vertex to the baſe.

In chuſing his wood, if he can have a choice, the cooper prefers old and thick and ſtraight trees, from which he hews thin planks to be formed into ſtaves; and in France, where this art is practiſed on a large ſcale, the winter months are allotted for the preparation of the ſtaves and bottoms, and the ſummer for putting them together or mounting the caſk. The author of the article in the *Encyclopedie Methodique* directs the cooper, when dreſſing the ſtaves with the plane, to cut the wood always acroſs; a practice which we doubt not is proper, though we think it would not be eaſy to aſſign the reaſon of it. Plaining is the moſt laborious and difficult part of the work; and there are but few coopers who plane quickly, and at the ſame time well. In ſhops where the work is diſtributed into parts, plaining is reckoned a great object; and in France, before the revolution, a good plainer gained from three ſhillings and threepence ſterling to four ſhillings and three farthings a day.

In forming the ſtaves, it muſt never be forgotten that each is to conſtitute part of a double conoid; that it muſt therefore be broadeſt at the middle, becoming gradually, though not in ſtraight lines, narrower towards the extremities; that the outſide acroſs the wood muſt be wrought into the ſegment of a circle; and that the ſtave muſt be thickeſt near the middle, growing thinner, by very gentle degrees, towards the ends. To adjuſt accurately theſe different curves (for even the *narrowing* of the ſtaves muſt be in a curve) to the ſize and intended ſhape of the caſk, would require either great experience, or a larger portion of mathematical ſcience than we have reaſon to think that many coopers poſſeſs. With reſpect to the inſide of the ſtave, it is of little conſequence whether it be rounded into the ſegment of a circle or not, and therefore the cooper very ſeldom takes that trouble.

The ſtaves being all dreſſed and ready to be arranged in a circular form, it might be thought neceſſary, in order to make the ſeems tight, to trim the thin edges, which are to be joined together, in ſuch a manner as that a ray paſſing from the outſide of the caſk through a ſeam to the centre, ſhould touch the contiguous ſtaves from the exterior to the interior ſide; in other words, that the thin edges ſhould be ſloped as the archſtones of a bridge are ſloped, ſo that the contiguous ſtaves may be brought into firm contact throughout the whole joint. This, however, is not the practice of the cooper. With great propriety he brings the contiguous ſtaves into contact at their inner ſurfaces only; ſo that by driving the hoops hard, he can make the joints much cloſer than he could poſſibly have done had the edges of the ſtaves been ſo ſloped as to permit them to touch each other throughout before being driven together by the compreſſion of the hoops. This, together with giving to the ſtaves the proper curvature, ſeems to be the only part of the cooper's work which deſerves the name of art; for the driving of the hoops and the forming of the bottoms could certainly be accompliſhed by any carpenter, we had almoſt ſaid by any man, though he had never ſeen a hoop driven or a bottom formed.

In many parts of Scotland, inſtead of ale or beer mugs, they uſe ſmall hooped wooden veſſels, of which the ſtaves are feather-edged or dove-tailed into one another. This, as the ſtaves are of different colours, increaſes the beauty of the veſſel, and to a ſuperficial obſerver appears to be an ingenious contrivance; but it adds nothing to the ſtrength or tightneſs of the ſeam, and cannot be attended with the ſmalleſt difficulty. We think, indeed, that in a large caſk or tub it would prove injurious to the ſeam; for either theſe dove-tails muſt be very thin ſlips raiſed from the interior edges of the ſtaves, which in many caſes could not be done if the wood were thoroughly ſeaſoned; or if they be cut out like inverted wedges, the contiguous ſtaves muſt be brought into contact from the interior to the exterior ſide previous to the driving of the hoops; and in that caſe, as we have ſeen, the ſeams could not be made completely tight.

COOPER, a large and navigable river which mingles its waters with Aſhley river below Charleſton city in S. Carolina. Theſe form a ſpacious and convenient harbor, which communicates with the ocean, juſt below Sullivan's iſland, which it leaves on the N. 7 miles S. E. of the city. In theſe rivers the tide riſes 6½ feet. Cooper river is a mile wide at the ferry, 9 miles above Charleſton.—*Morse.*

COOPER's *Iſland*, one of the leſſer Virgin Iſles in the Weſt-Indies, ſituated S. W. of Ginger Iſland, and uninhabited. It is 5 miles long, and 1 broad. N. lat. 18. 5. W. long. 62. 57.—*ib.*

COOPER's *Town*, a poſt town and townſhip, in Otſego co. New-York, and is the compact part of the townſhip of Otſego, and the chief town of the country round Lake Otſego. It is pleaſantly ſituated at the S. W. end of the lake, on its banks, and thoſe of its outlet; 12 miles N. W. of Cherry Valley, and 73 W. of Albany. Here are a court houſe, gaol, and academy. In 1791, it contained 292 inhabitants. In 1789, it had but 3 houſes only; and in the ſpring 1795, 50 houſes had been erected, of which above a fourth part were reſpectable 2 ſtory dwelling-houſes, with every proportionable improvement, on a plan regularly laid out in ſquares. N. lat. 42. 44. W. long. 74. 48.—*ib.*

COOPER's *Town*, Pennſylvania, is ſituated on the Suſquehanna river. This place in 1785, was a wilderneſs. Nine years after, it contained 1800 inhabitants —a large and handſome church, with a ſteeple—a market houſe and a bettering houſe—a library of 1200 volumes, and an academy of 64 ſcholars. Four hundred and ſeventy pipes were laid under ground, for the purpoſe of bringing water from Weſt Mountain, and conducting it to every houſe in town.—*ib.*

COOP's *Town*, in Harford co. Maryland, lies 12 miles N. W. of Harford, and 22 N. eaſterly of Baltimore; meaſuring in a ſtraight line.—*ib.*

COOS, or *Cohos*, the country called *Upper* and *Lower Coos*, lies on Connecticut river between 20 and 40 miles above Dartmouth college. Upper Cuos is the coun-

try

Coosades || Copernicus.

try S. of Upper Amonoosuck river on John and Israel rivers. Lower Coos lies below the town of Haverhill, S. of the Lower Amonoosuck. The distance from Upper Coos, to the tide in Kennebeck river, was measured in 1793, and was found to be but 90 miles.—*ib.*

COOSADES, an Indian town on Alabama river, about 60 miles above its mouth, on Mobile river; below M'Gillivray's town, and opposite the mouth of the Oaksuskee.—*ib.*

COOSA HATCHEE, or *Coosaw*, a river of S. Carolina, which rises in Orangeburg district, and running a S. S. W. course, empties into Broad river and Whale Branch, which separate Beaufort island from the main land.—*ib.*

COPERNICUS (Nicolaus), the restorer, if not the inventor, of the true system of the sun, holds so conspicuous a place in the republic of science, that every man of a liberal education must be interested both in the events of his life and in the history of his discoveries. Accordingly, in the Encyclopædia, we have given a short sketch of his history, as well as an account of what led him to suppose the sun placed in the centre of our system (see COPERNICUS, and ASTRONOMY, n° 22. *Encycl.*) Since these articles were published, Dr Adam Smith's *Essays on Philosophical Subjects* have been given to the world; and in that which is intitled *The History of Astronomy*, we have an account of Copernicus's discoveries, so much more perspicuous and satisfactory than any thing which we have elsewhere seen on the subject, that we are persuaded our readers will be pleased to meet with it here.

"The confusion (says Dr Smith) in which the old hypothesis represented the heavenly bodies, was, as Copernicus himself tells us, what first suggested to him the design of forming a new system, that these, the noblest works of Nature, might no longer appear devoid of that harmony and proportion which discover themselves in her meanest productions. What most of all dissatisfied him was, the notion of the equalizing circle, which, by representing the revolutions of the celestial spheres as equable only, when surveyed from a point that was different from their centres, introduced a real inequality into their motions; contrary to that most natural, and indeed fundamental idea, with which all the authors of astronomical systems, Plato, Eudoxus, Aristotle, even Hipparchus and Ptolemy themselves, had hitherto set out, that the real motions of such beautiful and divine objects must necessarily be perfectly regular, and go on, in a manner as agreeable to the imagination as the objects themselves are to the senses. He began to consider, therefore, whether, by supposing the heavenly bodies to be arranged in a different order from that in which Aristotle and Hipparchus had placed them, this so much sought for uniformity might not be bestowed upon their motions. To discover this arrangement, he examined all the obscure traditions delivered down to us, concerning every other hypothesis which the ancients had invented, for the same purpose. He found, in Plutarch, that some old Pythagoreans had represented the earth as revolving in the centre of the universe, like a wheel round its own axis; and that others, of the same sect, had removed it from the centre, and represented it as revolving in the ecliptic like a star round the central fire. By this central fire he supposed they meant the sun; and though in this he was very widely mistaken, it was, it seems, upon this interpretation that he began to consider how such an hypothesis might be made to correspond to the appearances. The supposed authority of those old philosophers, if it did not originally suggest to him his system, seems at least to have confirmed him in an opinion which, it is not improbable, he had before-hand other reasons for embracing, notwithstanding what he himself would affirm to the contrary.

"It then occurred to him, that if the earth was supposed to revolve every day round its axis, from west to east, all the heavenly bodies would appear to revolve, in a contrary direction, from east to west. The diurnal revolution of the heavens, upon this hypothesis, might be only apparent; the firmament, which has no other sensible motion, might be perfectly at rest, while the sun, the moon, and the five planets, might have no other movement beside that eastward revolution which is peculiar to themselves. That, by supposing the earth to revolve with the planets round the sun, in an orbit, which comprehended within it the orbits of Venus and Mercury, but was comprehended, within those of Mars, Jupiter and Saturn, he could, without the embarrassment of epicycles, connect together the apparent annual revolutions of the sun, and the direct, retrograde and stationary appearances of the planets; that while the earth really revolved round the sun, on one side of the heavens, the sun would appear to revolve round the earth on the other; that while she really advanced in her annual course, he would appear to advance eastward in that movement which is peculiar to himself. That, by supposing the axis of the earth to be always parallel to itself, not to be quite perpendicular, but somewhat inclined to the plane of her orbit, and consequently to present to the sun, the one pole when on the one side of him, and the other when on the other, he would account for the obliquity of the ecliptic, the sun's seemingly alternate progression from north to south, and from south to north, the consequent change of the seasons, and different lengths of days and nights in the different seasons.

"If this new hypothesis thus connected together all these appearances as happily as that of Ptolemy, there were others which it connected together much better. The three superior planets, when nearly in conjunction with the sun, appear always at the greatest distance from the earth, are smallest, and least sensible to the eye, and seem to revolve forward in their direct motion with the greatest rapidity. On the contrary, when in opposition to the sun, that is, when in their meridian about midnight, they appear nearest the earth, are largest, and most sensible to the eye, and seem to revolve backwards in their retrograde motion. To explain these appearances, the system of Ptolemy supposed each of these planets to be at the upper part of their several epicycles in the one case, and at the lower in the other. But it afforded no satisfactory principle of connection, which could lead the mind easily to conceive how the epicycles of those planets, whose spheres were so distant from the sphere of the sun, should thus, if one may say so, keep time to his motion. The system of Copernicus afforded this easily, and like a more simple machine, without the assistance of epicycles, connected together, by fewer movements, the complex appearances of the heavens. When the superior planets appear nearly in conjunction

conjunction with the ſun, they are then in the ſide of their orbits which is almoſt oppoſite to, and moſt diſtant from, the earth, and therefore appears ſmalleſt and leaſt ſenſible to the eye. But as they then revolve in a direction which is almoſt contrary to that of the earth, they appear to advance forward with double velocity; as a ſhip that ſails in a contrary direction to another; appears from that other to ſail both with its own velocity and the velocity of that from which it is ſeen. On the contrary, when thoſe planets are in oppoſition to the ſun, they are on the ſame ſide of the ſun with the earth, are neareſt it, moſt ſenſible to the eye, and revolve in the ſame direction with it; but as their revolutions round the ſun are ſlower than that of the earth, they are neceſſarily left behind by it, and therefore ſeem to revolve backwards; as a ſhip which ſails ſlower than another, though it ſails in the ſame direction, appears from that other to ſail backwards. After the ſame manner, by the ſame annual revolution of the earth, he connected together the direct and retrograde motions of the two inferior planets, as well as the ſtationary appearances of all the five.

"Thus far did this new account of things render the appearances of the heavens more completely coherent than had been done by any of the former ſyſtems. It did this, too, by a more ſimple and intelligible, as well as more beautiful machinery. It repreſented the ſun, the great enlightener of the univerſe, whoſe body was alone larger than all the planets taken together, as eſtabliſhed immoveable in the centre, ſhedding light and heat on all the worlds that circulated around him in one uniform direction, but in longer or ſhorter periods, according to their different diſtances. It took away the diurnal revolution of the firmament, whoſe rapidity, upon the old hypotheſis, was beyond what even thought could conceive. It not only delivered the imagination from the embarraſſment of epicycles, but from the difficulty of conceiving theſe two oppoſite motions going on at the ſame time, which the ſyſtem of Ptolemy and Ariſtotle beſtowed upon all the planets; I mean, their diurnal weſtward, and periodical eaſtward revolutions. The earth's revolution round its own axis took away the neceſſity for ſuppoſing the firſt, and the ſecond was eaſily conceived when by itſelf. The five planets, which ſeem, upon all other ſyſtems, to be objects of a ſpecies by themſelves, unlike to every thing to which the imagination has been accuſtomed, when ſuppoſed to revolve along with the earth round the ſun, were naturally apprehended to be objects of the ſame kind with the earth, habitable, opaque, and enlightened only by the rays of the ſun. And thus this hypotheſis, by claſſing them in the ſame ſpecies of things, with an object that is of all others the moſt familiar to us, took off that wonder and uncertainty which the ſtrangeneſs and ſingularity of their appearance had excited; and thus far, too, better anſwered the great end of philoſophy.

"Neither did the beauty and ſimplicity of this ſyſtem alone recommend it to the imagination; the novelty and unexpectedneſs of that view of nature which it opened to the fancy, excited more wonder and ſurpriſe than the ſtrangeſt of thoſe appearances, which it had been invented to render natural and familiar, and theſe ſentiments ſtill more endeared it. For though it is the end of philoſophy to allay that wonder which either the unuſual or ſeemingly disjointed appearances of nature excite, yet ſhe never triumphs ſo much as when, in order to connect together a few, in themſelves perhaps inconſiderable objects, ſhe has, if I may ſay ſo, created another conſtitution of things, more natural indeed, and ſuch as the imagination can more eaſily attend to, but more new, more contrary to common opinion and expectation, than any of thoſe appearances themſelves. As in the inſtance before us, in order to connect together ſome ſeeming irregularities in the motions of the planets, the moſt inconſiderable objects in the heavens, and of which the greater part of mankind have no occaſion to take any notice during the whole courſe of their lives, ſhe has, to talk in the hyperbolical language of Tycho Brahé, moved the earth from its foundations, ſtopt the revolution of the firmament, made the ſun ſtand ſtill, and ſubverted the whole order of the univerſe.

"Such were the advantages of this new hypotheſis, as they appeared to its author when he firſt invented it. But though that love of paradox, ſo natural to the learned, and that pleaſure which they are ſo apt to take in exciting, by the novelty of their ſuppoſed diſcoveries, the amazement of mankind, may, notwithſtanding what one of his diſciples tells us to the contrary, have had its weight in prompting Copernicus to adopt this ſyſtem; yet when he had completed his Treatiſe of Revolutions, and began coolly to conſider what a ſtrange doctrine he was about to offer to the world, he ſo much dreaded the prejudice of mankind againſt it, that, by a ſpecies of continence, of all others the moſt difficult to a philoſopher, he detained it in his cloſet for thirty years together. At laſt, in the extremity of old age, he allowed it to be extorted from him, but died as ſoon as it was printed, and before it was publiſhed."

This noble theory, however, being repugnant to the prejudices of habit and education, was at firſt coldly received, or utterly rejected, by every claſs of men. The aſtronomers alone favoured it with their notice, though rather as a convenient hypotheſis than an important truth. By the vulgar it was conſidered as a chimera, belied by the cleareſt evidence of our ſenſes; while the learned beheld it with diſdain, becauſe it militated againſt the fanciful diſtinctions and the vague erroneous tenets of the Peripatetic philoſophy, which no one had ventured to call in queſtion. And it is amuſing to obſerve with what dexterity the Copernicans, ſtill uſing the ſame weapons, endeavoured to parry the blows of their antagoniſts. Its real merits and blemiſhes appear to have been overlooked by both parties. Brahé framed a ſort of intermediate ſyſtem; but this Daniſh aſtronomer was more remarkable for his patience and ſkill in obſerving the heavens, than for his talents of philoſophical inveſtigation. Towards the commencement of the 16th century, a new order of things emerged. The ſyſtem of Copernicus became generally known and daily made converts. Its reception alarmed the ever-watchful authority of the church, rouſed her jealouſy, and at length provoked her vindictive artillery. The *ultima ratio theologorum* was pointed at the head of the illuſtrious Galileo, whoſe elegant genius diſcovered the laws of motion, extended the ſcience of mechanics, and added luſtre and ſolidity to the true ſyſtem of the univerſe. From the ſtorms of perſecution Copernicus himſelf had been exempted only by a timely death.

COPPER, one of the metals; for the properties of which, ſee CHEMISTRY-*Index* in this Supplement.— The

The Chinese have a metal which they call *pe-tung*, but which Sir George Staunton denominates

White Copper. This metal has a beautiful silver-like appearance and a very close grain. It takes a fine polish, and many articles of neat workmanship, in imitation of silver, are made of it. An accurate analysis has determined it to consist of copper, zinc, a little silver; and in some specimens a few particles of iron and of nickel have been found. From this account it would appear that white copper is not an artificial mixture of metals, but is found native in the mine. Yet in the very same page and paragraph Sir George proceeds to say that Dr Gillan was informed at Canton, that the artists, in making their pe-tung, reduce the copper into as thin sheets or laminæ, as possible, which they make red hot, and increase the fire to such a pitch as to soften in some degree the laminæ, and to render them ready almost to flow. In this state they are suspended over the vapour of their purest tu-te-nag, or zinc, placed in a subliming vessel over a brisk fire. The vapour thus penetrates the heated laminæ of the copper, so as to remain fixed with it, and not to be easily dissipated or calcined by the succeeding fusion it has to undergo. The whole is suffered to cool gradually, and is then found to be of a brighter colour, and of a closer grain, than when prepared in the European way. Surely this is not the white copper which consists of copper, zinc, silver, iron and nickel.

Copper Mine, a large river of New-Britain, reckoned to be the most northern in North-America. Taking a northerly course it falls into the sea in lat. 72. N. and about 119. W. long. from Greenwich. The accounts brought by the Indians of this river to the British ports in Hudson bay, and the specimens of copper produced by them, induced Mr Hearne to set out from Fort Prince of Wales in Dec. 1770, on a journey of discovery. He reached the river on the 14th July, at 40 miles distance from the sea, and found it all the way incumbered with shoals and falls, and emptying itself into it over a dry flat of the shore, the tide being then out, which seemed by the edges of the ice to rise about 12 or 14 feet. This rise, on account of the falls, will carry it but a very small way within the river's mouth; so that the water in it has not the least brackish taste. Mr Hearne had the most extensive view of the sea, which bore N. W. by W. and N. E.; when he was about 8 miles up the river. The sea at the river's mouth, was full of islands and shoals; but the ice was only thawed away about ¾ths of a mile from the shore, on the 17th of July. The Esquimaux had a quantity of whale bone and seal skins at their tents on the shore.—*Morse*.

COQUIMBO, a town of St Jago, or Chili Proper, in S. America, situated at the lower end of the vale, bearing the same name, on a gently rising ground. The river of Coquimbo gives name to the agreeable valley through which it rolls to the sea; and the bay at its mouth is a very fine one, where ships lie safely and commodiously, though the coast is rocky, some islands lying so as to keep off the winds. The town is properly called *La Serena*, from the agreeableness of the climate; being continually serene and pleasant. The streets are well laid out, and there are 5 or 6 convents; but the houses are not handsome. The soil is fruitful in corn, wine, and oil, and the brooks bring down quantities of gold dust after heavy rains. Here are no gold mines, but plenty of copper; one of which, 5 leagues N. from the city on Mount Cerro Verde, or Green Hill, is high, and shaped like a sugar loaf; so that it may serve as a land mark to the port. It lies 260 miles N. of St Jago, and justly boasts of one of the finest situations in the world; but the arbitrary government of Spain renders it a place of little importance.—*ib.*

CORAL *River*, in New Mexico, runs a course W. by S. and empties into the head of the gulf of California, close by the mouth of Collerado river.—*ib.*

CORAM, a post town in Suffolk co. Long Island, New-York. It has about 60 houses, and lies 62 miles eastward of New-York city, and 10 from Smithtown.—*ib.*

CORCAS, or *Grand Corcas*, an island almost in the form of a crescent, N. of St Domingo, in the windward passage, about 7 leagues W. of Turk's Island, and about 20 E. of Little Inagua, or Heneagua. N. lat. 21. 55. W. long. 70. 55.—*ib.*

CORDOVA, DE LA NUEVA ANDALUSIA, a city of Peru, in S. America, in the jurisdiction of Charcas, 80 leagues S. of Santiago del Estero. Here is the Episcopal church of Tucuman, with some monasteries, and a convent. It is fruitful in grain, honey, wax, fruits, cotton, and sugar. It abounds with salt-pits, and has luxuriant pastures for mules. It drives a great trade with Buenos Ayres. The inhabitants are Spaniards, who are farmers and manufacturers of cotton cloth, which they send to Potosi. S. lat. 31. 30. W. long. 63. 30. In Cordova, in the Tucuman, there has been found the greatest instance of longevity since the days of the patriarchs. From indisputable evidence, a negress, named Louisa Truxo, was alive in 1774, aged *one hundred and seventy-five years*.—*ib.*

CORE *Sound*, on the coast of North Carolina, lies S. of, and communicates with Pamlico.—*ib.*

CORIENTES, a cape of Mexico, or New-Spain, on the N. Pacific ocean. N. lat. 21. W. long. 109. 30. Also, the name of the S. westernmost point of the island of Cuba.—*ib.*

Corientes, Los, a small city within the government of Buenos Ayres, in S. America, was built by the Spaniards on the confluence of the Parana and Paraguay, 80 leagues higher than Santa Fe, on the Rio de la Plata.—*ib.*

CORINTH, a township in Orange co. Vermont, W. of Bradford, containing 578 inhabitants.—*ib.*

CORK is the exterior bark of a tree which has been described in the Encyclopædia. When the tree is about 15 years old it is fit to be barked, and this can be done successively for eight years. The bark always grows up again, and its quality improves as the age of the tree increases. It is commonly singed a little over a strong fire or glowing coals, or laid to soak a certain time in water, after which it is placed under stones in order to be pressed straight. We were wont to procure the greater part of our cork from the Dutch, who brought it principally from France; but they imported some also from Portugal and Spain.

This tree, as well as the uses to which its bark is put, was known to the Greeks and the Romans; by the former of whom it was called φελλος, and by the latter *suber*. By the Romans, as we learn from Pliny, it it was even employed to ftop veffels of every kind; but its application to this ufe feems not to have been very common till the invention of glafs bottles, of which Profeffor Beckmann finds no mention before the 15th century.

In later times, fome other vegetable productions have been found which can be employed inftead of cork for the laft mentioned purpofe. Among thefe is the wood of a tree common in South America, particularly in moift places, which is called there *monbin* or *monbain*, and by botanifts *fpondias lutea*. This wood is brought to England in great abundance for that ufe. The fpongy root of a North American tree, known by the name of *nyffa*, is alfo ufed for the fame end, as are the roots of liquorice, which on that account is much cultivated in Sclavonia, and exported to other countries.

CORNISH, a townfhip in Chefhire co. New-Hampfhire, on the E. bank of Connecticut river, between Claremont and Plainfield, about 15 miles N. of Charlef-town, and 16 S. of Dartmouth College. It was incorporated in 1763. In 1775, it contained 309, and in 1790—982 inhabitants.—*Morse*.

CORNUA AMMONIS, in natural hiftory, are foffil fhells, of which a pretty full account is given in the Encyclopædia. See CORNU *Ammonis* and SNAKE-*Stones*. It was obferved, in the laft of thefe articles, that few, if any, of thefe fhells are known in their recent ftate, or as occupied by the living animal; but fome authors have afferted on the authority of Linnæus, that *ammonites*, with fhells, fimilar to all the varieties of the foffil ones, are yet found alive in the depth of the fea. We are much inclined to embrace this opinion; but it has been controverted by *M. de Lamanon*, who accompanied *La Peroufe* on his voyage of difcovevery, by fuch arguments as we know not how to anfwer. This unfortunate naturalift (fee LAMANON in this Supplement) allows that there are ftill in the fea living *cornua ammonis*; but he thinks that they are in very fmall numbers, and materially different from the greater part of the foffil ones. According to him, thefe laft ought to be confidered as a race, formerly the moft numerous of all, of which, either there are no defcendants, or thofe defcendants are reduced to a few degenerate individuals. That there are no living animals with fhells of the very fame kind with fome of the foffil *cornua ammonis*, the following obfervations he confiders as a fufficient proof.

" The foffil fhells are very light and thin, whereas the fhells of thofe animals that live in very deep water are always thick and ponderous; befides, the form of the foffil cornua ammonis points out to us, in fome meafure, the organization of the animal which inhabited it. The celebrated Juffieu proved, in 1721, that there exifted a very clofe analogy between the ammonite and nautilus (A). It is well known that the nautilus, by filling or emptying a part of its fhell, has the power of remaining ftationary in any depth it pleafes: the fame was doubtlefs the cafe with the ammonite; and if this fpecies ftill abounds in the fea, it would furely be occafionally difcovered by failors.

" The waves alfo would throw fragments of it on the fhore; fifhermen might fometimes entangle it in their nets; or, a leaft, there would be fragments fticking to the lead of the founding line when afcertaining great depths. It may alfo be added, that if the ammonites never quitted the abyfs of the fea, thofe which are found petrified would not be conftantly met with on the fame level, and in the fame bed, as thofe fhell fifh that only inhabit the fhallows. There are, however, found in Normandy, Province, Touraine, and a multitude of other places, ammonites mixed with turbines, buccina (whelks), and other littoral fhells. They are found, hefides, at every degree of elevation from below the level of the fea to the fummits of the higheft mountains. Analogy alfo lead us to fuppofe, that Nature, who has given eyes to the nautilus, has not refufed them to the ammonite; now what ufe could thefe be of if they remained confined to thofe depths which the light is unable to penetrate?

" The extinction of the ancient race of ammonites is therefore an eftablifhed fact, which no rational fuppofition can deftroy; and this fact is undoubtedly the moft furprifing of any that is prefented to us in the hiftory of aquatic animals. The difcovery of a few living fpecies of cornua ammonis does not deftroy the truth of this, for thefe ammonites are very different from thofe which are found petrified. They are extremely rare, and cannot be looked up to as the reprefentatives of the old ammonites, fo varied in their fpecies, and the number of which in the ancient ocean was probably far more confiderable than that of all the other fhells befides."

To every univalve fhell, rolled in a fpiral, fo as that a horizontal plane will divide it into two equal parts, formed of united fpirals, and bearing a certain proportion to each other, our author gives the name of an *ammonite*. " I thought it abfolutely neceffary (fays he) to afcertain the precife meaning of the term *ammonite*, previous to defcribing that which I found during our voyage round the world. The form of this is almoft orbicular, the long diameter being to the fhort one as three lines to two lines and three quarters. The firft fpire is by far the largeft, occupying nearly half of the longitudinal diameter. The fummit is placed at the diftance of about two-thirds of this diameter; it is terminated on the right fide by a very fmall knob vifible only through a magnifier, thus differing from the ammonite of Rimini, which befides is microfcopical and eelled, the infide of this which we are now fpeaking of being entirely plain. The number of fpiral circumvolutions is four and a half; they are equally convex on both fides, and are fixed on a plane, dividing the fhell into two equal parts: there is on each fide a kind of bofs formed by the increafe of the perpendicular diameter of the fpires, in proportion as they recede from the centre. The furface is fmooth; the back is armed with a flat, even, brittle creft, as thin as paper, furrounding it on every fide like a ruff; it is about half a line broad, extends over the fummit of the fpires, and ferves to join them together. The mouth of the fhell is

(A) There are, however, fome ftriking internal differences: firft, the partitions in the fhell of the nautilus are more curved than thofe of the ammonite: fecondly, the ammonite wants the fmall hole which communicates from one cell to the other.

is nearly triangular; its edges project in the form of lips, and are rounded at the border. I have often found this ammonite enclosed in the stomach of the bonetta (scomber pelamis, Linn.), caught in the South Sea, between the tropics, where no bottom was found with a line of more than two hundred fathoms. These shells were covered with a black clayey mud. Their size varies from one to four lines across; they are consequently the largest living ammonites that have yet been discovered."

It is well known for what purpose the modern philosophers of France have been so indefatigable in the study of natural history; and there can be little doubt but that it is to serve the same purpose that Lamanon thus reasons for the destruction of the ancient race of ammonites in some universal convulsion of the world. But supposing his arguments conclusive, they affect not the truth of the Jewish and Christian scriptures. It is nowhere said in the Bible, that the *matter* of this globe was brought into being at the moment when Moses represents the Creator as beginning to reduce the chaos into order; and it is more than insinuated that there will be a *new earth* after the present system of things shall be dissolved. That *new* earth will certainly be stored with some kind of inhabitants; and could it be demonstrated that there was an *old* earth, previous to the era of the Mosaic cosmogony, inhabited by creatures rational and irrational, and that the fossil *cornua ammonis* make part of the wreck of that system, the cause of revelation would remain uninjured. "Moses, as a real philosopher* has well observed, writes the history, not of this globe through all its revolutions, but of the race of Adam."

* *Professor Robinson of Edinburgh.*

This secret attack, therefore, made by Lamanon against that religion of which he once professed to discharge the duties of a priest, is nothing more than *telum imbelle sine ictu*. Yet it may be worth some naturalist's while to enquire, whether, though feeble, it has been fairly made. We confess that our own suspicions of unfair dealing are strong; for when a man of science contradicts himself in the course of two pages, the blunder must be attributed to some other source than mere inadvertency. M. de Lamanon wishes to prove, among other things, that the ancient ammonites did not inhabit great depths of the sea; and that Linnæus was mistaken when he supposed that in great depths they may still be found. Yet he himself tells us, that he frequently caught ammonites in the South Sea, where no bottom was to be found with a line of *more than* 200 *fathoms*; and to put it beyond a doubt that the animals had been at that bottom, he informs us, that their shells were covered with a *black clayey mud*. It is true these ammonites were but small; while of 300 varieties of fossil ammonites which he mentions, some, he says, have been found ten feet in circumference. But is it certain that these large shells were real *cornua ammonis?* If they agree not exactly with our author's description of the shell of the ammonite (a fact into which we have had no opportunity of inquiring), his arguments for the extinction of the ancient race are gross sophisms, unworthy of a man either of science or of candour.

CORNWALL, a township in Addison co. Vermont, E. of Bridport, on Lake Champlain, containing 826 inhabitants.—*Morse.*

Cornwall, New, a township in Orange co. New-York, of whose inhabitants, 350 are electors.—*ib.*

Cornwall, a township in Litchfield co. Connecticut, about 9 miles N. of Litchfield, 11 S. of Salisbury, and about 40 W. by N. of Hartford city.—*ib.*

Cornwall, a small town in Upper Canada, on the bank of Iroquois river near Lake St Francis, between Kingston and Quebec, containing a small church, and about 30 or 40 houses.—*ib.*

CORNWALLIS. a town in King's co. in the province of New-Brunswick, situated on the S. W. side of the Basin of Minas; 18 miles N. W. of Falmouth, and 55 N. W. of Annapolis.

Also, a river in the same province, navigable for vessels of 100 tons 5 miles; for vessels of 50 tons 10 miles.—*ib.*

CORO, a town of S. America, in Terra Firma, at the bottom of the gulf of Venezuela, 60 miles W. of La Guaira. N. lat. 11. W. long. 70.—*ib.*

COROPA, a province of S. America, situated between the river Amazon and the lake Parime.—*ib.*

CORRECTION-house is a prison where idle vagrants are compelled to work, and where persons guilty of certain crimes suffer punishment and make reparation to the public. Of the former kind of *correction-houses*, perhaps enough has been said in the Encyclopædia under the title Work-*House;* but of the latter very little will be found in that work under the titles Bridewell and Idleness.

Perhaps houses of correction, as means of punishment, are not, in this country, employed so frequently as justice and expediency seem to require. In the opinion of Dr Paley, whose opinions are always worthy of attention, it is one of the greatest defects of the laws of England (and we may say the same thing of the laws of Scotland), that "they are not provided with any other punishment than that of death, sufficiently terrible to keep offenders in awe. Transportation, which is the punishment second in the order of severity, answers the purpose of example very imperfectly; not only because exile is in reality a slight punishment to those who have neither property, nor friends, nor regular means of subsistence at home, but because the punishment, whatever it be, is unobserved and unknown. A transported convict *may* suffer under his sentence, but his sufferings are removed from the view of his countrymen; his misery is unseen; his condition strikes no terror into the minds of those for whose warning and admonition it was intended. This chasm in the scale of punishment produces also two farther imperfections in the administration of penal justice; of which the first is, that the same punishment is extended to crimes of very different characters and malignancy; and the second, that punishments, separated by a great interval, are assigned to crimes hardly distinguishable in their guilt and mischief."

Perhaps this chasm might be properly filled up by houses of correction under judicious management, which might likewise promote another important purpose, better than the punishments in common use.

The end of punishment is twofold, *amendment* and *example*. In the first of these, the *reformation* of criminals, little has ever been effected, and little indeed seems practicable by the punishments known to the laws

Correction. of Britain. From every ſpecies of puniſhment inflicted among us, from impriſonment and exile, from pain and infamy, malefactors return more hardened in their crimes, and more inſtructed. The caſe we think would often be different when they returned to the world from a well-regulated houſe of correction. As experience is the only ſafe guide in matters of legiſlation and police, we ſhall lay before our readers *M. Thouin's* account of the houſe of correction at Amſterdam, which ſeems to corroborate our opinion.

The Amſterdam correction houſe, from the employment of the priſoners confined in it, is called the *raſping-houſe*, and is deſtined to the reception of thoſe malefactors whoſe crimes do not amount to a capital offence. Their puniſhment cannot ſo properly be denominated ſolitary confinement as a ſequeſtration from ſociety during a limited term of years. The building is ſituated in a part of the ſuburbs to the north eaſt of the city. The exterior has nothing remarkable, either with reſpect to form or extent. It is detached from the ſtreet by a ſpacious court, which contains the keeper's lodge, together with apartments for the different ſervants belonging to the eſtabliſhment. Over the gate, which opens from this court into the priſon, are placed two ſtatues, as large as life, repreſenting two men in the act of ſawing a piece of logwood.

The inner court is in the form of a ſquare, round which are arranged the apartments of the priſoners, together with the neceſſary warehouſes. One part of the ground ſtory is divided into different chambers; the other ſerves as a depot for the logwood, and the implements employed in its preparation.

The keeper, whoſe countenance, contrary to the general cuſtom of perſons of his profeſſion, was ſtrongly indicative of urbanity and gentleneſs, introduced M. Thouin into an apartment where two priſoners were at work in ſawing a large log of Campeachy wood. The ſaw is compoſed of four blades joined together, with very ſtrong, large, and ſharp teeth, which make a ſciſſure in the wood of nearly two inches in breadth. The operation is repeated, till the pieces become too ſmall to undergo the ſaw, when they are ground in mills peculiarly conſtructed for this purpoſe.

This employment requires an extraordinary exertion of ſtrength, and is at firſt a ſevere penance even to robuſt perſons; but habit, addreſs, and practice, ſoon render it eaſy; and the priſoners in a ſhort time become competent to furniſh, without painful exertion, their weekly contingent of 200lb. weight of ſawed pieces. After completing this taſk, they even find time to fabricate a variety of little articles in wood and ſtraw, which they ſell to thoſe who viſit the priſon, or diſpoſe of, by means of agents, in the town.

M. Thouin next inſpected three apartments of different dimenſions, which opened into the inner court. The one was inhabited by four, the ſecond by ſix, and the third by ten priſoners. The furniture of the rooms conſiſted in hammocks, with a matraſs, a blanket, and a coverlid to each, tables, chairs, and ſtools, glaſs, &c. earthen veſſels, and various other articles of convenience. Every thing in theſe apartments was diſtinguiſhed by neatneſs and propriety; and notwithſtanding the number of inhabitants allotted to each, was fully adequate to the dimenſions of the rooms; the ſenſes were not offended with any diſagreeable ſcent, and the air was in every reſpect as pure and wholeſome as the ſurrounding atmoſphere. Correction.

In an obſcure part of the building are a number of cells, in which formerly thoſe priſoners who revolted againſt the proper ſubordination of the place, or ill-treated their comrades, were confined for a few days. But the keeper aſſured M. Thouin that theſe cells had not been made uſe of for upwards of 10 years. They are dark gloomy dungeons, with only a ſmall aperture for the admiſſion of light and air. The ſuppreſſion of this barbarous and coercive puniſhment does honour to the humanity of government.

The ſtore-rooms are filled with various kinds of wood for the purpoſes of dyeing; as the haemotoxylum campechianum, the morus tinctoria, the caeſalpinia ſappan, &c. They are all exotics, with the exception of the Evonymus Europæus. The warehouſes were not of ſufficient extent to contain the quantity of wood, which was depoſited in piles in different parts of the court.

The priſoners, amounting to 76 in number, were uniformly habited in coarſe woollens; wear very good ſtockings, large leather ſhoes, white ſhirts, and caps or hats. They are, by the rules of the houſe, obliged to frequent ablutions, which greatly contribute to the preſervation of their health. There was only one ſick perſon among them; and, what is not a little remarkable, almoſt all the priſoners had formerly lived in large commercial towns; very few villagers were amongſt them. They had all been ſentenced to impriſonment for theft; but it depends upon themſelves, by reformation and good behaviour, to ſhorten the term of their confinement, which many of them frequently do.

The keeper, whoſe humanity to the unfortunate perſons committed to his care intitles him rather to the title of their protector than their gaoler (and M. Thouin informs us, that the priſoners generally called him by no other name than *father)*, aſſiſts them with his counſels and friendly admonitions. He regiſters every week, in a book appropriated to this purpoſe, both the inſtances of good and bad behaviour, which is annually ſubmitted to the examination of the magiſtracy, who, from this report, abridge or prolong the term of confinement according to the degree of indulgence which each priſoner appears to merit. Caſes frequently happen, where a malefactor, condemned to an impriſonment of eight years, by his good behaviour procures his enlargement at the expiration of four; and ſo in proportion for a ſhorter term. But great attention is paid to diſcriminate between actual reform and hypocritical artifice.

The reward of good behaviour is not, however, confined to, or withheld till, the period of actual liberation. Their reſtoration to ſociety is preceded by a progreſſive amelioration of their lot. Their work is gradually rendered leſs laborious, they are accommodated with ſeparate apartments, and employed in the ſervices of domeſtic economy. The keeper even entruſts them with commiſſions beyond the precincts of the priſon; and ſcarce a ſingle inſtance has occurred of their abuſing this indulgence. By this prudent management, a conſiderable ſaving is effected in the expence of the eſtabliſhment, at the ſame time that it tends to wear away prejudice, and to initiate the priſoners, by gradual advances, into the reciprocal duties of ſocial life.

M. Thouin made particular inquiries whether it was cuſtomary

customary for persons after their discharge to be confined a second and third time, as is but too often the case in many countries, for a repetition of their offence. He was informed, that such instances very rarely occur; but the case is not without precedent, as he observed in the person of a young Jew, who was then in the rasping-house for the third time. The case of this man is somewhat extraordinary. During the period of his detention, he always conforms, with the most scrupulous observance, to the rules of the place, and gives general satisfaction by his exemplary conduct. But such, as he himself avowed to our traveller, is his constitutional propensity to thieving, that no sooner is the term of his imprisonment elapsed, than he returns with redoubled ardour to his lawless courses. It is not so much for the sake of plunder as to gratify his irresistible impulse, that he follows this vicious life; and M. Thouin adds, that he recounted his different exploits with as much exultation and triumph, as a veteran displays when rehearsing his warlike atchievements.

Another salutary regulation in this institution, from which the best consequences result, is the indulgence granted to the prisoners of receiving the visits of their wives and mistresses twice every week. Proper care, however, is taken to guard against the introduction of disease; and the ladies, in one sense, purchase their admission by giving a trifling sum of money at the gate, which becomes the perquisite of the aged prisoners, whose wants are of a different nature from their youthful comrades. Thus the pleasures of one class contribute to the comforts of the other; and the entrance money, trifling as it is, keeps away a crowd of idle vagabonds, who have no acquaintance with the prisoners. The ladies at their visits are permitted to eat and drink with their lovers; and when the conversation becomes too animated for a third person to be present, the rest of the company obligingly take the hint, and leave them to enjoy a *tete-a-tete*.—By this prudent regulation, many hurtful consequences attendant on a total seclusion from female society are guarded against.

M. Thouin concludes his account with observing, that the rasping-house at Amsterdam bears a greater resemblance to a well-ordered manufactory than to a prison. It were to be wished that all similar institutions were conducted upon a similar plan (A).

So says our author: But though we have admitted experience to be the only safe guide in regulating institutions of this kind, we cannot help thinking that the plan is susceptible of improvement. We do not see the propriety of locking up four, six or ten thieves in the same apartment. The uncommon attention to cleanliness, which distinguishes all ranks among the Dutch, may indeed prevent the room from having an offensive scent; but what can prevent such a number of unprincipled persons from corrupting each other in Holland, as we know that they do in Great Britain? The introduction of females of loose character to felons suffering punishment for their offences in a prison, is a practice which we trust will be approved only by philosophers of the French school. The British philosopher, whom we have already quoted with approbation, is of opinion, and we heartily agree with him, that "of reforming punishments, none promises so much success as that of solitary imprisonment, or the confinement of criminals in separate apartments. This improvement of the Amsterdam house of correction would augment the terror of the punishment, would seclude the criminal from the society of his fellow prisoners, in which society the worst are sure to corrupt the better; would wean him from the knowledge of his companions, and from the love of that turbulent pernicious life in which his vices had engaged him; would raise up in him reflections on the folly of his choice, and dispose his mind to such bitter and continual penitence, as might produce a lasting alteration in the principles of his conduct."

In some houses of correction the prisoners are subjected to the discipline of flagellation at stated intervals. We will not take it upon us to say that this punishment is never proper; but we are fully convinced that it is not often so; and that flagellation, if it can at all produce any good effect, must be administered in private. It is observed by Fielding, who well understood human nature, that fasting is the proper punishment of profligacy, not any punishment that, like flagellation, is attended with shame. Punishment (says he) that deprives a man of all sense of honour, never will contribute to make him virtuous; and we believe it is generally admitted by the gentlemen of the army, that a soldier who has suffered the punishment of whipping seldom proves good for any thing.

CORTLANDT, a township in the northern part of the county of West Chester, on the E. bank of Hudson river, New-York, containing 1932 inhabitants, of whom 66 are slaves. Of its inhabitants, in 1796, 305 were electors.—*Morse*.

COSTA RICA, or the *Rich Coast*, as its name signifies, is so called from its rich mines of gold and silver, those of Tinsigal being preferred by the Spaniards to the mines of Potosi; but in other respects, it is mountainous and barren. It is situated in the audience of Guatimala, in New-Spain, bounded by the province of Veragua on the S. E. and that of Nicaragua on the N. E. It reaches from the N. to the S. sea, about 90 leagues from E. to W. and is 50 where broadest, from N. to S. It has much the same productions as its neighbouring provinces; and in some places the soil is good, and it produces cocoa. On the N. sea it has two convenient bays, the most westerly called St Jerom's, and that near the frontiers of Veragua, called Caribaco; and on the S. sea it has several bays, capes, and convenient places for anchorage. Chief town Nycoya.—*ib.*

COTABAMBO, a jurisdiction in Peru, S. America, subject to the bishop of Cusco, and lies 20 leagues S. W. of that city. It abounds in grain, fruits, and cattle. Its rich mines are now almost exhausted.—*ib.*

COTEAUX, LES, a town on the road from Tiburon to Port Salut, on the S. side of the S. peninsula of the island of St Domingo, $13\frac{1}{2}$ leagues E. by S. of the

(A) We do not know that M. Thouin's journal of his travels has been yet published. Extracts from it have been inserted into the *Decade*, a periodical publication at Paris, whence this account of the *Amsterdam house of correction* was first copied into the Monthly Magazine for June 1798.

the former, and 4 N. W. of the latter. N. lat. 18. 12.—*ib.*

COTOPAXI, a large volcano near Lataacungo, an affiento or dependence on the province of Quito, in Peru, S. America. It lies nearly under the line, yet the tops of it are generally covered with ice and fnow. It firft fhewed itfelf in 1553, when Sebaftian de Belacazar firft entered thefe countries, which eruption proved favourable to his enterprife, as it coincided with a prediction of the Indian priefts, that the country fhould be invaded on the burfting of this volcano; and accordingly it fo happened; for before 1559 he had fubdued all the country.—*ib.*

COTUY, a canton and town in the Spanifh part of the ifland of St Domingo, bounded E. by the bay of Samana, N. by the chain of mountains called Monte-Chrifti, W. by the territory of la Vega, and S. by the chain of mountains called Sévico. In 1505, the gold mines were worked here. In the mountain of Meymon, whence comes the river of the fame name, there is a copper mine, fo rich, that when refined will produce 8 per cent. of gold. Here are alfo found excellent lapis-lazuli, a ftreaked chalk, that fome painters prefer to bole for guilding; loadftone, emeralds, and iron. The iron is of the beft quality, and might be conveyed from the chain of Sévico by means of the river Yuna. The foil here is excellent, and the plantanes produced here are of fuch fuperior quality, that this manna of the Antilles is called at St Domingo Sunday plantanes. The people cultivate tobacco, but are chiefly employed in breeding fwine. The inhabitants are called clownifh, and of an unfociable character.

The town is fituated half a league from the S. W. bank of the Yuna, which becomes unnavigable near this place, about 13 leagues from its mouth in the bay of Samana. It contains 160 fcattered houfes, in the middle of a little favanna, and furrounded with woods, 30 leagues northerly of St Domingo, and 12 S. E. of St Yago. N. lat. 19. 11. W. long. from Paris 72. 27.—*ib.*

COUDRAS, a fmall ifland in St. Lawrence river, about 45 miles N. E. of Quebec.—*ib.*

COUNTRY *Harbor*, fo called, is about 20 leagues to the eaftward of Halifax, in Nova-Scotia.—*ib.*

COUPEE', or *Cut Point*, a fhort turn in the river Miffiffippi, about 35 miles above Mantchac fort, at the gut of Ibberville, and 259 from the mouth of the river. Charlevoix relates that the river formerly made a great turn here, and fome Canadians, by deepening the channel of a fmall brook, diverted the waters of the river into it, in the year 1722. The impetuofity of the ftream was fuch, and the foil of fo rich and loofe a quality, that in a fhort time the point was entirely cut through, and the old channel left dry, except in inundations: by which travellers fave 14 leagues of their voyage. The new channel has been founded with a line of 30 fathoms, without finding bottom.

The Spanifh fettlements of Point Coupeé, extend 20 miles on the W. fide of the Miffiffippi, and there are fome plantations back, on the fide of La Faufe Riviere, through which the Miffiffippi paffed about 70 years ago. The fort at Point Coupeé is a fquare figure, with four baftions, built with ftockades. There were, fome years fince, about 2000 white inhabitants and 7000 flaves. They cultivate Indian corn, tobacco, and indigo; raife vaft quantities of poultry, which they fend to New-Orleans. They alfo fend to that city fquared timber, ftaves, &c.—*ib.*

COURTESEY OF SCOTLAND. See LAW *(Encycl.)*, Part III. fect ix § 28.

COVENTRY, a townfhip in Tolland co. Connecticut, 20 miles E. of Hartford city. It was fettled in 1709, being purchafed by a number of Hartford gentlemen of one Jofhua, an Indian.—*Morse.*

COVENTRY, in Rhode-Ifland ftate, is the N. eafternmoft townfhip in Kent co. It contains 2477 inhabitants.—*ib.*

COVENTRY, a townfhip in the northern part of New-Hampfhire, in Grafton co. It was incorporated in 1764, and contains 80 inhabitants.—*ib.*

COVENTRY, a townfhip in Orleans co. Vermont. It lies in the N. part of the ftate, at the S. end of Lake Memphremagog. Black river paffes through this town in its courfe to Memphremagog.—*ib.*

COVENTRY, a townfhip in Chefter co. Pennfylvania. —*ib.*

COWE', is the capital town of the Cherokee Indians, fituated on the foot of the hills, on both fides of the river Tenneffee. Here terminates the great vale of Cowé, exhibiting one of the moft charming, natural, mountainous landfcapes that can be feen. The vale is clofed at Cowé by a ridge of high hills, called the *Jore mountains*. The town contains about 100 inhabitants.

In the conftitution of the ftate of Tenneffee, Cowé is defcribed as near the line which feparates Tenneffee from Virginia, and is divided from Old-Chota, another Indian town, by that part of the Great Iron or Smoaky mountain, called Unicoi, or Unaca mountain.—*ib.*

COWETAS, or *Kowetas*, a town of the Lower Creeks, in Eaft-Florida, called the Bloody-town. It lies on the W. bank of Chata-Uche river and contains 280 men.—*ib.*

COWPENS, a place fo called, in S. Carolina, between Pacolet river and the head branch of Broad river. This is the fpot where Gen. Morgan gained a complete victory over lieut. col. Tarleton, Jan. 11, 1781, having only 12 men killed and 60 wounded. The Britifh had 39 commiffioned officers killed, wounded and taken prifoners; 100 rank and file killed, 200 wounded, and 500 prifoners. They left behind 2 pieces of artillery, 2 ftandards, 800 mufkets, 35 baggage-waggons, and 100 dragoon horfes, which fell into the hands of the Americans. The field of battle was in an open wood.—*ib.*

COWRY-SHELLS, the loweft money in fome parts of the Eaft. See MONEY *(Encycl.)*, where they are called *karis*.

COXHALL, a townfhip in York co. diftrict of Maine, containing 775 inhabitants.—*Morse.*

COXSAKIE, a townfhip in the weftern part of Albany co. New-York, containing 3406 inhabitants, of whom 302 are flaves. Of the citizens 613 are electors.—*ib.*

COYAU, a fettlement on Tenneffee river, 30 miles below Knoxville —*ib.*

CRAB-ORCHARD, a poft town, on Dick's river, in Kentucky, 8 miles from Cumberland river, and 25 miles

Cranberry || Crane.

miles S. E. of Danville. The road to Virginia passes through this place.—*ib.*

CRANBERRY, a thriving town in Middlesex co. New-Jersey, 9 miles E. of Princeton, and 16 S. S. W. of Brunswick. It contains a handsome Presbyterian church, and a variety of manufactures are carried on by its industrious inhabitants. The stage from New-York to Philadelphia passes through Amboy, this town, and thence to Bordentown.—*ib.*

CRANBERRY *Islands*, on the coast of the district of Maine.—*ib.*

CRANE, in mechanics, a machine used for raising or lowering great weights. For the principles on which these machines act, see DYNAMICS in this *Supplement*, and likewise MECHANICS, *Encycl.* where descriptions are given of several very powerful cranes.

The crane in common use is employed with some danger to those who work it; and therefore a machine of this kind, acting upon a simple and certain principle, by which the men walking in the wheel can lower goods with safety as well as expedition, has long been considered as a great desideratum in mechanics. Repeated premiums have been offered by the *Society for the Encouragement of Arts*, to induce ingenious men to attempt the invention of such a machine; and various have been the contrivances for accomplishing so desirable a purpose. A clergyman, who subscribes E. C. we suppose as the initials of his name, proposes, through the medium of the Repertory of Arts, to accomplish it merely by introducing the action of a worm or screw into the crane.

Whenever a worm of two threads is introduced into a machine, all retrograde motion is stopped, unless that worm receive its reaction from the first moving force; for, powerfully as a worm acts upon a wheel, a wheel has no power upon a worm, whatever force may be applied to it. Suppose, then, the first motion in a crane were given by a worm upon the axis of the wheel in which the man walks, the man would have perfect command of the machine, to raise or lower the goods at pleasure, with the remotest possibility of being overpowered by the descending weight.

"Were I to construct (says the author) a crane upon this principle, I would have the axis of the wheel in which the man walks, and the axis of the worm, in separate parts, and occasionally united by a coupling-box, When goods were to be raised, the two axes should be connected; when lowered, they might be disunited, and the worm turned by a winch, which would be done much more expeditiously that way than by the wheel. For the reasons before suggested, the descent of the weight could be accelerated or stopped at pleasure, at the discretion of the person turning the winch.

"This contrivance might be not inconveniently applied to a crane already erected upon the common principle: Let there be a wheel put upon any convenient axis in the machine as it now stands; upon this let there lie a worm that can be thrown in or out of gear at pleasure; and let the lever by which it is done lie within reach of the man's hand in the wheel. The goods being fastened to the crane, and raised off the floor of the warehouse ready for letting down, the man puts the worm into gear, leaves the wheel, and lets the goods down by the winch. Provided it can be conveniently done, it would be advisable to throw the wheel in which the man walks out of gear, when the winch is made use of: this, however, I should apprehend, would not be a matter of absolute necessity."

Crane.

Our author is aware of two objections which may be urged against the introduction of a worm into a crane in the manner which he proposes. The first arises from the slowness of the motion produced by the turning of a screw which he considers as unworthy of regard; because the necessary speed is to be gained by the first pair of wheels, and the diameter of the barrel of the windlass.

To the second, arising from the supposed greater friction between a worm and wheel, he replies, that as the friction between the teeth of two wheels (if not formed on the true epicycloidal principle) must, while it lasts, be greater than between a worm and wheel for the same space of time, it seems no unreasonable supposition that the aggregate of friction will, in the two cases, nearly balance each other; especially if it be taken into the account, that to obtain the power of one worm and wheel, there will be, in most cases, required two pair of wheels, and two additional axes—all which will add to the friction. But granting the balance of friction to be against the action of the worm, the power to overcome it is greater in proportion than to overcome the friction of two wheels.

Mr James Whyte of Chevening, in the county of Kent, whose improvement in the construction of pullies, has with due respect been noticed elsewhere*, gives, in *the Transactions of the Society for the Encouragement of Arts*, &c. the following description of a new crane for wharfs:

* See *Mechanics*, n° 27. *Encycl.*

Plate XX.

A (fig. 1.), a circular inclined plane, moving on a pivot underneath it, and carrying round with it the axis E. A person walking on this plane, and pressing against the lever B, throws off the gripe D, by means of an iron rod C; and thus admits the plane and its axis to move freely, and raise the weight G by the coiling of the rope F round the axis E.

To shew more clearly the construction and action of the lever and gripe, a plan of the circular inclined plane, with the lever and gripe, is added (see fig. 2.), where B represents the lever, D the spring or gripe. In this plan, when the lever B is in the situation in which it now appears, the spring or gripe D presses against the periphery of the plane, as shewn by the double line, and the machine cannot move; but when the lever B is pressed out to the dotted line H, the gripe is also thrown off to the dotted line I, and the whole machine left at liberty to move. One end of a rope or cord, of a proper length, is fixed near the end of the lever B, and the other end made fast to one of the uprights, serving to prevent the lever moving too far when pressed by the man.

The properties of this crane, for which the premium of 40 guineas was adjudged by the society to the inventor, are as follows:

1. It is simple, consisting merely of a wheel and axle. 2. It has comparatively little friction, as is obvious from the bare inspection of the figure. 3. It is durable, as is evident from the two properties above-mentioned. 4. It is safe; for it cannot move but during the pleasure of the man, and while he is actually pressing on the gripe-lever. 5. This crane admits of an almost infinite variety of different powers, and this variation is obtained without the least alteration of any part of the machine.

machine. If, in unloading a veſſel, there ſhould be found goods of every weight, from a few hundreds to a ton and upwards, the man that does the work will be able ſo to adapt his ſtrength to each as to raiſe it in a ſpace of time proportionate to its weight; he walking always with the ſame velocity as nature and his greateſt eaſe may teach him.

It is a great diſadvantage in ſome cranes, that they take as long time to raiſe the ſmalleſt as the largeſt weight, unleſs the man who works them turn or walk with ſuch velocity as muſt ſoon tire him. In other cranes, perhaps, two or three different powers may be procured; to obtain which, ſome pinion muſt be ſhifted, or freſh handle applied or reſorted to. In this crane, on the contrary, if the labourer find his load ſo heavy as to permit him to aſcend the wheel without its turning, let him only move a ſtep or two toward the circumference, and he will be fully equal to the taſk. Again, if the load be ſo light as ſcarcely to reſiſt the action of his feet, and thus to oblige him to run through ſo much ſpace as to tire him beyond neceſſity, let him move laterally towards the centre, and he will ſoon feel the place where his ſtrength will ſuffer the leaſt fatigue by raiſing the load in queſtion. One man's weight applied to the extremity of the wheel would raiſe upwards of a ton; and it need not be added, that a ſingle-ſheaved block would double that power. Suffice it to ſay, that the ſize may be varied in any required *ratio;* and that this wheel will give as great advantage at any point of its plane as a common walking-wheel of equal diameter, as the inclination can be varied at pleaſure, as far as expediency may require. It may be neceſſary to obſerve, that what in the figure is the frame, and ſeems to form a part of the crane, muſt be conſidered as a part of the houſe in which it is placed; ſince it would be moſtly unneceſſary ſhould ſuch cranes be erected in houſes already built. With reſpect to the horizontal part, by walking on which the man who attends the gib occaſionally aſſiſts in raiſing the load, it is not an eſſential part of this invention, where the crane is not immediately contiguous to the gib, although, where it is, it would be certainly very convenient and economical.

Crane is alſo a popular name for a ſyphon, employed in drawing off liquors.

CRANEY, a ſmall iſland, on the S. ſide of James river, in Virginia, at the mouth of Elizabeth river, and 5 miles S. W. of Fort George, on Point Comfort. It commands the entrance of both rivers.—*Morſe.*

CRANSTON, is the ſouth-eaſternmoſt townſhip of Providence co. Rhode-Iſland, ſituated on the W. bank of Providence river, 5 miles S. of the town of Providence. The compact part of the town contains 50 or 60 houſes, a Baptiſt meeting-houſe, handſome ſchool-houſe, a diſtillery, and a number of ſaw and griſt mills, and is called Pawtuxet, from the river, on both ſides of whoſe mouth it ſtands, and over which is a bridge, connecting the two parts of the town. It makes a pretty appearance as you paſs it on the river. The whole townſhip contains 1877 inhabitants.—*ib.*

CRAVEN *Co.* in Newbern diſtrict, N. Carolina, is bounded N. by Pitt, and S. by Carteret and Onſlow counties. Its chief town is Newbern. It contains 10,469 inhabitants, of whom 3658 are ſlaves.—*ib.*

CREE INDIANS, They inhabit weſt of little lake Winnipeg, around fort Dauphin, in Upper Canada. —*ib.*

CREEGER's *Town*, in Frederick co. Maryland, lies on the W. ſide of Monococy river, between Owing's and Hunting creeks, which fall into that river; 9 miles ſoutherly of Ermmtſburgh, near the Pennſylvania line, and about 11 northerly of Fredericktown.—*ib.*

CREEKS *Croſſing Place*, on Tenneſſee river, is about 40 miles E. S. E. of the mouth of Elk river at the Muſcle ſhoals, and 36 S. W. of Nickajack, in the Georgia weſtern territory.—*ib.*

CROIX, ST, a ſmall navigable river in Nova-Scotia, which runs into the Avon, or Pigiguit.—*ib.*

Croix, St, a river which forms part of the boundary line between the United States and the Britiſh province of New-Brunſwick, and empties into Paſſamaquoddy bay. Which is the true St Croix is undetermined. Commiſſioners are appointed by both countries, in conformity to the late treaty, to decide this point.—*ib.*

Croix, St, a river in the N. W. territory, which empties into the Miſſiſſippi from the N. N. E. about 50 miles below the falls of St Anthony.—*ib.*

Croix, St, or *Santa Cruz*, an iſland in the Weſt-Indies, belonging to the king of Denmark, lying about 5 leagues S. E. of St Thomas, and as far E. by S. of Crab iſland, which lies on the E. end of Porto Rico. It is about 30 miles in length, and 8 where it is broadeſt, and is rather unhealthy. It is ſaid to produce 30,000 or 40,000 hhds. of ſugar, annually, and other Weſt-India commodities in tolerable plenty. It is in a high ſtate of cultivation, and has about 3000 white inhabitants, and 30,000 ſlaves. A great proportion of the negroes of this iſland have embraced chriſtianity, under the Moravian miſſionaries, whoſe influence has been greatly promotive of the proſperity of this iſland. N. lat. 17. 50. W. long. 64. 30.—*ib.*

CROOKED *Iſland*, one of the Bahama or Lucayo iſlands, in the Weſt-Indies. The middle of the iſland lies in N. lat. 23. W. long. 73. 30.—*ib.*

Crooked *Lake*, in the Geneſſee country, communicates in an E. by N. direction with Seneca lake.—*ib.*

Crooked *Lake*, one of the chain of ſmall lakes which connects the lake of the Woods with lake Superior, on the boundary line between the United States and Upper Canada, remarkable for its rugged cliffs, in the cracks of which are a number of arrows ſticking.—*ib.*

Crooked *River*, in Camden co. Georgia, empties into the ſea oppoſite Cumberland iſland, 12 or 14 miles N. from the mouth of St Mary's. Its banks are well timbered, and its courſe is E. by N.—*ib.*

CROSS, *in ſurveying*, is an inſtrument conſiſting of a braſs circle, divided into four equal parts by two lines croſſing each other in the centre. At each extremity of theſe lines is fixed a perpendicular ſight, with ſmall holes below each ſlit, for the better diſcovering of diſtant objects. The croſs is mounted on a ſtaff or ſtand, to fix it in the ground, and is very uſeful for meaſuring ſmall pieces of land, and taking offſets, &c.

Cross ſtaff, or *Fore-ſtaff*, is a mathematical inſtrument of box or pear-tree, conſiſting of a ſquare ſtaff of about three feet long, having each of its faces divided like a line of tangents, and having four croſs pieces of unequal lengths to fit on the ſtaff, the halves of theſe being as the radii to the tangent lines on the faces of the ftaff.—The inftrument was ufed in taking the altitudes of the celeftial bodies at fea.

Cross *Cape*, in Upper Canada, projects from the N. E. fide of St Mary's river, at the outlet of lake Superior, oppofite the falls, in N. lat. 46. 30. W. long. 84. 50.—*Morse.*

Cross-Creek, a townfhip in Wafhington county, Pennfylvania.—*ib.*

Cross-Roads, the name of a place in North Carolina, near Duplin court-houfe, 23 miles from Sampfon court-houfe, and 23 from South-Wafhington.—*ib.*

Cross-Roads, a village in Kent co. Maryland, fituated 2 miles S. of Georgetown, on Saffafras river, and is thus named from 4 roads which meet and crofs each other in the village.—*ib.*

Cross-Roads, a village in Chefter co. Pennfylvania, where 6 different roads meet. It is 27 miles S. E. of Lancafter; 11 N. by W. of Elkton, in Maryland, and about 18 W. N. W. of Wilmington in Delaware. —*ib.*

CROSSWICKS, a village in Burlington co. New-Jerfey; through which the line of ftages paffes from New-York to Philadelphia. It has a refpectable Quaker meeting-houfe; 4 miles S. W. of Allen Town, 8 S. E. of Trenton, and 14 S. W. of Burlington.—*ib.*

CROTON *River*, a N. eaftern water of Hudfon river, rifes in the town of New-Fairfield, in Connecticut, and running through Dutchefs co. empties into Tappan bay. Croton bridge is thrown over this river 3 miles from its mouth, on the great road to Albany. This is a folid fubftantial bridge, 1400 feet long, the road narrow, piercing through a flate hill. It is fupported by 16 ftone pillars. Here is an admirable view of Croton Falls, where the water precipitates itfelf between 60 and 70 feet perpendicular; high flate banks, in fome places 100 feet; the river fpreading into three ftreams, as it enters the Hudfon.—*ib.*

CROW *Creek*, falls into the Tenneffee, from the N. W. oppofite the Crow Town, 15 miles below Nickajack Town.—*ib.*

CROWN, *in aftronomy*, a name given to two conftellations, the fouthern and the northern.

Crown, *in geometry*, a plane ring included between two parallel or concentric peripheries of unequal circles.

Crown-Poft, is a poft in fome buildings ftanding upright in the middle between two principal rafters; and from which proceed ftruts or braces to the middle of each rafter. It is otherwife called a *king poft*, or *king's-piece*, or *joggle-piece*.

Crown *Point*, is the moft foutherly townfhip in Clinton co. New-York, fo called from the celebrated fortrefs, which is in it, and which was garrifoned by Britifh troops, from the time of its reduction by gen. Amherft in 1759, till the late revolution. It was taken by the Americans the 14th of May 1775, and retaken by the Britifh the year after. The point upon which it was erected, by the French in 1731, extends N. into lake Champlain. It was called *Kruyn Punt*, or *Scalp Point*, by the Dutch, and by the French, *Pointe à la Cheveleure*. The fortrefs they named Fort St Frederick. After it was repaired by the Britifh, it was the moft regular and expenfive of any conftructed by them in America. The walls are of wood and earth, about 16 feet high and about 20 feet thick, nearly 150 yards fquare, and furrounded by a deep and broad ditch, dug out of the folid rock. The only gate opened on the N. towards the lake, where was a draw-bridge and a covert-way, to fecure a communication with the waters of the lake, in cafe of a fiege. On the right and left, as you enter the fort, is a row of ftone barracks, not inelegantly built, which are capable of containing 2000 troops. There were formerly feveral out-works, which are now in ruins, as is indeed the cafe with the principal fort, except the walls of the barracks. The famous fortification called Ticonderoga is 15 miles S. of this; but that fortrefs is alfo fo much demolifhed, that a ftranger would fcarcely form an idea of its original conftruction. The town of Crown Point has no rivers; a few ftreams, however, iffue from the mountains, which anfwer for mills and common ufes. In the mountains, which extend the whole length of lake George, and part of the length of lake Champlain, are plenty of moofe, deer, and almoft all the other inhabitants of the foreft. In 1790, the town contained 203 inhabitants. By the ftate cenfus of 1796, it appears there are 126 electors. The fortrefs lies in N. lat. 44. 20. W. long. 73. 36.—*Morse.*

CROWS *Meadows*, a river in the N. W. territory, which runs N. weftward into Illinois river oppofite to which are fine meadows. Its mouth is 20 yards wide, and 240 miles from the Miffiffippi. It is navigable between 15 and 18 miles.—*ib.*

CROYDEN, a townfhip in Chefhire co. New-Hampfhire, adjoining Cornifh, and about 18 miles N. E. of Charleftown. It was incorporated in 1763. In 1775, it contained 143, and in 1790, 537 inhabitants.—*ib.*

CRUCES, a town of Terra Firma, S. America, 5 leagues from Panama, and fituated on Chagre river. —*ib.*

La CRUZ, an excellent harbour on the north-weft coaft of America, difcovered by the Spaniards in 1779. They were introduced into it by a paffage which they called *Bucarelli's entrance*, and which they placed in 55° 18′ N. Lat. and 139° 15′ W. Long. from the meridian of Paris. There is no good reafon to queftion the exactnefs of the latitude of this paffage as laid down by the Spaniards; but the editor of Peroufe's voyage juftly concludes, from the furvey made by our celebrated navigator Captain Cook on the coafts adjacent to the entrance of Bucarelli, that this entrance is about 135° 20′ to the weft of Paris, or very nearly 133° weft of Greenwich.

The Spaniards were not long in the harbour of *La Cruz* before they received a vifit from the inhabitants in its neighbourhood. Bartering took place. The Indians gave their peltry, and various trifles, for glafs beads, bits of old iron, &c. By this traffic the Spaniards were enabled to gain a fufficiently exact knowledge of their genius, of their offenfive and defenfive arms, of their manufactures, &c.

Their colour is a clear olive; many among them have, however, a perfectly white fkin: their countenance is well proportioned in all its parts. They are robuft, courageous, arrogant, and warlike.

They clothe themfelves in one or two undreffed fkins (with the fur apparently); thefe are the fkins of otters, of fea-wolves, of benades (a fpecies of deer), of bears, or other animals, which they take in hunting. Thefe dreffes cover them from the neck to the middle of the

La Cruz. leg; there are, however, many among them who wear boots of ſmooth ſkin, reſembling Engliſh boots, only that thoſe of the Indians open before, and are laced tight with a ſtring. They wear hats woven from the fine bark of trees, the form of which reſembles that of a funnel or a cone. At the wriſts they have bracelets of copper or iron, or for want of theſe metals the fins of whales; and round the neck, necklaces of ſmall fragments of bones of fiſhes and other animals, and even copper collars of the bigneſs of two fingers. They wear in their ears pendants of mother of pearl, or flat pieces of copper, on which is emboſſed a reſin of a topaz colour, and which are accompanied with jet beads. Their hair is long and thick, and they make uſe of a comb to hold it together in a ſmall queue from the middle to the extremity; a narrow ribbon of coarſe linen, woven for this purpoſe, ſerves as a ligament. They wear alſo as a covering a kind of ſcarf, woven in a particular manner, ſomething more than a yard and a half long, and about half a yard broad, round which hangs a fringe ſomething more than half a quarter of a yard deep, of which the thread is regularly twiſted.

The women give proofs of their modeſty and decency by their dreſs. Their phyſiognomy is agreeable, their colour freſh, their cheeks vermilioned, and their hair long; they plait it together in one long treſs. They wear a long robe of a ſmooth ſkin tied round the loins, like that of a nun; it covers them from the neck as low as the feet; the ſleeves reach down to the wriſts. Upon this robe they put divers ſkins of otters or other animals to defend themſelves from the inclemency of the weather. Better dreſſed, many of them might diſpute charms with the moſt handſome Spaniſh women; but diſſatisfied with their natural charms, they have recourſe to art, not to embelliſh, but to disfigure themſelves. All the married women have a large opening in the under lip, and this opening or orifice is filled up by a piece of wood cut in an oval ſhape, of which the ſmalleſt diameter is almoſt an inch; the more a woman is advanced in years the more this curious ornament is extended: it renders them frightful, the old women eſpecially, whoſe lip, deprived of its wonted ſpring, and dragged by the weight of this extraordinary jewel, neceſſarily hangs in a very diſagreeable manner. The girls wear only a copper needle, which croſſes the lip in the place where the ornament is intended hereafter to be placed.

Theſe Indians in war make uſe of cuiraſſes and ſhoulder pieces of a manufacture like that of the whalebone ſtays among the Europeans. Narrow boards or ſcantlings form, in ſome ſort, the woof of the texture, and threads are the warp: in this manner the whole is very flexible, and leaves a free uſe to the arms for the handling of weapons. They wear round the neck a coarſe and large gorget which covers them as high as below the eyes, and their head is defended by a morion, or ſkull piece, uſually made of the head of ſome ferocious animal. From the waiſt downwards, they wear a kind of apron, of the ſame contexture as their cuiraſs. Laſtly, a fine ſkin hangs from their ſhoulders down to the knee. With this armour, they are invulnerable to the arrows of their enemies; but thus armed they cannot change poſition with ſo much agility as if they were leſs burdened.

Their offenſive arms are arrows; bows, of which the ſtrings are woven like the large cords of our beſt muſical inſtruments; lances four yards in length, tongued with iron; knives of the ſame metal, longer than European bayonets, a weapon however not very common among them; little axes of flint, or of a green ſtone, ſo hard that they cleave the moſt compact wood without injury to their edge.

The pronunciation of their language is extremely difficult; they ſpeak from the throat, with a movement of the tongue againſt the palate; the little uſe the women make of the inferior lip greatly injures the diſtinctiveneſs of their language; the Spaniards could neither pronounce nor write the words which they heard.

From the vivacity of ſpirit in theſe Indians, and from their attention amply to furniſh the market eſtabliſhed in the harbour, it may be concluded that they are pretty laborious. They continually brought ſtuffs well woven and ſhaded by various colours, the ſkins of land and ſea wolves, of otters, bears, and other ſmaller animals; of theſe ſome were raw, and others dreſſed. There were to be found at this market alſo coverlets of coarſe cloth, ſhaded with white and brown colours, very well woven, but in ſmall quantities: large ribbons of the ſame linen which might match with that of the Spaniſh officers mattreſſes; ſkeins of thread ſuch as this cloth was made of; wooden plates or bowls neatly worked; ſmall boats or canoes painted in various colours, the figures of which repreſented heads with all their parts; frogs in wood nicely imitated, which opened like tobacco boxes, and which they employed to keep their trinkets in: boxes made of ſmall planks, of a cubical form, being three quarters of a yard on each ſide, with figures well drawn, or carved on the outſide, repreſenting various animals; the covers fabricated like Flanders etwees, with rabbeted edges, formed ſo as to ſhut into the body of the box; animals in wood, as well thoſe of the earth as of the air: figures of men of the ſame material, with ſkull-caps repreſenting the heads of various fierce animals; ſnares and nets for fiſhing; copper collars for the neck, and bracelets of iron for the wriſt, but which they would not part with except at a very high price; beak-like inſtruments, from which they drew ſounds as from a German flute. The principal officers took ſuch of theſe merchandizes as were moſt agreeable to them, and left the remainder to the ſhips crews.

As the Indians diſcovered that the Spaniards were very dainty in their fiſh, they did not let them want for choice: the greateſt abundance was in ſalmon, and a ſpecies of ſole or turbot three yards and a quarter long, broad and thick in proportion; cod and pilchards were alſo brought to market, and fiſhes reſembling trout. From all this it may be inferred that this gulf is full of fiſh; the banks too are covered with ſhells.

The quantity of mother-of-pearl that theſe Indians cut to pieces for making ear-rings awakened the curioſity of the Spaniards: they tried to diſcover whether theſe people had not in their poſſeſſion, or whether their country did not produce pearls, or ſome precious ſtones: their reſearches were fruitleſs, they only found ſome ſtones which they judged to be metallic, and which they carried on board, not having the neceſſary means for extracting the metal they might contain.

Theſe Indians feed upon fiſh, freſh or dry, boiled or roaſted; herbs and roots which their mountains yielded them,

them, and particularly that which in Spain is called sea parsley; and, lastly, upon the flesh of animals which they take in hunting: the productions of the chase are undoubtedly abundant, seeing the number of dogs they keep for this purpose.

These Indians appeared to the Spaniards to worship the sun, the earliest and most natural of all idolatrous worship; and they paid a decent respect to the remains of their dead. Don Maurelle, one of the Spanish officers, in an expedition round the gulf, found in two islands three dead bodies laid in boxes of a similar form to those which have been described above, though considerably larger, and decked in their furs. These biers were placed in a little hut upon a platform, or raised floor, made of the branches of trees.

The country is very hilly, the mountains are lofty, and their slope extends almost every where to the sea. The soil, lime-stone; it is nevertheless covered with an impenetrable forest of tall fir trees, very large and very strait. As these trees cannot stike very deep into the earth, the violence of the wind often tears them up by the roots: they rot and become a light mould, upon which grows a bushy thicket; and in this are found nettles, camomile, wild celery, anise, a species of cabbage, celandine, elder, wormwood, sorrel; and without doubt there are other plants along the rivers.

The Spaniards saw ducks, gulls, divers, kites, ravens, geese, storks, gold-finches, and other little birds unknown to them.

The commerce between the Spaniards and the Indians was quite undisturbed; and so desirous were the latter to obtain iron, cloth, and other stuffs, that they sold their children for broken iron hoops and other wares. The Spaniards in this manner bought three young lads, one from five to six years old, another of four, and the third from nine to ten, not to make slaves, but Christians of them; they hoped besides to derive useful information from them as to the nature of the country and its inhabitants. These youths were so contented in being with the Spaniards, that they hid themselves when their parents came on board, from the apprehension of being again restored to them. Two young girls were also purchased with the same view; one very ugly, seven years of age; the other younger, better made, but sickly, and almost at the gates of death.

At the full and change of the moon, the sea rises in the harbour of La Cruz seventeen feet three inches English; it is then high water at a quarter after 12 at noon: the lowest tides are fourteen feet three inches: the night tides exceed by one foot nine inches those of the day.

Cruz, Santa, a considerable town on the N. coast of the island of Cuba, about 30 miles E. by N. of the Havannah, and 115 N. W. by N. of Cadiz.—Also the chief town of Cuzumel island.—*Morse.*

Cruz, Santa, a town of Mexico, or New-Spain, about 75 miles N. by E. of St Salvadore, on the Pacific ocean. It is situated on the gulf of Dulce, which communicates with the sea of Honduras.—*ib.*

Cruz, Santa, De la Sierra, a government and generalship, also a jurisdiction and bishoprick, under the bishop of Charcas, 90 leagues E. of Plata, in Peru.—*ib.*

CRYSTAL, CRYSTALLIZATION, and *Rock Chrystal.* } See Chrystal and Crystallization, *Encycl.* and Chemistry-*Index* in this Supplement.

CUBAGUA, an island of America, situated between that of Margaretta and Terra Firma, subject to Spain, and is about 8 miles long. There are a number of pearls got here, but not of the largest size. N. lat. 10. 15. W. long. 54. 30.—*Morse.*

CUBIC Hyperbola, is a figure expressed by the equation $y^2=a$, having two asymptotes, and consisting of two hyperbolas, lying in the adjoining angles of the asymptotes, and not in the opposite angles, like the Apollonian hyperbola; being otherwise called by Newton, in his Enumeratio Linearum Tertii Ordinis, an hyperbolismus of a parabola; and is the 65th species of those lines according to him.

Cubic Parabola, a curve of the second order, having two infinite legs tending contrary ways. The curve of this parabola cannot be rectified even by means of the conic sections.

CUENCA, or *Bamba*, a city and considerable jurisdiction in the province of Quito, in Peru, under the torrid zone; lying in 25. 3. 49. S. lat. The town is computed to contain 20, or 30,000 people; and the weaving of baize, cottons, &c. is carried on by the women, the men being averse to labour, and prone to all manner of profligacy. It is situated on the river Curary, or St Jago; which, after many windings from W. to E. falls at last into the river Amazon. The town stands at the foot of the Cordillera mountains. It has two convents, and lies about 170 miles S. of Quito.—*Morse.*

CUEYTE, a river in the island of Cuba, which abounds with alligators.—*ib.*

CULIACAN, a province of Guadalaxara, in the audience of New-Galicia, in Mexico or New-Spain. It has Cinaloa on the N. New-Biscay and the Zacatecas on the E. Chiametlan on the S. and the gulf of California on the W. It is 60 or 70 leagues long and 50 broad. It abounds with all sorts of fruit. The great river La Sal in this country is well inhabited on each side. According to Dampier, it is a salt lake, or bay, in which is good anchorage, though it has a narrow entrance, and runs 12 leagues E. and parallel with the shore. There are several Spanish farms, and salt ponds about it; and 5 leagues from it are two rich mines, worked by slaves belonging to the citizens of Compostella. Here also is another great river, whose banks are full of woods and pastures. On this river, Guzman, who discovered the country, built a town, which he called *St Michael.*—*ib.*

CULLEN (Dr William) was a man to whom physical science is so deeply indebted, that it has often struck us with wonder that no account of him has yet been given to the public, which deserves to be classed with British biography. We know indeed that a life of him has been written by an eminent physician well qualified and strongly inclined to do justice to the merits of his revered preceptor; but that life has been withheld from us by him who has certainly the best right to consider himself as the guardian of the Doctor's fame, and who, we have been told, is to enlarge and publish it himself. In this state of things our rea-

ders

ders muft pardon us for laying before them a very imperfect account of this eminent man, to whom we were ourfelves almoft ftrangers. There is a character of him in the periodical publication called *The Bee*, which we fhall appropriate to our own ufe, we are perfuaded, with the entire approbation of its author, though fometimes we may exprefs our fufpicions that his praife is exaggerated.

Dr William Cullen was born in Lanarkfhire, in the weft of Scotland, 11th December 1712. His father was for fome time chief magiftrate of the town of Hamilton; but though a very refpectable man, his circumftances were not fuch as to permit him to lay out much money on the education of his fon. William therefore, after ferving an apprenticefhip to a furgeon apothecary in Glafgow, went feveral voyages to the Weft Indies as a furgeon in a trading veffel from London: but of this employment he tired, and fettled himfelf, at an early period of life, as a country furgeon in the parifh of Shotts, where he ftaid a fhort time practifing among the farmers and country people, and then went to Hamilton with a view to practice as a phyfician, having never been fond of operating as a furgeon.

While he refided near Shotts, it chanced that Archibald Duke of Argyle, who at that time bore the chief political fway in Scotland, made a vifit to a gentleman of rank in that neighbourhood. The Duke was fond of literary purfuits, and was then particularly engaged in fome chemical refearches, which required to be elucidated by experiment. Eager in thefe purfuits, his Grace, while on this vifit, found himfelf much at a lofs for the want of fome fmall chemical apparatus, which his landlord could not furnifh: but happily recollecting young Cullen in the neighbourhood, he mentioned him to the Duke as a perfon who could probably furnifh it. —He was accordingly invited to dine; was introduced to his Grace,—who was fo much pleafed with his knowledge, his politenefs and addrefs, that he formed an acquaintance which laid the foundation of all Doctor Cullen's future advancement.

The name of Cullen by this time became familiar at every table in that neighbourhood; and thus he came to be known, by character, to the Duke of Hamilton, who then refided, for a fhort time, in that part of the country: and that nobleman having been fuddenly taken ill; the affiftance of young Cullen was called in; which proved a fortunate circumftance in ferving to promote his advancement to a ftation in life more fuited to his talents than that in which he had hitherto moved.

The character of the Douglaffes, of which name the family of Hamilton now forms a principal branch, has always been fomewhat of the fame ftamp with that of the rifing Cullen. Genius, benevolence, franknefs, and conviviality of difpofition, have been, with them in general very prominent features: and if to that be added a fpirit of frolic and diffipation, thefe will be accounted as only natural confequences of thofe youthful indulgences that fpring from an excefs of wealth at an early period of life, and the licence allowed to people of elevated rank. The Duke was therefore highly delighted with the fprightly character and ingenious converfation of his new acquaintance. Receiving inftruction from him in a much more pleafing, and an infinitely eafier way than he had ever before obtained, the converfation of Cullen proved highly interefting to his Grace—No wonder then that he foon found means to get his favourite Doctor, who was already the efteemed acquaintance of the man through whofe hands all preferments in Scotland were obliged to pafs, appointed to a place in the univerfity of Glafgow, where his fingular talents for difcharging the duties of the ftation he now occupied foon became very confpicuous (A).

During his refidence in the country, however, feveral important incidents occurred, that ought not to be paffed over in filence. It was during this time that was formed a connection in bufinefs in a very humble line between two men, who became afterwards eminently confpicuous in much more exalted ftations. William, afterwards Doctor, Hunter, the famous lecturer on anatomy in London, was a native of the fame part of the country; and not being in affluent circumftances more than Cullen, thefe two young men, ftimulated by the impulfe of genius to profecute their medical ftudies with ardour, but thwarted by the narrownefs of their fortune, entered into a copartnery bufinefs as furgeons and apothecaries in the country. The chief end of their contract being to furnifh the parties with the means of profecuting their medical ftudies, which they could not feparately fo well enjoy, it was ftipulated, that one of them alternately fhould be allowed to ftudy in what college he inclined, during the winter, while the other fhould carry on the bufinefs in the country for their common advantage. In confequence of this agreement, Cullen was firft allowed to ftudy in the Univerfity of Edinburgh for one winter; but when it came to Hunter's turn next winter, he, preferring London to Edinburgh, went thither. There his fingular neatnefs in diffecting, and uncommon dexterity in making anatomical preparations, his affiduity in ftudy, his mildnefs of manner, and pliability of temper, foon recommended him to the notice of Dr Douglafs, who then read lectures upon anatomy and midwifery there; who engaged Hunter as an affiftant, and whofe chair he afterwards filled with fo much honour to himfelf and fatisfaction to the public.

Thus was diffolved, in a premature manner, a copartnery perhaps of as fingular a kind as is to be found in the annals of literature: nor was Cullen a man of that difpofition to let any engagement with him prove a bar to his partner's advancement in life. The articles were freely departed from by him; and Cullen and Hunter ever

(A) It was not, however, folely to the favour of thefe two great men that Cullen owed his literary fame. He was recommended to the notice of men of fcience in a way ftill more honourable to himfelf. The difeafe of the Duke of Hamilton having refifted the effect of the firft applications, Dr Clarke was fent for from Edinburgh; and he was fo much pleafed with every thing that Cullen had done, that he became his eulogift upon every occafion. Cullen never forgot this; and when Clarke died, gave a public oration in his praife in the Univerfity of Edinburgh; which, it is believed, was the firft of the kind in this country.

Cullen. ever after kept up a very cordial and friendly correſpondence; though, it is believed, they never from that time had a perſonal interview.

During the time that Cullen practiſed as a country ſurgeon and apothecary, he formed another connection of a more permanent kind, which, happily for him, was not diſſolved till a very late period of his life. With the ardour of diſpoſition he poſſeſſed, it cannot be ſuppoſed he beheld the fair ſex with indifference. Very early in life he took a ſtrong attachment to an amiable woman, a Miſs Johnſton, daughter to a clergyman in that neighbourhood, nearly of his own age, who was prevailed on to join with him in the ſacred bonds of wedlock, at a time when he had nothing elſe to recommend him to her except his perſon and diſpoſitions; for as to riches and poſſeſſions he had little of theſe to boaſt of. She was beautiful, had great good ſenſe, equanimity of temper, an amiable diſpoſition, and elegance of manners, and brought with her a little money, which, though it would be accounted nothing now, was ſomething in thoſe days to one in his ſituation in life. After giving to him a numerous family, and participating with him the changes of fortune which he experienced, ſhe peacefully departed this life in ſummer 1786.

In the year 1746, Cullen, who had now taken the degree of doctor in phyſic, was appointed a lecturer in chemiſtry in the Univerſity of Glaſgow: and in the month of October began his lectures in that ſcience. His ſingular talents for arrangement, his diſtinctneſs of enunciation, his vivacity of manner, and his knowledge of the ſcience he taught, rendered his lectures intereſting to the ſtudents to a degree that had been till then unknown at that univerſity. He became, therefore, in ſome meaſure, adored by the ſtudents. The former profeſſors were eclipſed by the brilliancy of his reputation; and he had to experience all thoſe little rubs that envy and diſappointed ambition naturally threw in his way. Regardleſs, however, of theſe ſecret chagreens, he preſſed forward with ardour in his literary career; and, ſupported by the favour of the public, he conſoled himſelf for the contumely he met with from a few individuals. His practice as a phyſician increaſed from day to day; and a vacancy having occurred in the year 1751, he was then appointed by the king profeſſor of medicine in that univerſity. This new appointment ſerved only to call forth his powers, and to bring to light talents that it was not formerly known he poſſeſſed; ſo that his fame continued to increaſe.

As, at that period, the patrons of the univerſity of Edinburgh were conſtantly on the watch for the moſt eminent medical men to ſupport the riſing fame of the college, their attention was ſoon directed towards Cullen; who on the death of Dr Plumber, profeſſor of chemiſtry, was, in 1756 unanimouſly invited to accept the vacant chair. This invitation he accepted: and having reſigned all his employments in Glaſgow, he began his academical career in Edinburgh in the month of October of that year, and there he reſided till his death.

If the admiſſion of Cullen into the univerſity of Glaſgow gave great ſpirit to the exertions of the ſtudents, this was ſtill, if poſſible, more ſtrongly felt in Edinburgh. Chemiſtry, which had been till that time of ſmall account in that univerſity, and was attended to by very few of the ſtudents, inſtantly became a favourite ſtudy; and the lectures upon that ſcience were more frequented than any others in the univerſity, anatomy alone excepted. The ſtudents, in general, ſpoke of Cullen with the rapturous ardour that is natural to youth when they are highly pleaſed. Theſe eulogiums appeared extravagant to moderate men, and could not fail to prove diſguſting to his colleagues. A party was formed among the ſtudents for oppoſing this new favourite of the public; and theſe ſtudents by miſrepreſenting the doctrines of Cullen to others who could not have an opportunity of hearing theſe doctrines themſelves, made even ſome of the moſt intelligent men in the univerſity think it their duty publicly to oppoſe theſe imaginary tenets. The ferment was thus augmented; and it was ſome time before the profeſſors diſcovered the arts by which they had been impoſed upon, and univerſal harmony reſtored.

During this time of public ferment Cullen went ſteadily forward, without taking any part himſelf in theſe diſputes. He never gave ear to any tales reſpecting his colleagues, nor took any notice of the doctrines they taught: That ſome of their unguarded ſtrictures might at times come to his knowledge, is not impoſſible; but if they did, they ſeemed to make no impreſſion on his mind.

Theſe attempts of a party of ſtudents to lower the character of Cullen on his firſt outſet in the univerſity of Edinburgh having proved fruitleſs, his fame as a profeſſor, and his reputation as a phyſician, became more and more reſpected every day. Nor could it well be otherwiſe: Cullen's profeſſional knowledge was always great, and his manner of lecturing ſingularly clear and intelligible, lively and entertaining; and to his patients, his conduct in general as a phyſician was ſo pleaſing, his addreſs ſo affable and engaging, and his manner ſo open, ſo kind, and ſo little regulated by pecuniary conſiderations, that it was impoſſible for thoſe who had occaſion to call once for his medical aſſiſtance, ever to be ſatisfied on any future occaſion without it. He became the friend and companion of every family he viſited; and his future acquaintance could not be diſpenſed with.

But if Dr Cullen in his public capacity deſerved to be *admired*, in his private capacity by his ſtudents he deſerved to be *adored*. His conduct to them was ſo attentive, and the intereſt he took in the private concerns of all thoſe ſtudents who applied to him for advice, was ſo cordial and ſo warm, that it was impoſſible for any one who had a heart ſuſceptible of generous emotions, not to be enraptured with a conduct ſo uncommon and ſo kind. Among ingenuous youth, gratitude eaſily degenerates into rapture—into reſpect nearly allied to adoration. Thoſe who advert to this natural conſtruction of the human mind, will be at no loſs to account for that popularity that Cullen enjoyed—a popularity, that thoſe who attempt to weigh every occurrence by the cool ſtandard of *reaſon* alone, will be inclined to think exceſſive. It is fortunate, however, that the bulk of mankind will ever be influenced in their judgment not leſs by feelings and affections than by the cold and phlegmatic dictates of *reaſon*. The adoration which generous conduct excites, is the reward which nature hath appropriated excluſively to diſintereſted beneficence. This was the ſecret charm that Cullen ever carried about with him, which faſcinated ſuch numbers of thoſe who had intimate acceſs to him.

This

Cullen. This was the power, which his envious opponents never could have an opportunity of feeling.

The general conduct of Cullen to his students was thus. With all such as he observed to be attentive and diligent, he formed an early acquaintance, by inviting them by twos, by threes, or by fours at a time, to sup with him, conversing with them on these occasions with the most engaging ease, and freely entering with them on the subjects of their studies, their amusements, their difficulties, their hopes, and future prospects. In this way, he usually invited the whole of his numerous class, till he made himself acquainted with their abilities, their private character, and their objects of pursuit. Those among them whom he found most assiduous, best disposed, or the most friendless, he invited the most frequently, till an intimacy was gradually formed, which proved highly beneficial to them. Their doubts, with regard to their objects of study, he listened to with attention, and solved with the most obliging condescension. His library, which consisted of an excellent assortment of the best books, especially on medical subjects, was at all times open for their accommodation; and his advice in every case of difficulty to them they always had it in their power most readily to obtain. They seemed to be his family; and few persons of distinguished merit have left the university of Edinburgh in his time with whom he did not keep up a correspondence till they were fairly established in business. By these means he came to have a most accurate knowledge of the state of every country, with respect to practitioners in the medical line; the only use he made of which knowledge, was to direct the students in their choice of places where they might have an opportunity of engaging in business with a reasonable prospect of success. Many, very many, able men has he thus put into a good line of business where they never could have thought of it themselves, and they are now reaping the fruits of this beneficent foresight on his part.

Nor was it in this way only that he befriended the students at the university at Edinburgh. Possessing a benevolence of mind that made him ever think first of the wants of others, and recollecting the difficulties that he himself had had to struggle with in his younger days, he was at all times singularly attentive to their pecuniary concerns. From his general acquaintance among the students, and the friendly habits he was on with many of them, he found no difficulty in discovering those among them who were rather in hampered circumstances, without being obliged to hurt their delicacy in any degree. To such persons, when their habits of study admitted of it, he was peculiarly attentive. They were more frequently invited to his house than others; they were treated with more than usual kindness and familiarity; they were conducted to his library, and encouraged by the most delicate address to borrow from it freely whatever books he thought they had occasion for; and as persons in these circumstances were usually more shy in this respect than others, books were sometimes pressed upon them as a sort of constraint, by the Doctor insisting to have their opinion of such or such passages they had not read, and desiring them to carry the book home for that purpose. He, in short, behaved to them rather as if he courted their company, and stood in need of their acquaintance than they of his. He thus raised them in the opinion of their acquaintance to a much higher degree of estimation than they could otherwise have obtained; which, to people whose minds were depressed by penury, and whose sense of honour was sharpened by the consciousness of an inferiority of a certain kind, was singularly engaging. Thus they were inspired with a secret sense of dignity, which elevated their minds, and excited an uncommon ardour of pursuit, instead of that melancholy inactivity which is so natural in such circumstances, and which too often leads to despair. Nor was he less delicate in the manner of supplying their wants, than attentive to discover them. He often found out some polite excuse for refusing to take payment for a first course, and never was at a loss for one to an after course. Before they could have an opportunity of applying for a ticket, he would sometimes lead the conversation to some subject that occurred in the course of his lectures; and as his lectures were never put in writing by himself, he would sometimes beg the favour to see their notes, if he knew they had been taken with attention, under a pretext of assisting his memory. Sometimes he would express a wish to have their opinion of a particular part of his course, and presented them with a ticket for that purpose; and sometimes he refused to take payment, under the pretext that they had not received his full course the preceding year, some part of it having been necessarily omitted for want of time, which he meant to include in this course. By such delicate address in which he greatly excelled, he took care to forerun their wants. Thus he not only gave them the benefit of his own lectures, but by refusing to take their money, he also enabled them to attend those of others that were necessary to complete their course of studies. These were particular devices he adopted to individuals to whom economy was necessary; but it was a general rule with him never to take money from any student for more than two courses of the same set of lectures, permitting him to attend these lectures as many years longer as he pleased *gratis*.

He introduced another general rule into the university, that was dictated by the same principle of disinterested beneficence, that ought not to be here passed over in silence. Before he came to Edinburgh, it was the custom of medical professors to accept of fees for their medical assistance when wanted, even from medical students themselves, who were perhaps attending the professor's own lectures at the time. But Cullen never would take fees as a physician from any student at the university, though he attended them, when called in as a physician, with the same assiduity and care as if they had been persons of the first rank, who paid him most liberally. This gradually induced others to adopt a similar practice; so that it is now become a general rule for medical professors to decline taking any fees when their assistance is necessary to a student. For this useful reform, with many others, the students of the university of Edinburgh are solely indebted to the liberality of Dr Cullen.

The first lectures which Cullen delivered in Edinburgh were on chemistry; and for many years he also gave clinical lectures on the cases which occurred in the royal infirmary. In the month of February, 1763, Dr Alston died, after having begun his usual course of lectures on the materia medica; and the magistrates of Edinburgh, as patrons of that professorship in the university, Cullen.

versity, appointed Dr Cullen to that chair, requesting that he would finish the course of lectures that had been begun for that season; this he agreed to do; and though he was under a necessity of going on with the course in a few days after he was nominated, he did not once think of reading the lectures of his predecessor, but resolved to deliver a new course entirely his own. The popularity of Cullen at this time may be guessed at by the increase of new students who came to attend his course in addition to the eight or ten who had entered to Dr Alston. The new students exceeded 100. An imperfect copy of these lectures thus fabricated in haste, having been published, the Doctor thought it necessary to give a more correct edition of them in the latter part of his life. But his faculties being then much impaired, his friends looked in vain for those striking beauties that characterized his literary exertions in the prime of life.

Some years afterwards, on the death of Dr White, the magistrates once more appointed Dr Cullen to give lectures on the theory of physic in his stead. And it was on that occasion Dr Cullen thought it expedient to resign the chemical chair in favour of Dr Black, his former pupil, whose talents in that department of science were then well known, and who has filled the chair ever since with great satisfaction to the public. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applause on the practice of physic, Dr John Gregory, (whose name can never be mentioned by any one who had the pleasure of his acquaintance, without the warmest tribute of a grateful respect) having become a candidate for this place along with Dr Cullen, a sort of compromise took place between them, by which they agreed each to give lectures alternately on the theory and on the practice of physic during their joint lives, the longest survivor being allowed to hold either of the classes he should incline. In consequence of this agreement Dr Cullen delivered the *first* course of lectures on the practice of physic in winter 1766, and Dr Gregory succeeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the students than this. Both these men possessed great talents, though of a kind extremely dissimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and respected the talents of the other. They co-operated, therefore, in the happiest manner, to enlarge the understanding, and to forward the pursuits of their pupils. Unfortunately this arrangement was soon destroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a sudden and unforeseen event. After this time, Cullen continued to give lectures on the practice of physic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

In drawing the character of Dr Cullen, Dr Anderson, to whom we are indebted for this sketch, observes, that in scientific pursuits men may be arranged into two grand classes, which, though greatly different from each other in their extremes, yet approximate at times so near as to be blended indiscriminately together; those who possess a talent for detail, and those who are endowed with the faculty of arrangement. The first may be said to view objects individually as through a microscope. The field of vision is confined; but the objects included within that field, which must usually be considered singly and apart from all others, are seen with a wondrous degree of accuracy and distinctness. The other takes a sweeping view of the universe at large, considers every object he perceives, not individually, but as a part of one harmonious whole: His mind is therefore not so much employed in examining the separate parts of this individual object, as in tracing its relations, connections, and dependencies, on those around it.—Such was the turn of Cullen's mind. The talent for arrangement was that which peculiarly distinguished him from the ordinary class of mortals; and this talent he possessed perhaps in a more distinguished degree than any other person of the age in which he lived. Many persons exceeded him in the minute knowledge of particular departments, who, knowing this naturally looked upon him as their inferior; but possessing not at the same time that glorious faculty, which, "with an eye wide roaming, glances from the earth to heaven," or the charms which this talent can infuse into congenial minds, felt disgust at the pre-eminence he obtained, and astonishment at the means by which he obtained it. An Aristotle and a Bacon have had their talents in like manner appreciated; and many are the persons who can neither be exalted to sublime ideas with Homer, nor ravished with the natural touches of a Shakespeare. Such things are wisely ordered, that every department in the universe may be properly filled by those who have talents exactly suited to the task assigned them by heaven.

Had Cullen, however, possessed the talents for arrangement alone, small would have been his title to that high degree of applause he has attained. Without a knowledge of *facts*, a talent for arrangement produces nothing but chimeras; without materials to work upon, the structures which an over-heated imagination may rear up are merely "the baseless fabric of a vision." No man was more sensible of the justness of this remark than Dr Cullen, and few were at greater pains to avoid it. His whole life, indeed, was employed, almost without interruption, in collecting facts. Whether he was reading, or walking, or conversing, these were continually falling into his way. With the keen perception of an eagle, he marked them at the first glance; and without stopping at the time to examine them, they were stored up in his memory, to be drawn forth as occasion required, to be confronted with other facts that had been obtained after the same manner, and to have their truth ascertained, or their falsity proved, by the evidence which should appear when carefully examined at the impartial bar of justice. Without a memory retentive in a singular degree, this could not have been done; but so very extraordinary was Dr Cullen's memory, that till towards the very decline of life, there was scarcely a fact that had ever occurred to him which he could not readily recollect, with all its concomitant circumstances, whenever he had occasion to refer to it. It was this faculty which so much abridged his labour in study, and enabled him so happily to avail himself of the labour of others in all his literary speculations. He often reaped more by the conversation of an hour than another man would have done in whole weeks of laborious study.

In his prelections, Dr Cullen never attempted to read.

read. His lectures were delivered *viva voce*, without having been previously put into writing, or thrown into any particular arrangement. The vigour of his mind was such, that nothing more was necessary than a few short notes before him, merely to prevent him from varying from the general order he had been accustomed to observe. This gave to his discourses an ease, a vivacity, a variety, and a force, that are rarely to be met with in academical discourses. His lectures, by consequence, upon the same subject were never exactly the same. Their general tenor indeed was not much varied; but the particular illustrations were always new, well suited to the circumstances that attracted the general attention of the day, and were delivered in the particular way that accorded with the cast of mind the prelector found himself in at the time. To these circumstances must be ascribed that energetic artless elocution, which rendered his lectures so generally captivating to his hearers. Even those who could not follow him in those extensive views his penetrating mind glanced at, or who were not able to understand those apt allusions to collateral objects which he could only rapidly point at as he went along, could not help being warmed in some measure by the vivacity of his manner. But to those who could follow him in his rapid career, the ideas he suggested were so numerous, the views he laid open were so extensive, and the objects to be attained were so important—that every active faculty of the mind was roused; and such an ardour of enthusiasm was excited in the prosecution of study, as appeared to be perfectly inexplicable to those who were merely unconcerned spectators. In consequence of this unshackled freedom in the composition and delivery of his lectures, every circumstance was in the nicest unison with the tone of voice and expression of countenance, which the particular cast of mind he was in at the time inspired. Was he joyous, all the figures introduced for illustration were fitted to excite hilarity and good humour: was he grave, the objects brought under view were of a nature more solemn and grand: and was he peevish, there was a peculiarity of manner in thought, in word, and in action, which produced a most striking and interesting effect. The languor of a nerveless uniformity was never experienced, nor did an abortive attempt to excite emotions that the speaker himself could not at the time feel, ever produce those discordant ideas which prove disgusting and unpleasing.

It would seem as if Dr Cullen had considered the proper business of a preceptor to be that of putting his pupils into a proper train of study, so as to enable them to prosecute those studies at a future period, and to carry them on much farther than the short time allowed for academical prelections would admit. He did not, therefore, so much strive to make those who attended his lectures deeply versed in the particular details of objects, as to give them a general view of the whole subject; to shew what had been already attained respecting it; to point out what remained yet to be discovered; and to put them into a train of study that should enable them, at a future period, to remove those difficulties that had hitherto obstructed our progress; and thus to advance of themselves to farther and farther degrees of perfection. If these were his views, nothing could be more happily adapted to them than the mode he invariably pursued. He first drew, with the striking touches of a master, a rapid and general outline of the subject, by which the whole figure was seen at once to start boldly from the canvas, distinct in all its parts, and unmixed with any other object. He then began anew to retrace the picture, to touch up the lesser parts, and to finish the whole in as perfect a manner as the state of our knowledge at the time would permit. Where materials were wanting, the picture there continued to remain imperfect. The wants were thus rendered obvious; and the means of supplying these were pointed out with the most careful discrimination. The student, whenever he looked back to the subject, perceived the defects; and his hopes being awakened, he felt an irresistible impulse to explore that hitherto untrodden path which had been pointed out to him, and fill up the chasm which still remained. Thus were the active faculties of the mind most powerfully excited; and instead of labouring himself to supply deficiencies that far exceeded the power of any one man to accomplish, he set thousands at work to fulfil the task, and put them into a train of going on with it, when he himself should be gone to that country "from whose dread bourne no traveller returns."

It was to these talents, and to this mode of applying them, that Dr Cullen owed his celebrity as a professor; and it was in this manner that he has perhaps done more towards the advancement of science than any other man of his time, though many individuals might perhaps be found who were more deeply versed in the particular departments he taught than he himself was. Chemistry, which was before his time a most disgusting pursuit, was by him rendered a study so pleasing, so easy, and so attractive, that it is now prosecuted by numbers as an agreeable recreation, who but for the lights that were thrown upon it by Cullen and his pupils, would never have thought of engaging in it at all; though perhaps they never heard of Cullen's name, nor have at this time the most distant idea that they owe any obligations to him; and the same may be said of the other branches of science which he taught.

According to a man who knew him well, there are three things which eminently distinguished Cullen as a professor. "The energy of his mind, by which he viewed every subject with ardour, and combined it immediately with the whole of his knowledge.

"The scientific arrangement which he gave to his subject, by which there was a *lucidus ordo* to the dullest scholar. He was the first person in this country who made chemistry cease to be a chaos.

"A wonderful art of interesting the students in every thing which he taught, and of raising an emulative enthusiasm among them."

We are well aware that this character will by many be deemed an extravagant panegyric; but having no opportunity of judging for ourselves, we would rather adopt from others an extravagant panegyric than an unmerited censure. Dr Anderson himself admits that Cullen's character was far from perfect; and, in the opinion of most other men with whom we have conversed on the subject, and who were at the same time qualified to form an estimate of his mental powers, his imagination was not balanced by his judgment. Hence the common remark in the university of Edinburgh, that Dr Cullen was more successful in demolishing the theories of others than in giving stability to those which were reared by himself.

Dr Cullen's external appearance, though striking and not

not unpleafing, was not elegant. His countenance was expreffive, and his eye in particular remarkably lively, and at times wonderfully penetrating. In his perfon he was tall and thin, ftooping very much about the fhoulders. When he walked, he had a contemplative look, and did not feem much to regard the objects around him.

CULPEPPER, a county in Virginia, between the Blue Ridge and the tide waters, which contain 22,105 inhabitants, of whom 8226 are flaves. The courthoufe of this county is 45 miles from Fredericksburg, and 95 from Charlottefville.—*Morse.*

CUMANA, or *Comana*, the capital of New-Andalufia, a province of Terra Firma, S. America. It fometimes gives its name to the province. The Spaniards built this city in 1520, and it is defended by a ftrong caftle. This town, fays Dampier, ftands near the mouth of a great lake, or branch of the fea, called Laguna de Carriaco, about which are feveral rich towns; but its mouth is fo fhallow that no fhips of burden can enter it. It is fituated 3 leagues S. of the N. Sea, and to the S. W. of Margaretta, in about 10. 20. N. lat. and in 64. 20. W. long.—*ib.*

CUMANAGATE, a fmall town in a bay on the coaft of Terra Firma, in the province of Cumana or Andalufia. It is fituated on a low flat fhore, which abounds with pearl oyfters.—*ib.*

CUMBERLAND, a harbour in the ifland of Juan Fernandes.—*ib.*

Cumberland, a harbour on the S. E. part of the ifland of Cuba, and one of the fineft in the Weft-Indies, capable of fheltering any number of fhips. N. lat. 20. 30. W. long. 76. 50. It is 20 leagues E. from St Jago de Cuba.—*ib.*

Cumberland, an ifland on the coaft of Camden co. Georgia, between Prince William's found at the S. end, and the mouth of Great Satilla river at its N. end, and 20 miles S. of the town of Frederica. Before the revolution there were two forts, called William and St Andrews, on this ifland. The former, at the S. end, commanded the inlet of Amelia's found, was ftrongly pallifadoed and defended by 8 pieces of cannon, and had barracks for 200 men, ftore-houfes, &c.; within the pallifadoes were fine fprings of water.—*ib.*

Cumberland, a harbour on the E. fide of Wafhington's ifles, on the N. W. coaft of N. America. It lies S. of Skitikifs, and N. of Cummafhawaa.—*ib.*

Cumberland, a bay in the moft northern part of America; its mouth lies under the polar circle, and runs to the N. W. and W. and is thought to communicate with Baffin's bay on the N.—*ib.*

Cumberland *Houfe*, one of the Hudfon bay company's factories, is fituated in New South Wales in North America, 158 miles E. N. E. of Hudfon's houfe, on the S. fide of Pine-Ifland lake. N. lat. 53. 56. 41. W. long. 102. 13.—*ib.*

Cumberland, a fort in New-Brunfwick, fituated at the head of the bay of Fundy, on the E. fide of its northern branch. It is capable of accommodating 300 men.—*ib.*

Cumberland, a county of New-Brunfwick, which comprehends the lands at the head of the bay of Fundy, on the bafon called Chebecton, and the rivers which empty into it. It has feveral townfhips; thofe which are fettled are Cumberland, Sackville, Amherft, Hillfborough, and Hopewell. It is watered by the rivers Au Lac, Miffiquafh, Napan, Macon, Memramcook, Petcoudia, Chepodie, and Herbert. The 3 firft rivers are navigable 3 or 4 miles for veffels of 5 tons. The Napan and Macon are fhoal rivers; the Herbert is navigable to its head, 12 miles, in boats; the others are navigable 4 or 5 miles.—*ib.*

Cumberland, a town of New-Brunfwick, in the county of its own name. Here are coal mines.—*ib.*

Cumberland *Co.* in the diftrict of Maine, lies between York and Lincoln counties; has the Atlantic ocean on the S. and Canada on the N. Its fea coaft, formed into numerous bays and lined with a multitude of fruitful iflands, is nearly 40 miles in extent in a ftraight line. Saco river, which runs S. eafterly into the ocean, is the dividing line between this county and York on the S. W. Cape Elizabeth and Cafco bay are in this county. Cumberland is divided into 24 townfhips, of which Portland is the chief. It contains 25,450 inhabitants.—*ib.*

Cumberland *Co.* in New-Jerfey, is bounded S. by Delaware bay, N. by Gloucefter co. S. E. by Cape May, and W. by Salem co. It is divided into 7 townfhips, of which Fairfield and Greenwich are the chief; and contains 8248 inhabitants, of whom 120 are flaves.—*ib.*

Cumberland, the N. eafternmoft townfhip of the ftate of Rhode-Ifland, Providence co. Pawtucket bridge and falls, in this town, are 4 miles N. E. of Providence. It contains 1964 inhabitants, and is the only town in the ftate which has no flaves.—*ib.*

Cumberland *Co.* in Pennfylvania, is bounded N. and N. W. by Mifflin; E. and N. E. by Sufquehanna river which divides it from Dauphin; S. by York, and S. W. by Franklin co. It is 47 miles in length and 42 in breadth, and has 10 townfhips, of which Carlifle is the chief. The county is generally mountainous; but between North and South mountain, on each fide of Conedogwinet creek, there is an extenfive, rich, and well cultivated valley. It contains 18,243 inhabitants, of whom 223 are flaves.—*ib.*

Cumberland, a townfhip in York co. Pennfylvania. ——Alfo the name of a townfhip in Wafhington co. in the fame ftate.—*ib.*

Cumberland *Co.* in Fayette diftrict, N. Carolina, contains 8671 inhabitants, of whom 2181 are flaves. Chief town Fayetteville.—*ib.*

Cumberland, a townfhip of the above county, in N. Carolina.—*ib.*

Cumberland, a poft town and the chief townfhip of Alleghany co. Maryland, lies on the N. bank of a great bend of Potowmack river, and on both fides of the mouth of Will's creek. It is 148 miles W. by N. of Baltimore, 109 meafured miles above Georgetown, and about 105 N. W. of Wafhington city. Fort Cumberland ftood formerly at the W. fide of the mouth of Will's creek.—*ib.*

Cumberland *Co.* in Virginia, on the N. fide of Appamatox river, which divides it from Prince Edward. It contains 8153 inhabitants, of whom 4434 are flaves. The court-houfe is 28 miles from Powhatan court-houfe, and 52 from Richmond.—*ib.*

Cumberland *Mountain*, occupies a part of the uninhabited country of the ftate of Tenneffee, between the diftricts of Wafhington and Hamilton and Mero diftrict;

diftrict; and between the two firft named diftricts and the ftate of Kentucky. The ridge is about 30 miles broad, and extends from Crow creek, on Tenneffee river from S. W. to N. E. The place where the Tenneffee breaks through the Great ridge, called the *Whirl* or *Suck*, is 250 miles above the Mufcle fhoals. Limeftone is found on both fides the mountain. The mountain confifts of the moft ftupendous piles of craggy rocks of any mountain in the weftern country. In feveral parts of it, it is inacceffible for miles, even to the Indians on foot. In one place particularly, near the fummit of the mountain, there is a moft remarkable ledge of rocks of about 30 miles in length, and 200 feet thick, fhewing a perpendicular face to the S. E. more noble and grand than any artificial fortification in the known world, and apparently equal in point of regularity.—*ib.*

CUMBERLAND *River*, called by the Indians "Shawanee," and by the French "Shavanon," falls into the Ohio 10 miles above the mouth of Tenneffee river, and about 24 miles due E. from fort Maffac, and 1113 below Pittfburg. It is navigable for large veffels to Nafhville in Tenneffee, and from thence to the mouth of Obed's or Obas river. The Caney fork, Harpeth, Stones, Red, and Obed's, are its chief branches; fome of them are navigable to a great diftance.

The Cumberland mountains in Virginia feparate the head waters of this river from thofe of Clinch river. It runs S. W. till it comes near the S. line of Kentucky, when its courfe is wefterly, in general, through Lincoln co. receiving many ftreams from each fide; thence it flows S. W. into the ftate of Tenneffee, where it takes a winding courfe, inclofing Sumner, Davidfon, and Tenneffee counties; afterwards it takes a N. weftern direction and re-enters the ftate of Kentucky; and from thence it preferves nearly an uniform diftance from Tenneffee river to its mouth, where it is 300 yards wide. It is 200 yards broad at Nafhville, and its whole length is computed to be above 450 miles.—*ib.*

CUMBERLAND-RIVER, a place fo called, where a poft office is kept, in Tenneffee, 13 miles from Cumberland mountain, and 80 from the Crab-Orchard in Kentucky.—*ib.*

CUMMASHAWAS, or *Cummafhawaa*, a found and village on the E. fide of Wafhington ifland, on the N. W. coaft of N. America. The port is capacious and fafe, and its mouth lies in 53. 2. 30. N. lat. and in 228. 22. W. long. In this port Capt. Ingraham remained fome time; and he obferves, in his journal, that here, in direct oppofition to moft other parts of the world, the women maintained a precedency to the men in every point; infomuch that a man dares not trade without the concurrence of his wife; and that he has often been witnefs to men's being abufed for parting with fkins before their approbation was obtained: and this precedency often occafioned much difturbance.—*ib.*

CUMMINGTON, a townfhip in Hampfhire co. Maffachufetts, having 873 inhabitants; lying about 20 miles N. W. of Northampton, and 120 N. W. by W. of Bofton. It was incorporated in 1779.—*ib.*

CURFEU-BELL (fee CURFEW, *Encycl.*), called in the law Latin of the middle ages *ignitegium* or *pyritegium*, and in French, *cuvre-feu*—was a fignal for all perfons to extinguifh their fires at a certain hour. In thofe ages people made fires in their houfes in a hole or pit in the centre of the floor, under an opening formed in the roof; and when the fire was burnt out, or the family went to bed, the hole was fhut by a cover of wood or of earth. This practice ftill prevails among the cottagers in fome parts of Scotland, and we doubt not of other countries. In the dark ages, when all ranks of people were turbulent, a law was almoft everywhere eftablifhed, that the fire fhould be extinguifhed at a certain time in the evening; that the cover fhould be put over the fire-place; and that all the family fhould retire to reft, or at leaft keep within doors. The time when this ought to be done was fignified by the ringing of a bell, called therefore the *curfeu-bell* or *ignitegium*. The law of William the Conqueror, which introduced this practice into England, as has been mentioned in the Encyclopædia, was abolifhed by Henry I. in 1100.

The ringing of the curfeu-bell gave rife to the prayer bell, as it is called, which is ftill retained in fome Proteftant countries. Pope John XXIII. with a view to avert certain apprehended misfortunes, which rendered his life uncomfortable, gave orders, that every perfon, on hearing the *ignitegium* fhould repeat the *Ave Maria* three times. When the appearance of a comet, and a dread of the Turks, afterwards alarmed all Chriftendom, Pope Calixtus III. increafed thefe periodical times of prayer, by ordering the prayer-bell to be rung alfo at noon. *Beckmann's Hiftory of Inventions.*

CURRITUCK *Co.* is fituated on the fea coaft of Edenton diftrict, N. Carolina, and forms the N. E. corner of the ftate; being bounded E. by Currituck found, N. by the ftate of Virginia, S. by Albemarle found, and W. by Camden co.; containing 5219 inhabitants, of whom 1103 are flaves. Difmal fwamp lies in this county, on the S. fide of Albemarle found, and is now fuppofed to contain one of the moft valuable rice eftates in America. In the midft of this Difmal, which contains upwards of 350,000 acres, is a lake of about 11 miles long and 7 miles broad. A navigable canal, 20 feet wide and $5\frac{1}{2}$ miles long, connects the waters of the lake with the head of Skuppernong river. About 500 yards from the lake, the proprietors have erected feveral faw mills: and as the water of the lake is higher than the banks of the canal, the company can at any time lay under water about 10,000 acres of rich fwamp, which proves admirably fitted for rice.—*Morse.*

CURRITUCK, or *Caratunk*, a townfhip in the diftrict of Maine, 28 miles above Norridgewalk. In 1792 this was the uppermoft fettlement on Kennebeck river, and then confifted of about 20 families.—*ib.*

CURVE OF EQUABLE APPROACH. It was firft propofed by Leibnitz, namely, to find a curve, down which a body defcending by the force of gravity fhall make equal approaches to the horizon in equal portions of time. It has been found by Bernoulli and others, that the curve is the fecond cubical parabola, placed with its vertex uppermoft, and which the defcending body muft enter with a certain determinate velocity. Varignon rendered the queftion general for any law of gravity, by which a body may approach towards a given point by equal fpaces in equal times. And Maupertuis alfo refolved the problem in the cafe of a body defcending

defcending in a medium which refifts as the fquare of the velocity.

CUSCOWILLA, in Eeaft-Florida, is the capital of the Alachua tribe of Indians, and ftands in the moft pleafant fituation that could be defired in an inland country; upon a high, fwelling ridge of fand hills, within 300 or 400 yards of a large and beautiful lake, abounding with fifh and wild fowl. The lake is terminated on one fide by extenfive forefts, confifting of orange groves, overtopped with grand magnolias, palms, poplar, tilia, live-oaks, &c.; on the other fide by extenfive green plains and meadows. The town confifts of 30 habitations, each of which confifts of 2 houfes, nearly of the fame fize, large and convenient, and covered clofe with the bark of the cyprefs tree. Each has a little garden fpot, containing corn, beans, tobacco, and other vegetables. In the great Alachua favanna, about 2 miles diftant, is an inclofed plantation, which is worked and tended by the whole community, yet every family has its particular part. Each family gathers and depofits in its granary its proper fhare, fetting apart a fmall contribution for the public granary, which ftands in the midft of the plantation. —*Morse.*

CUSHAI, a fmall river which empties into Albemarle found, between Chowan and the Roanoke, in North Carolina.—*ib.*

CUSHING, a townfhip in Lincoln co. diftrict of Maine, feparated from Warren and Thomafton by St George's river. It was incorporated in 1789, contains 942 inhabitants, and lies 216 miles W. by N. of Bofton.—*ib.*

CUSSENS, a fmall river in Cumberland co. Maine, which runs a S. E. courfe to Cafco-bay, between the towns of Freeport and North-Yarmouth.—*ib.*

CUSSEWAGA, a fettlement in Pennfylvania.—*ib.*

CUSSO, or Banksia Abyssinica, is a beautiful and ufeful tree, indigenous to the high country of Abyffinia. At leaft Mr Bruce, who has given of it the only defcription which we have feen, fays, that he never faw it in any other part of Afia or Africa. It feldom grows above twenty feet high, very rarely ftraight, generally crooked or inclined. Its leaf, which is of a deep unvarnifhed green, having the fore part covered with foft hair or down, is about 2¼ inches long, divided by a ftrong rib into two unequal divifions, of which the upper is broader and larger than the lower. It is more indented than even the nettle leaf, which it in fome meafure refembles, only the leaf of the *Cuffo* is narrower and longer.

Thofe leaves grow two and two upon a branch, having between each two the rudiments of *two pair* of leaves, which probably are *deciduous;* but the branch is terminated with a fingle leaf or *ftipula* at the point. The end of this ftalk is broad and ftrong, like that of a palm branch. It is not folid like the gerid of the date tree, but opens in the part that is without leaves about an inch and a half from the bottom, and out of this aperture proceeds the flower. There is a round ftalk, bare for about an inch and a quarter, from which proceed crooked branches with fingle flowers attached to their ends; the ftalk that carries thefe proceeds out of every crook or geniculation. The whole clufter of flowers has very much the fhape of a clufter of grapes; the ftalks which fupport it refemble the ftalks of the grape; and a very few fmall leaves are fcattered through the clufter of flowers.

"The calyx or flower cup is of a *greenifh* colour, tinged with purple; when fully blown it is altogether of a deep *red* or purple; the corolla is *white*, and confifts of five petals; in the midft is a fhort piftil, with a round head, furrounded by eight ftamina of the fame form, loaded with yellow farina. The cup confifts of five petals, which much refemble another flower; they are rounded at the top, and nearly of an equal breadth every way. The feed is very fmall, fmaller than even the femen fantonicum, and being likewife very bitter, it is ufed in Abyffinia as a vermifuge. From its fmallnefs, however, and its being very eafily fhed, no great quantity of it is ever gathered, and therefore the flower is often fubftituted in its ftead. The Abyffinians, fays our author, of both fexes, and at all ages, are troubled with the fort of worm called afcarides, of which every individual evacuates a large quantity once a-month The method of promoting thefe evacuations is by infufing a handful of dry cuffo flowers in about two Englifh quarts of bouza, or the beer they make of teff (See Teff *Encycl.*), and after it has been fteeped all night, the next morning it is fit for ufe.

"The bark of the tree is fmooth, of a yellowifh white, interfperfed with brown ftreaks which pafs through the whole body of the tree. It is not firm or hard, but rather ftringy and reedy. On the upper part, before the firft branch of leaves fet out, are rings round the trunk, of fmall filaments, of the confiftence of horfe hair: thefe are generally fourteen or fixteen in number, and are a very remarkable characteriftic belonging to the tree."

From this defcription, which, it muft be confeffed, is not remarkable for perfpicuity, and from an infpection of the figure which Mr Bruce has given of the cuffo, we are inclined to rank it with the palms, as a new genus neareft to the *caryota*.

CUVETTE, or Cunette, in fortification, is a kind of ditch within a ditch, being a pretty deep trench, about four fathoms broad, funk, and running along the middle of the great dry ditch to hold water; ferving both to keep off the enemy, and to prevent him from mining.

CUYA, or *Cutio*, a province of Chili, in S. America, and in the government of Santa Cruz, in the Sierra. The principal commodities are honey and wax. The chief town is St John de Frontiera.—*Morse.*

CUZUMEL, an ifland in the province of Yucatan, and audience of Mexico, fituated in the bay of Honduras; 15 leagues long and 5 broad; its principal town is Santa Cruz. N. lat. 19. long. 87.—*ib.*

CYCLE of Indiction, is a feries of 15 years, returning conftantly around like the other cycles, and commenced from the third year before Chrift; whence it happens that if 3 be added to any given year of Chrift, and the fum be divided by 15, what remains is the year of the indiction

CYCLOID (fee *Encycl.*) is a curve which is thus generated: Suppofe a wheel or circle to roll along a ftraight line till it has completed juft one revolution; a nail or point in that part of the circumference of the circle, which at the beginning of the motion touches the ftraight line, will at the end of the revolution, have defcribed on a vertical plane a cycloid.

DAGELET,

D.

DAGELET, the name given by *La Perouse*, the celebrated though unfortunate navigator, to an island on the coast of Corea (See Corea *Encycl.*) which he discovered in the year 1787. It is little more than three leagues in circumference; and our author almost made its circuit at the distance of a mile without finding bottom. This small spot is very steep, but covered with the finest trees from the sea-shore to the summit. A rampart of bare rock, like a wall, encircles the whole outline of it, with the exception of seven little sandy creeks where it is possible to land. In these creeks the Frenchmen saw upon the stocks some boats of a construction altogether Chinese; but the sight of their ships frightened the workmen, who fled from their dock-yard into the wood, which was not more than fifty paces distant. As a few huts were seen, but neither villages nor cultivation, La Perouse concluded that the island is without inhabitants, and that the men whom he saw at work were Corean carpenters, who during the summer months go with provision to Dagelet for the purpose of building boats, which they sell upon the continent. He places the north east point of this island in N. Lat. 37°. 25'. and E. Long. 129°. 2'. from Paris.

DAGSBOROUGH, a post town in Sussex co. Delaware, situated on the N. W. bank of Peper's creek, a branch of Indian river, and contains about 40 houses. It is 19 miles from Broad hill, or Clowes', and 127 S. from Philadelphia.—*Morse.*

DAIRY is a word which signifies sometimes the art of making various kinds of food from milk; sometimes the place where milk is manufactured; and sometimes the management of a milk-farm. On the *dairy*, in the first and second of these senses, enough has been said in the *Encyclopædia* under the titles Butter, Cheese, and Dairy; on the management of a milk-farm that work contains nothing.

When a dairy is established, the undertaker may sometimes think it his interest to obtain the greatest possible quantity of produce; sometimes it may be more beneficial for him to have it of the finest quality; and at other times it may be necessary to have both these objects in view, the one or the other in a greater or less proportion; it is therefore of importance that he should know how he may accomplish the one or the other of these purposes in the easiest and most direct manner.

To be able to convert his milk to the highest possible profit in every case, he ought to be fully acquainted with every circumstance respecting the manufacture both of butter and of cheese: as it may in some cases happen, that a certain portion of that milk may be more advantageously converted into butter than into cheese, while another portion of it would return more profit if made into cheese.

The first thing to be adverted to in an undertaking of this nature is to choose cows of a proper sort. Among this class of animals, it is found by experience, that some kinds give milk of a much thicker consistence, and richer quality, than others; nor is this richness of quality necessarily connected with the smallness of the quantity yielded by cows of nearly an equal size; it therefore behoves the owner of a dairy to be peculiarly attentive to this circumstance. In judging of the value of a cow, it ought rather to be the quantity and the quality of the cream produced from the milk of the cow, in a given time, than the quantity of the milk itself: this is a circumstance that will be shewn hereafter to be of more importance than is generally imagined. The small cows of the Alderney breed afford the richest milk hitherto known; but individual cows in every country may be found, by a careful selection, that afford much thicker milk than others; these therefore ought to be searched for with care, and their breed reared with attention as being peculiarly valuable.

Few persons, who have had any experience at all in the dairy, can be ignorant, however, that in comparing the milk of two cows, to judge of their respective qualities, particular attention must be paid to the time that has elapsed since their calving; for the milk of the same cow is always thinner soon after calving than it is afterwards; as it gradually becomes thicker, though generally less in quantity in proportion to the time since the cow has calved. The colour of the milk soon after calving is richer than it is afterwards; but this, especially for the first two weeks, is a faulty colour, that ought not to be coveted.

To make the cows give abundance of milk, and of a good quality, they must at all times have plenty of food. Grass is the best food yet known for this purpose, and that kind of grass which springs up spontaneously on rich dry soils is the best of all. If the temperature of the climate be such as to permit the cows to graze at ease throughout the day, they should be suffered to range on such pastures at freedom; but if the cows are so much incommoded by the heat as to be prevented from eating through the day, they ought in that case to be taken into cool shades for protection; where, after allowing them a proper time to ruminate, they should be supplied with abundance of green food fresh cut for the purpose, and given to them by hand frequently, in small quantities fresh and fresh, so as to induce them to eat it with pleasure. When the heat of the day is over, and they can remain abroad with ease, they may be again turned into the pasture, where they should be allowed to range with freedom all night, during the mild weather of summer.

Cows, if abundantly fed, should be milked three times a-day during the whole of the summer season (A); in the

(A) If cows be milked only twice in the day (24 hours), while they have abundance of succulent food, they will yield a much smaller quantity of milk, in the same time, than if they be milked three times. Some attentive

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the morning early, at noon, and in the evening, juſt before night-fall. In the choice of perſons for milking the cows, great caution ſhould be employed; for if that operation be not carefully and properly performed, not only the quantity of the produce of the dairy will be greatly diminiſhed, but its quality alſo will be very much debaſed; for if all the milk be not thoroughly drawn from a cow when ſhe is milked, that portion of milk which is left in the udder ſeems to be gradually abſorbed into the ſyſtem, and Nature generates no more than to ſupply the waſte of what has been taken away. If this leſſened quantity be not again thoroughly drawn off, it occaſions a yet farther diminution of the quantity of milk generated; and thus it may be made to proceed in perpetual progreſſion from little to leſs, till none at all is produced. In ſhort, this is the practice in all caſes followed, when it is meant to allow a cow's milk to dry up entirely, without doing her hurt. In this manner, therefore, the profits of a dairy might be wonderfully diminiſhed; ſo that it much behoves the owner of it to be extremely attentive to this circumſtance, if he wiſhes to avoid ruin. It ought to be a rule without an exception, never to allow this important department to be entruſted, without controul, to the management of hired ſervants (B). Its importance will be ſtill more manifeſt from what follows.

It is to Dr James Anderſon that we are indebted for theſe judicious obſervations, as well as for the following aphoriſms which though they may be in part known to attentive houſewives, he has reaſon to believe are not commonly adverted to as their importance deſerves.

Aphoriſm 1. "Of the milk that is drawn from any cow at one time, that which comes off at the firſt is always thinner, and of a much worſe quality, than that which comes afterwards; and the richneſs goes on continually increaſing to the very laſt drop that can be drawn from the udder at that time."

Few perſons are ignorant that the milk which is laſt of all taken from the cow at milking (in this country called *ſtroakings)* is richer than the reſt of the milk; but fewer ſtill are aware of the greatneſs of the diſproportion between the quality of the firſt and the laſt drawn milk, from the ſame cow, at one milking. The following facts (ſays our author) reſpecting this circumſtance were aſcertained by me many years ago, and have been confirmed by many ſubſequent experiments and obſervations.

Having taken ſeveral large tea-cups, exactly of the ſame ſize and ſhape, one of theſe tea-cups was filled at the beginning of the milking, and the others at regular intervals, till the laſt, which was filled with the dregs of the ſtroakings. Theſe cups were then weighed, the weight of each having been ſettled, ſo as to aſcertain that the quantity of milk in each was preciſely the ſame; and from a great number of experiments, frequently repeated with many different cows; the reſult was in all caſes as follows:

The quantity of cream obtained from the firſt drawn cup was, in every caſe, much ſmaller than from that which was laſt drawn; and thoſe between afforded leſs or more as they were nearer the beginning or the end. It is unneceſſary here to ſpecify theſe intermediate proportions; but it is proper the reader ſhould be informed, that the quantity of cream obtained from the laſt-drawn cup, from ſome cows, exceeded that from the firſt in the proportion of ſixteen to one. In other cows, however, and in particular circumſtances, the diſproportion was not quite ſo great; but in no caſe did it fall ſhort of the rate of eight to one. Probably, upon an average of a great many cows, it might be found to run as ten or twelve to one.

Secondly, The difference in the quality of the cream, however, obtained from theſe two cups, was much greater than the difference in the quantity. In the firſt cup, the cream was a thin tough film, thinner, and perhaps whiter, than writing paper; in the laſt, the cream was of a thick *butyrous* conſiſtence, and of a glowing richneſs of colour that no other kind of cream is ever found to poſſeſs.

Thirdly, The difference in the quality of the milk that remained, after the cream was ſeparated, was perhaps ſtill greater than either in reſpect to the quantity or the quality of the cream. The milk in the firſt cup was a thin bluiſh liquid, as if a very large proportion of water had been mixed with ordinary milk; that in the laſt cup was of a thick conſiſtence, and yellow colour, more reſembling cream than milk both in taſte and appearance.

From this important experiment, it appears that the perſon who, by bad milking of his cows, loſes but half a pint of his milk, loſes in fact about as much cream as would be afforded by ſix or eight pints at the beginning, and loſes, beſides, that part of the cream which alone can give richneſs and high flavour to his butter.

"If milk be put into a diſh, and allowed to ſtand till it throws up cream, that portion of cream which riſes firſt to the ſurface is richer in quality, and greater in quantity, than what riſes in a ſecond equal ſpace of time; and the cream that riſes in the ſecond interval of time is greater in quantity, and richer in quality, than that which riſes in a third equal ſpace of time; that of the third than the fourth, and ſo on; the cream that riſes decreaſing in quantity, and declining in quality, continually, as long as any riſes to the ſurface." Aphoriſm 2.

Our

tive obſervers think a cow, in theſe circumſtances, will give nearly as much milk at each time, if milked three times, as if ſhe were milked only twice. This fact, however, has not, that we know of, been aſcertained by experiment. There can be no doubt but they give more, how much more is not aſcertained; nor, whether it would be advantageous, in any caſe, to milk them four times, or oftener; nor, what effect frequent milking produces on the quality of the milk.

(B) Cows ſhould always be treated with great gentleneſs, and ſoothed by mild uſage, eſpecially when young and ticklish, or when the paps are tender; in which laſt caſe the udder ought to be fomented with warm water before milking, and touched with the greateſt gentleneſs, otherwiſe the cow will be in danger of contracting bad habits, becoming ſtubborn and unruly, and retaining her milk ever after. A cow never lets down her milk pleaſantly to the perſon ſhe dreads or diſlikes. The udder and paps ſhould always be waſhed with clean water before milking; but care ſhould be taken that none of that water be admitted into the milking-pail.

Dairy.

Our ingenious author confeffes, that his experiments not having been made with fo much accuracy in this cafe as in the former, he was not enabled to afcertain the difference in the proportion that takes place in equal portions of time; but they have been fo often repeated as not to leave any room to doubt the fact, and it will be allowed to be a fact of no fmall importance in the management of the dairy. It is not certain, however, but that a greater quantity of cream may, upon the whole, be obtained from the milk by taking it away at different times; but the procefs is fo troublefome as not to be counterbalanced by the increafed quantity obtained, if indeed an increafed quantity be thus obtained, which is not as yet quite certain.

Aphorifm 3. "Thick milk always throws up a fmaller proportion of the cream it actually contains, to the furface, than milk that is thinner; but that cream is of a richer quality. If water be added to that thick milk, it will afford a confiderably greater quantity of cream than it would have done if allowed to remain pure, but its quality is, at the fame time, greatly debafed."

This is a fact that every perfon attentive to a dairy muft have remarked; but I have never (fays our author) heard of any experiment that could afcertain, either the precife amount of the increafed quantity of cream that might thus be obtained, or of the ratio in the decreafe of its quality. The effects of mixing water with the milk in a dairy are at leaft afcertained; and the knowledge of this fact will enable attentive perfons to follow that practice which they think will beft promote their own intereft.

Aphorifm 4. "Milk which is put into a bucket or other proper veffel, and carried in it to any confiderable diftance, fo as to be much agitated, and in part cooled, before it be put into the milk-pans to fettle for cream, never throws up fo much, nor fo rich cream, as if the fame milk had been put into the milk-pans directly after it was milked."

In this cafe, it is believed the lofs of cream will be nearly in proportion to the time that has elapfed, and the agitation the milk has fuftained, after being drawn from the cow. But Dr Anderfon fays that he is not yet in poffeffion of any experiments which fufficiently afcertain how much is to be afcribed to the time, and the agitation, taken feparately. On every branch of agriculture we find experiments wanting, at each ftep we advance in our enquiries; and it is the duty of every enquirer to point out, as he goes along where they are wanted, fince the labours of no one man can poffibly complete the whole.

From the above facts, the following corollaries feem to be clearly deducible:

Firft. It is of importance that the cows fhould be always milked as near the dairy as poffible, to prevent the neceffity of carrying and cooling the milk before it is put into the difhes; and as cows are much hurt by far driving, it muft be a great advantage in a dairy-farm to have the principal grafs fields as near the dairy or homeftead as poffible.

Secondly. The practice of putting the milk of all the cows of a large dairy into one veffel, as it is milked, there to remain till the whole milking is finifhed, before any part of it is put into the milk-pans—feems to be highly injudicious; not only on account of the lofs that is fuftained by agitation and cooling, but alfo, more efpecially, becaufe it prevents the owner of the dairy from diftinguifhing the good from the bad cow's milk, fo as to feparate thefe from each other, where it is neceffary. He may thus have the whole of his dairy product greatly debafed by the milk of one bad cow, for years together, without being able to difcover it. A better practice, therefore, would be, to have the milk drawn from each cow put feparately into the creaming-pans as foon as it is milked, without being ever mixed with any other. Thus would the careful manager of the dairy be able on all occafions to obferve the particular quality of each individual cow's milk, as well as its quantity, and to know with precifion which of his cows it was his intereft to difpofe of and which of them he ought to keep and breed from.

Thirdly. If it be intended to make butter of a very fine quality, it will be advifable in all cafes to keep the milk that is firft drawn feparate from that which comes laft; as it is obvious, that if this be not done, the quality of the butter will be greatly debafed, without much augmenting its quantity. It is alfo obvious, that if this is done, the quality of the butter will be improved in proportion to the fmallnefs of the quantity of the laft-drawn milk that is retained; fo that thofe who wifh to be fingularly nice in this refpect, will do well to retain only a very fmall portion of the laft-drawn milk.

To thofe owners of dairies who have profit only in view, it muft ever be a matter of trial and calculation, how far it is expedient for them to carry the improving of the quality of their butter at the expence of diminifhing its quantity. In different fituations prudence will point out different kinds of practice as moft eligible; and all perfons muft be left, after making accurate trials, to determine for themfelves. It is likewife a confideration of no fmall importance, to determine in what way the inferior milk, that is thus to be fet apart where fine butter is wanted, can be employed with the greateft profit. In the Highlands of Scotland they have adopted, without thinking of the improvement of their butter, a very fimple and economical practice in this refpect. As the rearing of calves is there a principal object with the farmer, every cow is allowed to fuckle her own calf with a part of her milk, the remainder only being employed in the dairy. To give the calf its portion regularly, it is feparated from the cow, and kept in an inclofure, with all the other calves belonging to the fame farm. At regular times, the cows are driven to the door of the inclofure, where the young calves fail not to meet them. Each calf is then feparately let out, and runs directly to its mother, where it fucks till the dairy-maid judges it has had enough; fhe then orders it to be driven away, having previoufly fhackled the hinder legs of the mother, by a very fimple contrivance, to oblige her to ftand ftill. Boys drive away the calf with fwitches, and return it to the inclofure, while the dairy-maid milks off what was left by the calf; thus they proceed till the whole of the cows are milked. They obtain only a fmall quantity of milk, it is true, but that milk is of an exceeding rich quality; which, in the hands of fuch of the inhabitants as know how to manage it, is manufactured into the richeft marrowy butter that can be anywhere met with. This richnefs of the Highland butter is univerfally afcribed to the old grafs the cows feed upon in their remote glens; but it is in fact chiefly to be attributed to the practice here defcribed, which has long prevailed in in thoſe regions. Whether a ſimilar practice could be economically adopted elſewhere, our author takes not upon him to ſay; but doubtleſs other ſecondary uſes might be found for the milk of inferior quality. On ſome occaſions, it might be converted into butter of an inferior quality; on other occaſions, it might be ſold ſweet, where the ſituation of the farm was within reach of a market-town; and on others, it might be converted into cheeſes, which, by being made of ſweet milk, would be of a very fine quality if carefully made (c). Still other uſes might be deviſed for its application; of which the following is worthy of notice. Take common ſkimmed milk, when it has begun to turn ſour, put it into an upright ſtand churn, or a barrel with one of its ends out, or any other convenient veſſel. Heat ſome water, and pour it into a tub that is large enough to contain with eaſe the veſſel in which the milk was put. Set the veſſel containing the milk into the hot water, and let it remain there for the ſpace of one night. In the morning it will be found that the milk has ſeparated into two parts; a thick cream-like ſubſtance, which occupies the upper part of the veſſel, and a thin watery part, that remains at the bottom. Draw off the thin part, (called in Scotland *wigg*) by opening a ſtop-cock, placed for that purpoſe cloſe above the bottom, and reſerve the cream for uſe. Not much leſs than half of the milk is thus converted into a ſort of cream, which, when well made, ſeems to be as rich and fat as real cream itſelf, and is only diſtinguiſhable from it by its ſourneſs. It is eaten with ſugar, and eſteemed a great delicacy, and uſually ſells at double the price of freſh unſkimmed milk. It requires practice, however, to be able to make this nicely. The degree of the heat of the water, and many other circumſtances, greatly affecting the operation.

Fourthly. If the quality of the butter be the chief object attended to, it will be neceſſary, not only to ſeparate the firſt from the laſt drawn milk, but alſo to take nothing but the cream that is firſt ſeparated from the beſt milk, as it is this firſt riſing cream alone that is of the prime quality. The remainder of the milk, which will be ſtill ſweet, may be either employed for the purpoſe of making ſweet milk cheeſes, or may be allowed to ſtand, to throw up cream for making butter of an inferior quality, as circumſtances may direct.

Fifthly. From the above facts, we are enabled to perceive, that butter of the very beſt poſſible quality can only be obtained from a dairy of conſiderable extent, judiciouſly managed; for when only a ſmall portion of each cow's milk can be ſet apart for throwing up cream, and when only a ſmall proportion of that cream can be reſerved, of the prime quality, it follows (the quantity of milk being upon the whole very inconſiderable), that the quantity of prime cream produced would be ſo ſmall as to be ſcarcely worth manufacturing ſeparately.

Sixthly. From theſe premiſes we are alſo led to draw another concluſion, extremely different from the opinion that is commonly entertained on this ſubject, viz. That it ſeems probable, that the very beſt butter could be made with economy in thoſe dairies only where the manufacture of cheeſe is the principal object. The reaſons are obvious: If only a ſmall portion of milk ſhould be ſet apart for butter, all the reſt may be made into cheeſe, while it is yet warm from the cow, and perfectly ſweet; and if only that portion of cream which riſes during the firſt three or four hours after milking is to be reſerved for butter, the rich milk, which is left after that cream is ſeparated being ſtill perfectly ſweet, may be converted into cheeſe with as great advantage nearly as the newly milked milk itſelf.

But as it is not probable that many perſons could be found who would be willing to purchaſe the very fineſt butter, made in the manner above pointed out, at a price that would be ſufficient to indemnify the farmer for his trouble in making it, theſe hints are thrown out merely to ſhew the curious in what way butter poſſeſſing this ſuperior degree of excellence may be obtained, if they chooſe to be at the expence; but for an ordinary market, Dr Anderſon is ſatisfied, from experience and attentive obſervation, that if in general about the firſt drawn half of the milk be ſeparated at each milking,

(c) The making of cheeſe has never yet been reduced to ſcientific principles, and conſequently the reaſoning relating to it is very inconcluſive. It is in general ſuppoſed, that the goodneſs of cheeſe depends almoſt entirely upon its richneſs, by which is meant the proportion of oily matter, whether natural or extraneous, it contains; nothing, however, is more certain, than that this opinion is erroneous. Sometimes a very lean cheeſe is much better taſted than one that is much fatter; and, which will appear to moſt perſons ſtill more extraordinary, it frequently happens, that a cheeſe that taſtes ſoft and fat, is much leaner than one that is hard, dry, and ſticky. The mode of manufacturing it occaſions this, and not the quantity of cream it contains. It is very poſſible by art to make poor ſkim milk cheeſe aſſume the ſoft buttery taſte and appearance even of cream cheeſe. This ſubject, therefore, deſerves to be more particularly elucidated than it has hitherto been.

Connected as they are with the object diſcuſſed in the text, we beg leave with our author to ſuggeſt the following particulars as proper objects of examination and experiment, viz. Is the quantity of caſeous matter afforded by milk neceſſarily connected with the proportion of cream that milk contains, or does it depend upon ſome other principle not hitherto inveſtigated? Without pretending to decide this queſtion, Dr Anderſon feels himſelf ſtrongly inclined to believe it does not depend upon the quantity of cream. It is well known that cow's milk, which always throws up more cream, and that of a much richer quality, than ewe-milk, does in no caſe afford above one half the proportion of cheeſe that ewe-milk does. Nor can this ſingular tendency of ewe-milk, to yield a great proportion of curd, be attributed to its ſuperior thickneſs; for cow-milk can be often had that is thicker and richer than ewe-milk, but it always affords a much ſmaller proportion of curd. From theſe conſiderations, it is not impoſſible but it might be found, upon a careful inveſtigation, that the refuſe milk, which ought to be ſeparated from the other in making the beſt butter, might be equally proper, or very nearly ſo, for making cheeſe as if no ſuch ſeparation had been made. We therefore recommend this as a proper object of experimental enquiry.

ing, and the remainder only fet up for producing cream, and if that milk be allowed to ftand to throw up the whole of its cream (even till it begins fenfibly to tafte fourifh), and that cream be afterwards carefully managed, the butter thus obtained will be of a quality greatly fuperior to what can ufually be procured at market, and its quantity not confiderably lefs, than if the whole of the milk had been treated alike. This, therefore, is the practice that our author thinks moft likely to fuit the frugal farmer, as his butter, though of a fuperior quality, could be afforded at a price that would always enfure it a rapid fale.

Dr Anderfon throws out many other ingenious and ufeful obfervations on this important branch of rural economy. In particular, he points out, in the plaineft manner, the requifites of a good milk-houfe, which, as he truly obferves, fhould be cool in fummer and warm in winter, fo as to preferve a temperature nearly the fame throughout the year. But we have treated of this part of the fubject elfewhere, and muft therefore refer fuch as are defirous to know the doctor's fentiments on it, to *the Letters and Papers of the Bath and Weft of England Society* for the encouragement of agriculture, &c. or to the eighth volume of *the Repertory of Arts and Manufactures.*

DAHALAC, the largeft ifland in the Red Sea, is thus defcribed by Mr Bruce. It is low and even, the foil fixed gravel and white fand, mixed with fhells and other marine productions. It is deftitute of all forts of herbage, at leaft in fummer, unlefs a fmall quantity of bent grafs, juft fufficient to feed the few antelopes and goats that are on the ifland. There is a very beautiful fpecies of this laft animal found here, fmall, fhort-haired, with thin black fharp horns, having rings upon them, and they are very fwift of foot.

This ifland is, in many places, covered with large plantations of acacia trees, which grow to no height, feldom above eight feet, but fpread wide, and turn flat at top, probably by the influence of the wind from the fea. Though in the neighbourhood of Abyffinia, Dahalac does not partake of its feafons, no rain falls here from the end of March to the beginning of October; but in the intermediate months, efpecially December, January and February, there are violent fhowers for 12 hours at a time, which deluge the ifland, and fill the cifterns fo as to ferve all next fummer, for there are no hills nor mountains in Dahalac, and confequently no fprings. Thefe cifterns alone preferve the water, and of them there yet remain 370, all hewn out of the folid rock. They fay thefe were the works of the Perfians; it is more probable they were thofe of the firft Ptolemies. But whoever were the conftructors of thefe magnificent refervoirs, they were a very different people from thofe that now poffefs them, who have not induftry enough to keep one of the 370 clear for the ufe of man. All of them are open to every fort of animal, and half full of the filth they leave there, after drinking and wafhing in them; yet one of thefe cifterns, cleaned and fhut up with a door might afford them wholefome fweet water all the year over.

After the rains fall, a prodigious quantity of grafs immediately fprings up; and the goats give the inhabitants milk, which in winter is the principal part of their fubfiftence; for they neither plow nor fow; all their employment is to work the veffels which trade to the different parts of the coaft. One half of the inhabitants is conftantly on the Arabian fide, and by their labour is enabled to furnifh with *dora* (millet or Indian corn) and other provifions the other half who ftay at home; and when their time is expired, they are relieved by the other half, and fupplied with neceffaries in their turn. But the fuftenance of the poorer fort is entirely fhell and other fifh. Their wives and daughters are very bold and expert fifher-women. Several of them, entirely naked, fwam off to the veffel before it came to an anchor, begging handfuls of wheat, rice, or dora. They are very importunate and fturdy beggars, and not eafily put off with denials. Thefe miferable people, who live in the villages not frequented by barks from Arabia, are fometimes a whole year without tafting bread. Yet fuch is the attachment to their place of nativity, they prefer living in this bare, barren, parched fpot, almoft in want of neceffaries of every kind, efpecially of thefe effential ones, bread and water, to thofe pleafant and plentiful countries on both fides of them.

There are in Dahalac twelve villages or towns, of which each has a plantation of doomtrees round it, which furnifh the only manufacture in the ifland. The leaves of this tree, when dried, are of a gloffy white, which might very eafily be miftaken for fattin: of thefe they make bafkets of furprifing beauty and neatnefs, ftaining part of the leaves with red or black, and working them into figures very artificially. Our author knew fome of thefe refembling ftraw bafkets, continue full of water for 24 hours, without one drop coming through. They fell thefe at Loheia and Jidda, the largeft of them for four commefh, or fixpence. This is the employment, or rather amufement, of the men who ftay at home; for they work but very moderately at it, and all of them indeed take fpecial care not to prejudice their health by any kind of fatigue from induftry.

People of the better fort, fuch as the Shekh and his relations, men privileged to be idle, and never expofed to the fun, are of a brown complexion. But the common fort employed in fifhing, and thofe who go conftantly to fea, are not indeed black but red, and little darker than the colour of new mahogany.

The inhabitants of Dahalac feemed to be a fimple, fearful and inoffenfive people. It is the only part of Africa or Arabia (call it which you pleafe) where you fee no one carry arms of any kind; neither gun, knife, nor fword, is to be feen in the hands of any one. Whereas, at Loheia, and on all the coaft of Arabia, and more particularly at Yambo, every perfon goes armed; even the porters, naked, and groaning under the weight of their burden and heat of the day, have yet a leather belt, in which they carry a crooked knife, fo monftroufly long, that it needs a particular motion and addrefs in walking not to lame the bearer. This was not always the cafe at Dahalac; feveral of the Portuguefe, on their firft arrival here, were murdered, and the ifland often treated ill in revenge by the armaments of that nation. The men feemed healthy. They told our author they had no difeafes among them, unlefs fometimes in fpring, when the boats of Yemen and Jidda bring the fmall-pox among them, and very few efcape with life that are infected. He did not obferve among them a man that feemed to be fixty years old; from which he inferred that they are not long livers, though the air fhould be healthy, as being near the channel, Dahalac. channel, and as they have the north wind all ſummer, which moderates the heat.

Dahalac, like all the other iſlands in the Red Sea, depends upon Maſuah. The revenue of its governor conſiſts in a goat brought to him monthly by each of the twelve villages. Every veſſel that puts in there for Maſuah pays him alſo a pound of coffee, and every one from Arabia a dollar or pataka. No ſort of ſmall money is current at Dahalac, excepting Venetian glaſs-beads, old and new of all ſizes and colours, broken and whole.

Although this is the miſerable ſtate of Dahalac at preſent, matters were widely different in former times. The pearl fiſhery flouriſhed greatly here under the Ptolemies, and even long after, in the time of the caliphs, it produced a great revenue, and till the ſovereigns of Cairo, of the preſent miſerable race of ſlaves, began to withdraw themſelves from their dependency on the port, Dahalac was the principal iſland that furniſhed the pearl fiſhers or divers. It was, indeed, the chief port for the fiſhery, on the ſouthern part of the Red Sea, as Suakem was on the north; and the baſha of Maſuah paſſed part of every ſummer here, to avoid the heat at his place of reſidence on the continent.

The fiſhery extended from Dahalac and its iſlands nearly to lat. 20°. The inhabited iſlands furniſhed each a bark and ſo many divers, and they were paid in wheat, flour, &c. ſuch a portion to each bark for their uſe, and ſo much to leave with their family for their ſubſiſtence; ſo that a few months employment furniſhed them with every thing neceſſary for the reſt of the year. The fiſhery was rented in later times to the baſha of Suakem; but there was a place between Suakem and the ſuppoſed river Frat, in lat. 21° 28′ north, called *Gungunnah*, which was reſerved to the grand ſignior in particular, and a ſpecial officer was appointed to receive the pearls on the ſpot, and ſend them to Conſtantinople. The pearls found there were of the largeſt ſize, and inferior to none in water or roundneſs. Tradition ſays, that this was excluſively the property of the Pharaohs; by which is meant, in Arabian manuſcripts, the old kings of Egypt before Mahomet.

In the ſame extent, between Dahalac and Suakem, was another very valuable fiſhery, that of tortoiſes, from which the fineſt ſhells of that kind were produced, and a great trade was carried on with the Eaſt Indies (China eſpecially) at little expence, and with very conſiderable profits. But the immenſe treaſures in the bottom of the Red Sea, have now been abandoned for near 200 years, though they never were richer in all probability than at preſent. No nation can now turn them to any profit but the Engliſh Eaſt India Company, more intent on multiplying the number of their enemies, and weakening themſelves by ſpreading their inconſiderable force over new conqueſts, than creating additional profit by engaging in new articles of commerce. A ſettlement upon the river Frat, which never yet has belonged to any one but wandering Arabs, would open them a market both for coarſe and fine goods from the ſouthern frontiers of Morocco, to Congo and Angola, and ſet the commerce of pearls and tortoiſe ſhell on foot again. All this ſection of the gulf from Suez, as we are told, is in their charter, and twenty ſhips might be employed on the Red Sea, without any violation of territorial claims. The myrrh, the frankincenſe, ſome cinnamon, and variety of drugs, are all in the poſſeſſion of the weak king of Adel; an uſurper, tyrant, and Pagan, without protection, and willing to trade with any ſuperior power that only would ſecure him a miſerable livelihood.

There are neither horſes, dogs, ſheep, cows, nor any ſort of quadruped, but goats, aſſes, a few half-ſtarved camels and antelopes, at Dahalac, which laſt are very numerous. The inhabitants have no knowledge of fire-arms, and there are no dogs nor beaſts of prey in the iſland to kill them; they catch indeed ſome few of them in traps.

The language at Dahalac is that of the ſhepherds, though Arabic, too, is ſpoken by moſt of them. Our author ſtates the latitude of Dahalac to lie between 15° 27′ 30″, and 15° 54′ 30″ north.

Dalrymple. DALRYMPLE (Sir David), was born in Edinburgh on the 28th of October (N. S.) 1726. His father was Sir James Dalrymple of Hailes, Bart. and his mother Lady Chriſtian Hamilton, a daughter of the Earl of Hadinton. His grandfather Sir David Dalrymple was the youngeſt ſon of the firſt Lord Stair, and is ſaid to have been the ableſt of that family, ſo much diſtinguiſhed for ability. He was Lord Advocate for Scotland in the reign of George I. and his ſon Sir James had the auditorſhip of the exchequer for life.

The ſubject of this memoir was educated at Eton ſchool, where he was diſtinguiſhed as a ſcholar, and long remembered as a virtuous and orderly youth. In that juſtly celebrated ſeminary he acquired a claſſical taſte, which, though it was once prevalent in Scotland, has in that country been long on the decline; and formed, beſides, friendſhips to perſons, and attachments to things, which accompanied him through life. Hence probably ſprung his partiality to Engliſh manners and cuſtoms, which marked both his public conduct and private converſation, and was the ſource of much of his dignity, and ſome of his littleneſſes.

From Eton he returned to Edinburgh, whence, after the uſual courſe of a gentleman's ſtudies in that univerſity, he went to Utrecht to ſtudy the civil law; and remained there till after the rebellion in 1746. Upon his return to his native country, ſo promiſing were his parts, and ſuch his induſtry and ſoberneſs of mind, that very ſanguine expectations were entertained of his future eminence; and in ſome reſpects theſe expectations were not fruſtrated. To his intimate friends it was well known, that if left to follow the bent of his own inclinations, he would have devoted his time and his talents to the ſtudy of antiquities and the belles lettres; in both which departments of literature he was eminently qualified to excel. On the death of his father, however, he found his affairs ſo very much encumbered, that in order to retrieve them, and to provide for his brothers and ſiſters, he reſolved to follow the law as a profeſſion, in which ſome of his anceſtors had made a diſtinguiſhed figure.

He was called to the Scotch bar in 1748, where, notwithſtanding the elegant propriety of the caſes which he drew, it muſt be confeſſed, that his ſucceſs did not anſwer the expectations which had been formed of him. This was not owing either to want of ſcience or to want of induſtry, but to certain peculiarities, which, if not inherent in his nature, were the reſult of early and deep-rooted habits. He poſſeſſed on all occaſions a ſovereign contempt, not only for verbal antitheſis, but for well rounded periods, and every thing which had the ſemblance of declamation; and indeed he was wholly unfitted, by an ill-toned voice and ungraceful elocution, for ſhining as an orator. No wonder, then, that his pleadings, which were never addreſſed to the paſſions, did not rival thoſe of ſome of his opponents, who, poſſeſſed of great rhetorical powers, did not, like him, employ ſtrokes of irony too fine to be perceived by the bulk of any audience, but expreſſed themſelves in full, clear and harmonious periods. Even his memorials, though claſſically written, and often replete with valuable matter, did not on every occaſion pleaſe the court; for they were always brief, and ſometimes, as it was ſaid, indicated more attention to the minutæ of forms than to the merits of the cauſe. Yet on points which touched his own feelings, or the intereſts of truth and virtue, his language was animated, his arguments forcible, and his ſcrupulous regard to form thrown aſide.

He was ſometimes employed as a depute advocate, which gave him opportunities at the circuits of diſplaying that candour and tenderneſs of diſpoſition which ſo well becomes the public proſecutor in a criminal court. Of this the following inſtance may be worth relating. On the firſt day of the court at Stirling, he was once accoſted by another advocate in theſe words: "Sir David, why is there not a trial this forenoon? I would be getting on." "There are (replied he) ſome unhappy culprits to be tried for their *lives;* and therefore it is proper that they have time to confer with their men of law." "That is of little conſequence (ſaid the other). Laſt year I came to viſit Lord Kames when he was here on the circuit, and he appointed me counſel for a man accuſed of a rape. Though I had very little time to prepare, yet I made a decent ſpeech." "Pray, Sir, (ſaid Sir David), was your client acquitted or condemned." "O (replied the other) moſt unjuſtly condemned." "That, Sir (ſaid the depute advocate) is no good argument for hurrying on trials."

To return from this digreſſion, if it be conſidered as ſuch, it is ſurely to the honour of Sir David Dalrymple that whatever men thought of his ſingularities, his detractors concurred with his admirers in believing him incapable of miſleading the judge by a falſe ſtatement of facts; or his clients, by holding out to them fallacious grounds of hope.

His high ſenſe of honour, and his inflexible integrity, were indeed univerſally admitted; and it was with the warmeſt approbation of the public that in 1766 he was appointed one of the judges of the court of ſeſſion, the higheſt civil tribunal in Scotland. He took his ſeat on the bench, according to the uſage of that court, by the title of Lord Hailes, the deſignation by which he is generally known among the learned of Europe; and the expectations entertained of him were again ſanguine. His unwearied aſſiduity in ſifting dark and intricate matters to the bottom was well known; his elegant and conciſe manner of expreſſing his ſentiments was admirably ſuited to the character of a judge; and his legal opinions had been generally ſound. Yet it muſt be confeſſed, that as a judge he was neither ſo uſeful nor ſo highly revered as he ought to have been from the extent of his knowledge, and his unqueſtioned integrity. The ſame minute attention to forms, which had in ſome degree obſtructed his riſe at the bar, accompanied him to the bench, and brought upon him the ridicule of the wits about the court (A): and we all know that the character even of Socrates himſelf was not able to reſiſt the torrent of ridicule. In extenuation of this foible, it may be obſerved, that by ſome of the judges of the court of ſeſſion perhaps too little regard has been paid to form; and that forms, even apparently trifling, cannot in legal proceedings be wholly diſregarded without involving in danger truth and juſtice. Be this as it may, ſuch was the opinion which the other judges entertained of Lord Hailes's accuracy, diligence, and dignified manners, that, in the abſence of the preſident, they generally voted him into the vacant chair.

In May 1776 he was appointed one of the lords commiſſioners of juſticiary; and in that ſtation he commanded the reſpect of all mankind. Fully impreſſed with a deep ſenſe of the importance of his office, he ſeemed, in the criminal court, to lay aſide his ſingularities. So far from throwing his whole weight into the ſcale of the crown, a charge which has been ſometimes brought, we believe unjuſtly againſt the Scotch judges, Lord Hailes, like the judges of England, was always counſel for the priſoner when the king's counſel appeared too ſtrong for their opponents, or when there was any particular intricacy in the caſe. In adminiſtering the oath to the witneſſes, he had none of that indecorum which we have elſewhere cenſured in ſome of his brethren (ſee OATH *Encycl.*); but riſing ſolemnly from his ſeat, he repeated the words in ſo ſerious a manner, as left no doubt in the moſt profligate mind but that he was himſelf impreſſed with a ſenſe of the immediate preſence of the Supreme Being, and with the firm belief of a future judgment. When the witneſs appeared to be young or ignorant, we have beheld, with the utmoſt love and veneration, the pious pains which his Lordſhip took to diſcover whether he was duly acquainted with the nature and obligation of an oath before he admitted him to ſwear; and though it is perhaps impoſſible for human vigilance and ſagacity to prevent perjury altogether in courts of juſtice, he muſt ſurely have been a villain uncommonly hardened and artful who could perjure himſelf in the preſence of Lord Hailes. In doubtful caſes his Lordſhip inclined always to the ſide of mercy; but when it became his duty to paſs ſentence of death upon convicted criminals, he addreſſed them in a ſtrain of ſuch piety and commiſeration, as to draw tears from the eyes of every beholder, and was calculated to make a deep and proper impreſſion on the unhappy perſon himſelf. In the diſcharge of this painful duty we never ſaw him ſurpaſſed, and have ſeldom ſeen him equalled.

Had

(A) In a ſatirical ballad on the court of ſeſſion, Mr Boſwell, alluding to Lord Hailes's fondneſs for verbal criticiſm, makes him addreſs the preſident in the following words:

To judge of this matter I cannot pretend,
For juſtice, my Lord, wants an *e* at the end.

Had Lord Hailes been confpicuous only as a found lawyer, and an able and upright judge, we fhould ftill have thought his life intitled to a place in this Work; but he was no lefs eminent as a man of general erudition, and as a voluminous author. His fkill in claffical learning, the belles lettres, and hiftorical antiquities, efpecially thofe of his own country, is univerfally admitted; but it cannot be denied, that the fame faftidioufnefs, and the fame microfcopic attention to minutiæ, which characterifed him as a barrifter, prevented him from rifing to that rank in the republic of letters to which his learning and genius would otherwife have infallibly carried him. But if he was not one of the moft celebrated writers of the age, he was unqueftionably one of the moft virtuous; if his publications were not always edifying, they were at leaft innocent and ingenious; and fome of them are in the higheft degree valuable. In proof of this affertion, we need inftance only his *Annals of Scotland*, and his *Inquiry into the Secondary Caufes which Mr Gibbon has affigned for the Rapid Progrefs of Chriftianity*. Of the former of thefe works though little calculated to pleafe the common herd of readers, it may with truth be faid, that in refearch and ingenuity it ftands unrivalled among the writings of Scotch antiquaries; and of the latter, it is furely not too much to fay that it difplays uncommon accumen, clofenefs of reafoning, and zeal for the caufe of truth, without the ufual rancour of theological controverfy.

His tafte for retirement, which the ftate of his affairs rendered for a while neceffary, grew upon him as he advanced in years. His conftitution, of which he was very careful, as well as his principles and habits, rendered him averfe from diffipation of every kind. After he was made a judge, he confidered abftraction from the gay and fafhionable world as connected with the duty of one whofe time was no longer his own; and when he chofe to unbend his mind, it was in the fociety of a few eafy friends, whom he felected as much for their worth and good humour as for their genius or their learning. He had indeed occafionally much converfation with that conftellation of wits and men of fcience who flourifhed in Edinburgh at the fame period with himfelf; but it was impoffible for friendfhip or intimacy to fubfift between men who thought fo differently as he and they thought on the moft important of all fubjects. Though an old-fafhioned whig, zealoufly attached to the conftitution, he fcorned to take any fhare in the civil or ecclefiaftical broils in which fome of his brother judges were warmly engaged for the firft 20 years of the prefent reign; for he looked on thefe as either frivolous or mifchievous.

Although his Lordfhip's conftitution had been long in an enfeebled ftate he profecuted his ftudies, and attended his duty on the bench, till within three days of his death, which happened on the 29th of November 1792, in the 66th year of his age.

His Lordfhip was twice married; by his firft wife Anne Brown, only daughter of Lord Coalfton, one of the judges of the court of feffion, he left iffue one daughter, who inherits the family eftate. His fecond marriage (of which alfo there is iffue one daughter) was to Helen Ferguffon, youngeft daughter of Lord Kilkerran, who has the affliction to furvive him. Leaving no male iffue, the title of Baronet defcends to his nephew.

Though the church of Scotland does not much encourage funeral difcourfes, a very laudable endeavour was made to render the talents and virtues of Lord Hailes a theme of inftruction to mankind, in a fermon preached foon after his death in the church of Inverefk, by his learned friend, and venerable paftor, Dr Carlyle; from which we fhall tranfcribe a fummary view of his character as a judge, a fcholar, a Chriftian, and a citizen.

"His knowledge of the laws was accurate and profound, and he applied it in judgment with the moft fcrupulous integrity. In his proceedings in the criminal court, the fatisfaction he gave to the public could not be furpaffed. His abhorrence of crimes, his tendernefs for the criminals, his refpect for the laws, and his reverential awe of the Omnifcient Judge, infpired him on fome occafions with a commanding fublimity of thought, and a feeling folemnity of expreffion, that made condemnation feem juft as the doom of Providence to the criminals themfelves, and raifed a falutary horror of crimes in the breaft of the audience.

"Confcious of the dignity and importance of the high office he held, he never departed from the decorum that becomes that reverend character; which indeed it coft him no effort to fupport, becaufe he acted from principle and fentiment, both public and private. Affectionate to his family and relations, fimple and mild in his manners, pure and confcientious in his morals, enlightened and entertaining in his converfation; he left fociety only to regret, that, devoted as he was to more important employments, he had fo little time to fpare for intercourfe with them.

"He was well known to be of high rank in the republic of letters, and his lofs will be deeply felt through many of her departments. His labours in illuftration of the hiftory of his country, and many other works of profound erudition, remain as monuments of his accurate and faithful refearch for materials, and his found judgment in the felection of them. Of his unfeigned piety and devotion, you have very often been witneffes where we now are. I muft add, however, that his attendance on religious ordinances was not merely out of refpect to the laws and for the fake of example (motives which fhould never fail to have influence on perfons of fuperior rank, for the moft obvious reafons), but from principle and conviction, and the moft confcientious regard to his duty; for he not only practifed all the virtues and charities in proof of his faith, but he demonftrated the fincerity of his zeal by the uncommon pains he took to illuftrate primitive Chriftianity, and by his elaborate and able defences of it againft its enemies.

"His profound refearches into hiftory, and his thorough knowledge of the laws, made him perfectly acquainted with the progrefs of the conftitution of Britain, from the firft dawn of liberty in the common law of the land, and the trial by jury which precede all written records, and afterwards in the origin and eftablifhment of parliaments, through all its viciffitudes and dangers, till at laft, by the bleffing of divine Providence, which brought many wonderful events to concur to the fame end, it was renewed, ftrengthened, and finally confirmed by the Revolution.

"It was this goodly and venerable fabric of the Britifh conftitution which the deceafed moft refpectable character

Dalrymple. character contemplated with admiration and delight (of late, indeed, with a mixture of anxiety and fear), as the temple of piety, as the genuine ſource of greater happineſs and freedom, to a larger portion of mankind than ever flowed from any government upon earth.

"Ill indeed can the times bear the loſs of ſuch an affectionate patriot and the guardian of the laws of his country. But we muſt not murmur at the will of Providence, which in its mercy 'may have withdrawn the good man from the evil to come.' In mercy, I ſay, to him, whoſe righteous ſpirit was ſo deeply grieved when 'he ſaw the wicked rage, and the people imagine a vain thing."

Such is the memorial which, in the hour of recent ſorrow, followed this excellent man to the grave; and we believe it will yet be allowed to be juſt by all who had the happineſs of his Lordſhip's acquaintance, and are what he was, friends to the beſt intereſts of mankind.

This ſketch of the life of Lord Hailes would be more imperfect than even it is, if we could not ſubjoin to it a catalogue of his publications, of which the greater part are exceedingly curious. We call them *publications*, becauſe he employed almoſt as much of his time in republiſhing old and uſeful books as in preparing for the preſs his own valuable works.

Beſides his eſſays in the papers called *The World* and *The Mirror*, which are well known and univerſally admired, his Lordſhip publiſhed the following works:

Sacred Poems, or a Collection of Tranſlations and Paraphraſes from the Holy Scriptures; by various authors, Edinburgh, 1751, 12mo. Dedicated to Charles Lord Hope, with a preface of ten pages.

The Wiſdom of Solomon, Wiſdom of Jeſus the Son of Sirach, or Eccleſiaſticus, 12mo, Edin. 1755.

Select Diſcourſes (in number nine), by John Smith, late Fellow of Queen's College, Cambridge, 12mo, 291 pages. Edin. 1756; with a preface of five pages, "many quotations from the learned languages tranſlated,—and notes added, containing alluſions to ancient mythology, and to the erroneous philoſophy which prevailed in the days of the author,—various inaccuracies of ſtyle have been corrected, and harſh expreſſions ſoftened."

A Diſcourſe of the unnatural and vile Conſpiracy attempted by John Earl of Gowry and his Brother, againſt his Majeſty's perſon, at St Johnſtoun, upon the 5th of Aug. 1600. No date of the republication, but the edition and notes ſuppoſed by Lord Hailes, 12mo, 1757.

A Sermon, which might have been preached in Eaſt Lothian upon the 25th day of October 1761, on Acts xxvii. 1, 2. "The barbarous people ſhewed us no little kindneſs." Edin. 1761, pp. 25, 12mo. "Occaſioned by the country people pillaging the wreck of two veſſels, viz. the Betſy, Cunningham, and the Leith Packet, Pitcairn, from London to Leith, caſt away on the ſhore between Dunbar and North Berwick. All the paſſengers on board the former, in number 17, periſhed; five on board the latter, October 16. 1761."— A moſt affecting diſcourſe, admirably calculated to convince the offenders!

Memorials and Letters relating to the Hiſtory of Britain, in the reign of James I. publiſhed from the originals, Glaſgow, 1762.—Addreſſed to Philip Yorke, Viſcount Royſton, pp. 151. "From a collection in the advocate's library, by Balfour of Denmyln." The preface of four pages, ſigned Dav. Dalrymple. Dalrymple.

The Works of the ever memorable Mr John Hailes of Eaton, now firſt collected together in 3 vols, Glaſgow, 1765; preface of three pages. Dedicated to William (Warburton), Biſhop of Glouceſter. "The edition ſaid to be undertaken with his approbation; obſolete words altered, with corrections in ſpelling and punctuation."

A ſpecimen of a book intitled "Ane Compendious Booke of Godly and Spiritual Sangs, collectit out of ſundrie parts of the Scripture, with ſundrie of other Ballates changed out of prophaine Sanges, for avoyding of Sin and Harlotrie, with augmentation of ſundry Gude and Godly Ballates, not contained in the firſt edition. Edinburgh, printed by Andro Hart," 12mo. Edin. 1765, pp. 42; with a Gloſſary of four pages.

Memorials and Letters relating to the Hiſtory of Britain in the reign of Charles I. publiſhed from the originals, Glaſgow, 1766, pp. 189. Preface of ſix pages, ſigned Dav. Dalrymple, chiefly collected by Mr Wodrow, author of the Hiſtory of the Church of Scotland. Inſcribed to Robert Dundas of Arniſton, Lord Preſident of the Court of Seſſion.

An account of the preſervation of Charles II. after the Battle of Worceſter, drawn up by himſelf; to which are added, his Letters to ſeveral perſons. Glaſgow, 1766, pp. 190, from the MSS. of Mr Pepys, dictated to him by the king himſelf, and communicated by Dr Sandby, maſter of Magdalen College. The letters are collected from various books; ſome of them now firſt publiſhed, communicated by the tutors of the Duke of Hamilton, by the Earl of Dundonald, &c. The preface of four pages, ſigned Dav. Dalrymple, dedicated to Thomas Holles, Duke of Newcaſtle, chancellor of the univerſity of Cambridge.

The Secret Correſpondence between Sir Robert Cecil and James VI. 12mo, 1766.

A Catalogue of the Lords of Seſſion, from the Inſtitution of the College of Juſtice in the year 1532, with Hiſtorical Notes. *Suum cuique—rependet poſteritas.* Edin. 1767, 4to, pp. 26.

The Private Correſpondence of Dr Francis Atterbury, Biſhop of Rocheſter, and his friends, in 1725, never before publiſhed. Printed in 1768, 4to. Advertiſement, pp. 2. Letters, pp. 10. A fac ſimile of the firſt from Biſhop Atterbury to John Cameron of Lochiel, to prove their authenticity.

An Examination of ſome of the Arguments for the High Antiquity of *Regiam Majeſtatem*; and an Inquiry into the authenticity of the *Leges Malcolmi*; by Sir David Dalrymple, 4to, pp. 52. Edin. 1769.

Hiſtorical Memoirs concerning the Provincial Councils of the Scottiſh Clergy, from the earlieſt Accounts to the Æra of the Reformation; by Sir David Dalrymple. Edinburgh, 1769, 4to, pp. 41.—*Nota*, Having no high opinion of the popularity of his writings, he prefixes to this work the following motto. "Si delectamur quum ſcribimus quis eſt tam invidus qui ab eo nos abducat? ſin laboramus quis eſt qui alienæ modum ſtatuat induſtriæ."—*Cicero.*

Canons of the Church of Scotland, drawn up in the Provincial councils held at Perth, A. D. 1242, and 1269. Edinburgh, 1769, 4to, pp. 48.

Dalrymple.

Ancient Scottish Poems, published from the MS. of George Bannatyne, 1568. Edin. 1770, 12mo. Preface six pages; Poems pp. 221; very curious notes pp. 92; glossary and lists of passages and words not understood, pp. 14.

The additional Case of Elizabeth, claiming the title and dignity of Countess of Sutherland; by her Guardians. Wherein the facts and arguments in support of her claim are more fully stated, and the errors in the additional cases for the other claimants are detected, 4to.——This singularly learned and able case was subscribed by Alexander Wedderburn (present Lord Chancellor), and Sir Adam Fergusson, but is the well-known work of Lord Hailes. It ought not to be regarded merely as a law paper of great ability, but as a treatise of profound research into the history and antiquity of many important and general points of succession and family history. Introduction, pp. 21; the first four chapters, pp. 70; the fifth and sixth chapters, pp. 177.

Remarks on the History of Scotland, by Sir David Dalrymple.—" Utinam tam facile vera invenire possem quam falsa convincere." *Cicero*.—Edin. 1773, inscribed to George Lord Lyttleton, in nine chapters, pp. 284. 12mo.

Huberti Langueti Epistolæ ad Philippum Sydneium Equitem Anglum, accurante D. Dalrymple de Hailes, Eq. Edinburgh, 1776, 8vo. Inscribed to Lord Chief Baron Smythe.—Virorum Eruditorum Testimonia de Langueto, pp. 7. Epistolæ, pp. 289. Index Nominum, pp. 41.

Annals of Scotland, from the Accession of Malcolm III. surnamed Canmore, to the Accession of Robert I. by Sir David Dalrymple. Edin. 1776, pp. 311. Appendix, pp. 51.

Tables of the Succession of the Kings of Scotland, from Malcolm III. to Robert I. their marriages, children, and time of their death; and also of the Kings of England and France, and of the Popes who were their contemporaries.

Chronological Abridgement of the Volume, pp. 30. The Appendix contains eight dissertations: 1. Of the law of Evenus and Mercheta Mulierum, pp. 17. 2. A commentary on the 22d statute of William the Lion, pp. 8. 3. Of the 18th Statute of Alexander III. pp. 5. 4. Bull of Pope Innocent IV. pp. 6. 5. Of Walter Stewart, Earl of Menteeth, 1296, pp. 7. 6. Of M'Duff, slain at Falkirk, in 1298, pp. 3. 7. Of the death of John Comyn, 10th February, 1305, pp 4. 8. Of the origin of the house of Stuart, pp. 6.

Annals of Scotland from the accession of Robert I. surnamed Bruce, to the Accession of the House of Stuart; by Sir David Dalrymple, Edin. 1779, 4to, pp. 277. Appendix, pp. 54, containing, 1. Of the manner of the death of Marjory, daughter of Robert I. pp. 7. 2. Journal of the campaign of Edward III. 1327 pp. 9. 3. Of the genealogy of the family of Seton in the 14th century. 4. List of the Scottish commanders at the battle of Hallidon, 19th July, 1383, pp. 11. 5. Whether Edward 3d put to death the son of Sir Alexander Seton, pp. 8. 6. List of the Scottish commanders killed or made prisoners at the battle of Durham, pp. 8. 7. Table of kings, p. 1. 8. Corrections and additions to volume i, pp. 16. Chronological abridgement of the volume, pp. 39.

Account of the Martyrs of Smyrna and Lyons, in the 2d century, 12mo, with explanatory notes, Edin. 1776. Dedicated to Bishop Hurd, pp. 68. Notes and illustrations, pp. 142. This is a new and correct version of two most ancient epistles, the one from the church at Smyrna to the church at Philadelphia. The other from the Christians at Vienna and Lyons to those in Asia and Phrygia—their antiquity and authenticity are undoubted. Great part of both is extracted from Eusebius's Ecclesiastical History. The former was first completely edited by Archbishop Usher. The author of the notes says of them, with his usual and singular modesty, " That they will afford little new or interesting to men of erudition, though they may prove of some benefit to the unlearned reader." But the erudition he possessed in these branches is so rare, that this notice is unnecessary. They display much useful learning and ingenious criticism, and breathe the most ardent zeal, connected with an exemplary knowledge of Christianity. N. B. This is the first volume of the remains of Christian Antiquity.

Remains of Christian Antiquity, with explanatory notes, vol. ii. Edin. 1778, 12mo. Dedicated to Dr Newton bishop of Bristol. Preface, pp. 7. This volume contains the trial of Justin Martyr and his companions, pp. 8. Epistle of Dionysius bishop of Alexandria, to Fabius bishop of Antioch, pp. 16. The trial and execution of Cyprian bishop of Carthage, pp. 8. The trial and execution of Fructuosus bishop of Tarracona in Spain, and of his two deacons, Augurius and Eulogius, pp. 8. The Maiden of Antioch, pp 2. These are all newly translated by Lord Hailes from Ruinart, Eusebius, Ambrose, &c. The notes and illustrations of this volume extend from p. 47 to 165, and display a most intimate acquaintance with antiquity, great critical acumen, both in elucidating the sense, and detecting interpolations; and above all, a fervent and enlightened zeal, in vindicating such sentiments and conduct as are conformable to the word of God against the malicious sarcasms of Mr Gibbon. To this volume is added an appendix of pp. 22, correcting and vindicating certain parts of vol. i.

Remains of Christian Antiquity, vol. iii. Edin. 1780. Dedicated to Thomas Balguy, D. D. Preface, pp. 2. It contains the History of the martyrs of Palestine in the 3d century, translated from Eusebius, pp. 94. Notes and illustrations, pp. 135, in which Mr Gibbon again comes, and more frequently, under review.—The partiality and misrepresentations of this popular writer are here exposed in the calmest and most satisfactory manner.

Pity it is that Lord Hailes should have printed and published these valuable volumes, and indeed most of his other works, at his own expence; and dispersed them so liberally to his friends, that they have been little circulated among any other.

Octavius, a Dialogue, by Marcus Minucius Felix. Edin. 1781, pp. 16. Preface.—The speakers are, Cæcilius a Heathen, Octavius a Christian; whose arguments prevail with his friend to renounce Paganism and become a Christian proselyte. Notes and illustrations, pp. 120.

Of the manner in which the Persecutors Died; a Treatise by L. C. F. Lactantius, Edin. 1782. Inscribed to Dr Porteous bishop of Chester (present bishop of London). Preface, pp. 37. in which it is proved

proved that Lactantius is the author. Text, pp. 125. Notes and illustrations, pp. 109.

L. C. F. Lactantii Divinarum Institutionum Liber Quintus seu de Justitia, 1777.

Disquisitions concerning the Antiquity of the Christian Church. Glasgow, 1783. Inscribed to Dr Halifax, bishop of Gloucester, pp. 194.—This small original and most excellent work, consists of six chapters. Chap. 1. A commentary on the conduct and character of Gallio. Acts xviii. 5, 12, 17.—Chap. 2. Of the time at which the Christian religion became publicly known at Rome.—Chap. 3. Cause of the persecution of the Christians under Nero. In this the hypothesis of Mr Gibbon, vol. i. 4to, p. 641, is examined.—Chap. 4. Of the eminent Heathen writers who are said (by Gibbon) to have disregarded or contemned Christianity, viz. Seneca, Pliny sen. Tacitus, Pliny jun. Galen, Epictetus, Plutarch, Marcus Antonius. To the admirers of Heathen philosophers, and to those especially who state between them and the Christian doctrine any consanguinity, this chapter is earnestly recommended.—Chap. 5. Illustration of a conjecture by Gibbon, respecting the silence of Dio Cassius concerning the Christians. In this chapter, with extreme impartiality, he amplifies and supports an idea of Mr Gibbon on this head. Chap. 6. Of the circumstances respecting Christianity that are to be found in the Augustan history.

It seems very probable that the close attention which Lord Hailes appears to have given to such subjects, was in some measure the effect of the mistakes and partiality of Gibbon. In no one work, from 1776, the date of Mr Gibbon's first publication, has he omitted to trace this unfair and insinuating author; but in 1786 he came forth of set purpose with the most able and formidable reply, which he has received, intitled, "An Inquiry into the Secondary Causes which Mr Gibbon has assigned for the rapid growth of Christianity; by Sir David Dalrymple." Edin. 1786; gratefully and affectionately ascribed to Richard (Hurd) bishop of Worcester, 4to, pp. 213. In five chapters.

Sketch of the Life of John Barclay, 4to, 1786.

Sketch of the Life of John Hamilton, a Secular Priest, 4to (one of the most savage and bigotted adherents of Popery, who lived about A. D. 1600.)

Sketch of the Life of Sir James Ramsay, a general officer in the armies of Gustavus Adolphus king of Sweden, with a head.

Life of George Leslie (an eminent capuchin friar in the early part of the 17th century), 4to, pp. 24.

Sketch of the Life of Mark Alex. Boyd, 4to.

These lives were written and published as a specimen of the manner in which a *Biographia Scotica* might be executed; and it is likely that Lord Hailes selected purposely the least interesting.

The Opinions of Sarah Duchess Dowager of Marlborough, published from her original MSS. 1788, 12mo, pp. 120. (with a few foot notes by Lord Hailes, in which he corrects the splenetic partiality of her Grace).

The Address of Q. Sept. Tertullian to Scapula Tertullus, Proconsul of Africa, translated by Sir David Dalrymple, 12mo. Edin. 1790, inscribed to Dr John Butler, bishop of Hereford; preface, pp. 4; translation pp. 18; original, pp. 13; notes and illustrations, pp. 135.

This address contains many particulars relating to the church after the third century. The translator has rejected all words and phrases of French origin, and written entirely in the Anglo Saxon dialect. In the course of the notes many obscurities of the original, not adverted to by other commentators, are explained. Some strange inaccuracies of Mr Gibbon are also detected, not included in the misrepresentations of his two famous chapters.

This was the last work of this truly learned, respectable and useful man. Whether he left behind him any thing else finished for the press, is known only to his friends. We have repeatedly heard that he was engaged in examining the authenticity of the books of the New Testament, and that, with the exception of two or three, he found every verse contained in it in the writings of the first three centuries. This seems indeed to have been an object in all his works; for, at the end of each of his translations and editions of the primitive Christian writers. A table is given of passages quoted or mentioned by them. If his Lordship completed any work of this kind, it should not be withheld from the public. We may indeed be told that its utility in a great measure superceded by the laborious collection of Lardner (B), and the more elegant work of Paley (C); but not to mention the prejudices generally entertained against Lardner on account of his evident bias to Unitarianism, it would surely be proper, in the present age of wild opinions, to shew the multitude, who are guided by authority, how important a subject the Christian religion was deemed by this learned and accomplished layman.

DALTON, a fine township in Berkshire co. Massachusetts, having Pittsfield on the W. and contains 554 inhabitants. The stage road from Boston to Albany, runs through it. Dalton was incorporated in 1784, and lies 135 miles W. by N. of Boston, and about 35 the same course, from Northampton.—*Morse.*

Dalton, a township in Grafton co. New-Hampshire, first called Apthorpe, was incorporated in 1784, and has only 14 inhabitants. It lies on the E. bank of Connecticut river at the 15 mile falls, opposite Concord, in Essex co. Vermont.—*ib.*

DAMIENS (Robert François), as he possessed neither literature nor science, is not, strictly speaking, intitled to notice in this Work. His character, however, was so extraordinary, and the noise which he made in the world so great, that a short account of his life will probably be acceptable to a numerous class of our readers.

He was born in 1714, in the suburbs of Arras, called *St Catharines.* His infancy announced what he would one day become; for such were his wickedness and knaveries, that they procured to him the appellation of *Robert the Devil.*

He served in the army, was at several engagements, and

(B) See his *Credibility of the Gospel History*, and other works, in 11 vols 8vo.
(C) See his *Evidences of the Cristian Religion* in 2 vols 8vo.

Damiens.

and at the fiege of Philipfburgh. On his return to France, he entered in quality of a domeftic into the college of Jefuits at Paris, which he left in 1738 to be married.

After having ferved different mafters in the capital, and poifoned one of them by a glyfter, he committed a robbery of 240 louis d'ors; which being difcovered obliged him to abfcond. He lurked, therefore, about five months in the neighbourhood of St Omer, Dunkirk, and Bruffels, holding always the moft abfurd purpofes with regard to the difputes which at that time divided France. At Poperingue, a fmall town near Ypres, he was heard to fay: "If I return to France— Yes, I will return, I will die there, and the greateft man on earth fhall die likewife, and you fhall hear news of me!"

It was in the month of Auguft, 1756, that he uttered thefe extravagant fentiments. On the 21ft of December, in the fame year, being at Falefque near Arras, at the houfe of one of his relations, he talked in the fame ftrain, affirming, "That the kingdom, his wife, and daughter were all ruined!" His blood, his heart, and his head, were at this time in a dreadful ftate of effervefcence; and in this ftate of mind he fet out for Paris, at which he arrived on the 31ft day of the fame month. Having appeared at Verfailles on the firft day of the year 1757, he took opium for two or three days, probably with a view to invigorate his mind for the horrid purpofe, which he executed on the 5th of January, about three quarters of an hour after five in the evening.

This execrable parricide ftruck Louis XV. with a knife in the right fide, as that monarch, furrounded by his courtiers, was entering a carriage to go to Trianon. He was feized upon the fpot; and after having undergone fome interrogatories at Verfailles, was fent to Paris to the tower of Montgommeri, where a room was prepared for him, above that which Ravaillac had formerly occupied. The king charged the great court of parliament to inftitute his procefs; but notwithftanding the moft cruel tortures, which he fupported with unparalleled firmnefs, they could not get from him a fingle confeffion which could lead them to fufpect that he had any accomplices. This miferable wretch protefted, that if he had been blooded as copioufly as he wifhed, he would never have committed the crime. After being cruelly tortured to no purpofe, he was condemned to die by the fame punifhment as the infamous affaffin of Henry IV.

The fame year, on the 28th of March, which was the day of his execution, he arrived at the *Place de Greve* at a quarter paft three, looking with a tearlefs eye and a firm countenance on the place and the inftruments of his punifhment. They firft burned his right hand, afterwards tore his flefh with red hot pincers, and poured melted lead, wax and pitch, into the wounds. They then proceeded to quarter him, the four horfes trying in vain for 50 minutes to difmember his body. At the end of that time, Damiens being ftill alive, the executioners cut with knives the flefh and tendinous joinings of his legs and arms; which they had formerly been obliged to do to Ravaillac. They began with his legs; and even after they were cut, he continued to breathe till his arms were cut in like manner. His punifhment, from the time he was put upon the fcaffold to the moment of his death lafted about an hour and an half; during the greater part of which he retained his recollection, and raifed his head feven or eight times to view the horfes and his mangled and burned limbs. In the middle of the moft violent of the tortures, he even let fome jokes efcape him.

That the crime of Damiens was of the deepeft die, every man but an affaffin like himfelf, will readily acknowledge; but the cruel and lingering punifhment which was inflicted on him, was fuch as we think no human being intitled to inflict on another. It was likewife impolitic as well as cruel. We can conceive no reafon for lengthening out any punifhment, or accompanying it with circumftances of horror, but to infpire the fpectators with a deteftation of the crime; but a punifhment too fevere produces a contrary effect, by withdrawing the attention from the crime to the criminal, and exciting compaffion for his fufferings, and indignation againft the authors of them. Such at leaft would be its effect in this country; but the minds of Frenchmen feem to be differently conftituted from thofe of others.

Damiens was rather above the middle fize; he had a long face, a bold and piercing countenance, and his mouth was a little funk. He had contracted a kind of convulfive motion, by a cuftom he had of fpeaking to himfelf. He was full of vanity, defirous of fignalizing himfelf, curious of novelty, a ftickler againft government, though filent; converfing with himfelf internally; obftinate in profecuting whatever he projected; bold to put it into execution; full of effrontery, and a liar; by turns religious and wicked; committing faults at one time, and immediately after repenting of them, and continually agitated by violent impulfes. "His crime (fays a writer of genius) coft us as many groans as improbable projects of his came to light."

How, it has been afked, could a nation fo mild and fo polifhed as France, or an age which was called philofophic, produce an affaffin of a king fo much beloved by his people?

To this queftion the French author, whofe work we have tranflated, anfwers, That at all times there have been wretches who have taken neither of their age nor their country. A man, from the dregs of the people, accuftomed to crimes, heated by the propofals of fome turbulent fpirits, in the time of contefts which agitate both the church and the ftate—will end in a parricide. His brain is heated; he puts himfelf into a ferment of defpair, produced by mifery, by the fear of the punifhment his robberies deferve, and by feditious difcourfes. Agitated more and more by the contradictory movements which his mind experiences, and meditating on a project of this nature, his mind goes aftray as far as it can, and in the height of his frantic delirium, he perpetrates the crime juft as a mad dog precipitates himfelf upon the firft object he meets.

This is perhaps the beft account which could be given, at the time it was written, of the conduct of Damiens; but fubfequent events have fhewn that he did not in fact deviate fo much as was fuppofed from the principles of his age and country, though that age was philofophic, and that country highly polifhed. We have feen a defendant of Louis XV. poffeffed of ten times his virtues, and entitled to the love and gratitude of the whole nation, murdered openly in the

the midſt of his capital, under the *forms* of juſtice, and with circumſtances of atrocity at which the mind of Damiens would perhaps have recoiled. The guilt of an inſane aſſaſſin, who commits a murder in a fit of frenzy, ſinks into inſignificance when compared with that of legiſlators, who coolly departed, not only from every principle of juſtice, but alſo from the very letter of that law which conferred authority on themſelves, to cut off their innocent, their amiable ſovereign.

DAN, a conſiderable river of N. Carolina, which unites with the Staunton, and forms the Roanoke. In May, 1795, a boat 53 feet long, and about 7 tons burden, paſſed from Upper Saura town to Halifax, about 200 miles above Halifax, under the direction of Mr Jeremiah Wade. She brought about 9 hhds. from the above place, 6 of which ſhe diſcharged at St Taminy, 40 miles above Halifax; to which place the river has been cleared by the donations of individuals. From St Taminy to Halifax, ſhe brought about 5000 weight through the falls, which hitherto had been deemed impaſſable. Mr Wade thinks, ſafe navigation for boats of a larger burden may be made at a ſmall expenſe. The famous Burſted hill ſtands on the bank of the Dan, in Virginia, near the borders of N. Carolina. It appears to have been an ancient volcano. There are large rocks of the lava, or melted matter, from 1000 to 1500 weight, lying on the ſummit of the hill. The crater is partly filled, and covered with large trees.—*Morse.*

DANBURY, a poſt town in the co. of Fairfield, in Connecticut. It was ſettled in 1687, and the compact part of the town contains 2 churches, a court-houſe, and about 60 dwelling-houſes. On its ſmall ſtreams are iron works, and ſeveral mills. Mr Lazarus Beach preſented to the muſeum in New-York city, a quire of paper, made of the aſbeſtos, at his paper mill in Danbury, March, 1792, which the hotteſt fire would not conſume. It lies about 70 miles N. E. of New-York city, and 33 N. W. by W. of New-Haven. This town, with a large quantity of military ſtores, was burnt by the Britiſh on the 26th of April, 1777.—*ib.*

DANBY, a townſhip in Rutland co. Vermont, E. of Pawlet, and contains 1206 inhabitants. It lies about 32 miles N. of Bennington.—*ib.*

DANGEAU (Louis Courcillon de), member of the French academy, Abbe of *Fontaine Daniel* and of Clermont, was born at Paris in January, 1643, and died there the 1ſt of January 1723, aged 80. Few people of family have given ſo much time to the belles lettres, or paid ſuch attention to rendering the ſtudy of them eaſy and agreeable. He deviſed ſeveral methods for rendering of more eaſy acquiſition the knowledge of hiſtory, painting, geography, genealogy, the intereſts of princes, and French grammar. He publiſhed ſome tracts upon each of theſe ſubjects. 1. A new Method of Hiſtorical Geography, 1706, 2vols. folio; 2. The Principles of Painting, in 14 plates, 1715, 4to.; 3. An Hiſtorical Play of the Kings of France, which is played like that of *Oie*, with a ſmall book explaining the method; 4. Reflections on all the Parts of Grammar, 1684, 12mo. 5. On the Election of the Emperor, 1738, 8vo. The firſt of theſe, however, is his principal work, and a part of the tenth dialogue on the immortality of the ſoul, commonly attributed to the Abbe Choiſi, is likewiſe his. That book is very common; but his other productions are very rare, becauſe he only threw off a few copies for the uſe of his friends.

Dangeau was maſter of many languages; Greek, Latin, Italian, Spaniſh, Dutch, and almoſt all the languages which depend upon theſe. His virtues were equal to his learning. "Full of humanity for the unfortunate (ſays *M d'Alembert*), he diſtributed ſuccour to the indigent, and had the virtue to conceal his good actions. His heart was formed for friendſhip. If he had any faults, they were perhaps too great indulgence for the faults and failings of mankind; a fault which, from its rarity may be called a virtue, and for which few people have any reaſon to reproach themſelves, even towards their friends. He poſſeſſed, in a high degree, that knowledge of men and the world which neither books nor genius alone can give when one has neglected to live with his equals. Rejoicing in the eſteem and confidence which he poſſeſſed in a great degree in France, there could be no better counſellor than he in the moſt important concerns. Yet his noble ſoul, delicate and honourable, was ignorant of deceit; and his prudence was too evident to be taken for fineſſe. Pleaſant and agreeable in converſation, but preferring truth in all caſes, he never diſputed unleſs there was occaſion to defend it, which he did in ſuch a firm manner as to give ſome people an idea that he was obſtinate in diſputing, which is ſeldomer found among men than a cool and culpable indifference."

Dangeau (Philippe de Courcillon Marquis de), brother to the former, was born in 1638. The elegance of his wit and perſon advanced him at the court of Louis XIV. and his decided taſte for letters procured him a place in the French academy, and in that of ſciences. He died at Paris in 1720, at the age of 82, chevalier of the order of the king, and grand maſter of the royal and military orders of our lady of Mont Carmel and of St Lazarus of Jeruſalem. When he was inveſted with this laſt dignity, he paid more attention than was formerly done to the chooſing of chevaliers; he renewed the ancient pomp of their admiſſion, which the public, always malicious, ridiculed. But that which ſhould have ſcreened him from ridicule was, that it procured him the foundation of 25 commanderies, and he employed the revenues to bring up 12 young men of the beſt nobility in France. Even envy then excuſed his elevation. At the court (ſays Fontenelle), where credit is never given to probity and virtue, he held always a fair and unblemiſhed reputation. His converſation, his manners were all regulated by a politeneſs, which was not the conſequence merely of his aſſociating with good company, but the offspring of an obliging and benevolent heart. We ſhould paſs over in him, on account of his honourable manners, the deſire he had to be a great lord. Madame de Monteſpan, who did not believe he could play this part, uſed to ſay, in a malicious manner, that one could not help loving and deſpiſing him at the ſame time. He married, firſt *Françoiſe Morin*, ſiſter to the Marechal d'Eſtrées, and afterwards the Counteſs de *Leuveſtein*, of a very noble houſe, but not opulent.

There are extant manuſcript memoirs by the Marquis Dangeau, in which there are ſeveral curious anecdotes of Voltaire, Henault, and Beaumelle. Dangeau, however, did not always write theſe memoirs; which, according to the author of the age of Louis XIV. were compiled by an old valet de chambre, who inſerted in them

them without order, every ridiculous thing which he heard in the antichamber, or read in the gazettes. There ſtill remains a ſmall work of Dangeau's, which paints, in an intereſting manner, Louis the XIV. as he was in the midſt of his court.

DANVERS, a townſhip in Eſſex co. Maſſachuſetts, adjoining Salem on the N. W. in which it was formerly comprehended by the name of Salem village. It conſiſts of two pariſhes, and contains 2425 inhabitants, and was incorporated in 1757. The moſt conſiderable and compact ſettlement in it, is formed by a continuation of the principal ſtreet of Salem, which extends more than two miles toward the country, having many work ſhops of mechanics, and ſeveral for retailing goods. Large quantities of bricks and coarſe earthen ware are manufactured here. Another pleaſant and thriving ſettlement is at the head of Beverly river, called New-Mills; where a few veſſels are built and owned. The town of Danvers receives an annual compenſation of £.10 from the proprietors of Eſſex bridge, for the obſtruction of the river.—*Morse*.

DANVILLE, a thriving poſt town in Mercer co. and formerly the metropolis of Kentucky, pleaſantly ſituated in a large, fertile plane, on the S. W. ſide of Dick's river, 35 miles S. S. W. of Lexington. It conſiſts of about 50 houſes, and a Preſbyterian church. From Leeſburg to Danville, the country, for the firſt 20 miles, is of an inferior rate for lands in this country; but round Lexington, and from Leeſburgh to Lexington and Boonſborough, is the richeſt land in the country. It is 40 miles S. by E. of Frankfort, 83 from Louiſville, 201 from Hawkins in Tenneſſee, and 830 from Philadelphia. N. lat. 37. 30. W. long. 85. 30.—*ib.*

Danville, a very thriving townſhip in Caledonia co. Vermont. It was a wilderneſs, without ſo much as a ſingle family, a few years ago, and now contains 574 inhabitants. It lies 8 miles N. W. of Barnet.—*ib.*

DARBY, a ſmall town in Delaware co. Pennſylvania, on the E. ſide of Darby Creek. It contains about 50 houſes, and a Quaker meeting-houſe, and lies 7 miles S. W. by W. of Philadelphia. There are two townſhips of this name, in the county, called Upper and Lower, from their relative ſituation.—*ib.*

DARCY (Count), an ingenious philoſopher and mathematician, was born in Ireland in the year 1725; but his friends being, like many other great and good families at that period, attached to the houſe of Stuart, he was at 14 years of age ſent to France, where he ſpent the reſt of his life. Giving early indications of a genius for ſcience, he was put under the care of the celebrated Clairaut (ſee Clairaut, *Encycl.*) under whoſe tuition he improved ſo rapidly in the mathematics, that at 17 years of age, he gave a new ſolution of the problem concerning the curve of equal preſſure in a reſiſting medium. This was followed the year after by a determination of the curve deſcribed by a heavy body, ſliding by its own weight along a moveable plane, at the ſame time that the preſſure of the body cauſes a horizontal motion in the plane.

Though Darcy ſerved in the war of 1744, he found leiſure, during the buſtle of a military life, to ſend two memoirs to the academy: the firſt of theſe contained a general principle in mechanics, that of the preſervation of the rotatory motion; a principle which he again brought forward in 1750, by the name of the principle of the preſervation of action. He was taken priſoner in this war by the Engliſh: and ſuch was either the reſpect paid to ſcience, or the mercy of the cabinet of St James's, that he was treated, not as an Iriſh rebel, but as a French ſubject fighting for his king and his country.

In 1760, Darcy publiſhed An Eſſay on Artillery, containing ſome curious experiments on the charges of gunpowder, &c. &c. and improvements on thoſe of the ingenious Robbins; a kind of experiments which our author carried on occaſionally to the end of his life. In 1765, he gave to the public the moſt ingenious of all his works his Memoir on the Duration of the Senſation of Sight, in which he endeavours to prove, and indeed completely proves, that a body may ſometimes paſs by our eyes without producing a ſenſation attended with conſciouſneſs, or marking its preſence, otherwiſe than by weakening the brightneſs of the object which it may chance to cover in its paſſage. If in this work he ſhall be thought to have taken hints from Dr Hartley, it is not perhaps too much to ſay, that ſome of our moſt celebrated writers on viſion have ſince been beholden to Darcy. No man indeed has cauſe to be aſhamed of being indebted to him; for all his works diſplay in an eminent degree the union of genius and philoſophy; but as he meaſured every thing upon the largeſt ſcale, and required extreme accuracy in experiment, neither his time, fortune, nor avocations, allowed him to execute more than a very ſmall part of what he projected.

In his diſpoſition, Darcy was amiable, ſpirited, lively, and a lover of independence; a paſſion to which he nobly ſacrificed, even in the midſt of literary ſociety.—He died of a cholera morbus in 1779, at 54 years of age. He was admitted of the French academy in 1749, and was made penſioner-geometrician in 1770. His eſſays printed in the Memoirs of the Academy of Sciences, are various and very ingenious, and are contained in the volumes for the years 1742, 1747, 1749, 1750, 1751, 1752, 1753, 1754, 1758, 1759, 1760, 1765, and in tom I. of the Savans Etrangers.

DARIEN, Gulf of, runs S. eaſterly into Terra Firma. On the eaſtern ſide of its mouth, is the town of St Sebaſtian.—*Morse*.

Darien, a town in Liberty co. Georgia, by the heights of which glides the N. channel of Alatamaha river, about 20 miles above Sapelo Iſland, and 10 below Fort Barrington. It lies 47 miles S. S. W. of Savannah. N. lat. 31. 23. W. long. 80. 14.—*ib.*

DARLINGTON, the moſt ſouthern county of Cheraws diſtrict, S. Carolina; bounded S. and S. W. by Lynch's creek. It is about 35 miles long, and 21 broad.—*ib.*

DARTMOUTH, a town in Grafton co. New-Hampſhire, north weſt of the foot of the White Mountains; 33 miles N. E. of Haverhill, New-Hampſhire, and 87 N. weſterly of Portſmouth. It contains 111 inhabitants, and was incorporated in 1772.—*ib.*

Dartmouth, a thriving ſea-port town in Briſtol co. Maſſachuſetts, ſituated on the W. ſide of Accuſhnet river, 70 miles ſoutherly of Boſton. It was incorporated in 1664, and contains 2499 inhabitants. N. lat. 41. 37. W. long. 70. 52.—*ib.*

Dartmouth, a town in Elbert co. Georgia, ſituated on the peninſula formed by the confluence of Broad and Savannah rivers, 2 miles from Fort James Dartmouth, which is a mile below Charlotte Fort. The town and fort derive their names from James, earl of Dartmouth, whose influence in the British councils obtained from the king, a grant and powers to the Indian trading company in Georgia to treat with the Creeks, for the territory called the *New Purchase*, ceded in discharge of debts due to the traders. This tract contains about 2,000,000 of acres, lying upon the head of the Great Ogechee, between the banks of the Savannah and Alatamaha, touching on the Oconee, including all the waters of Broad and Little rivers. This territory comprehends a body of excellent, fertile land, well watered by innumerable rivers, creeks and brooks. —*ib.*

DATA of Euclid, the first in order of the books that have been written by the ancient geometricians, to facilitate and promote the method of resolution or analysis. In general, a thing is said to be given which is either actually exhibited, or can be found out, that is, which is either known by hypothesis, or that can be demonstrated to be known: and the propositions in the book of Euclid's data, shew what things can be found out or known, from those that by hypothesis are already known: so that in the analysis or investigation of a problem, from the things that are laid down as given or known, by the help of these propositions, it is demonstrated that other things are given, and from these last that others again are given, and so on, till it is demonstrated that that which was proposed to be found out in the problem is given; and when this is done, the problem is solved, and its composition is made and derived from the compositions of the data which were employed in the analysis. And thus the data of Euclid are of the most general and necessary use in the solution of problems of every kind.

Marinus, at the end of his preface to the data, is mistaken in asserting that Euclid has not used the synthetical, but the analytical method in delivering them: for though in the analysis of a theorem, the thing to be demonstrated is assumed in the analysis; yet in the demonstrations of the data, the thing to be demonstrated, which is, that something is given, is never once assumed in the demonstration; from which it is manifest, that every one of them is demonstrated synthetically: though indeed if a proposition of the data be turned into a problem, the demonstration of the proposition becomes the analysis of the problem. *Simpson's Preface to his edition of the Data.*

DAUBENTON (William), who made so much noise early in this century, was born at Auxerre. He followed King Philip V. whose confessor he was, into Spain. He had the greatest influence with that prince until the courtiers, jealous of his power, prevailed upon the king to send him from court in 1706. By dint of solicitations, however, he was recalled in 1716, reinstated in his office, and then enjoyed more power than before. It is said, that when Philip V. disgusted with his throne, wished to abdicate it, he confided his design to Daubenton; that the latter, fearing that he should be obliged to follow him to his retreat, discovered this secret to the Duke of Orleans, regent of France, who was at that time projecting the double marriage of Mademoiselle de Montpensier his daughter, with the Prince of the Asturias, and that of Louis the XV. with the infanta, five years of age. It is added, that the Jesuit believed it would be for the interest of the Duke of Orleans to dissuade Philip from his purpose; that the Duke of Orleans sent the confessor's letter to the king, who shewed it to Daubenton, without saying a single word; that the confessor put a very different construction upon it; that an apoplexy seized him on going out of the chamber; and that he died a short time after in 1723; in the 75th year of his age. This story (for the truth of which we will avouch still the less, that it is not mentioned by the Marshal de Noailles in his memoirs) is related by the author of the Age of Louis XV. who quotes the civil history of Bellando, page 306, Part IV. It is only clear from the memoirs of Noailles, that Daubenton opposed the abdication of the King of Spain. The Abbe Grosier, in a letter inserted in the *Année Litteraire* (1777, N° 18), denies, 1*mo*, That Daubenton had revealed to the regent any secret entrusted to him by Philip V. in confession. 2*do*, That this Jesuit died, as Voltaire makes him from the authority of Bellando, an inaccurate historian, whose works were suppressed in Spain. 3*tio*, He pretends that Daubenton, far from being a man of intrigue, an ambitious monk, and capable of opposing the abdication of Philip, in order to prevent himself from being removed from court, had solicited permission to leave it several years before. We refer the reader to that letter, which deserves to be read for the sound criticism which it contains. This Jesuit had preached with some success. There are extant some tolerable funeral orations of his, and a life of St. Francois Regis, 12mo.

DAUPHIN, Fort, a jurisdiction, fort and seaport town in the N. part of the island of St Domingo. This division contains 5 parishes. Its exports from Jan. 1, 1789 to Dec. 31 of the same year, consisted of sugar, coffee, cotton, indigo, spirits, molasses, and tanned hides, in value 35,252 dolls. 13 cents. The town of Fort Dauphin is remarkable for a fountain constructed by the orders of M. de Marbois, which cost 10,678 dollars. N. lat. 19. 41.—*Morse.*

Dauphin, an island about 10 miles long, in the mouth of Mobile bay, 5 miles from Massacre Island, with a shoal all the way between them. These are supposed formerly to have been but one, and went by the general name of Massacre, so called by Monf. d'Ibberville, from a large heap of human bones found thereon at his landing. It was afterwards called Dauphin Island. The W. end, a distance of between 3 and 4 miles, is a narrow slip of land with some dead trees; the rest is covered with thick pines, which come close to the water's edge on the E. side, forming a large bluff. There is the remains of an old French post on the S. side of the island, and of some old houses of the natives. N. lat. 30. 10. W. long. 88. 7. —*ib.*

Dauphin, a fort in the island of Cape Breton, round which the French had their principal settlement, before they built Louisburg.—*ib.*

Dauphin *Co.* in Pennsylvania, was formerly contained in that of Lancaster, until erected into a separate county, March 4, 1785. Its form is triangular; its contents 586.400 acres, and is surrounded by the counties of Mifflin, Cumberland, York, Berks, and Northumberland. It is divided into 9 townships, the chief

chief of which is Harriſburg; the number of its inhabitants 18,177. Nearly one half of the land is under cultivation; but the northern part is very rough and mountainous. In ſeveral of the mountains is found abundance of iron ore of the firſt quality; a furnace and forge have been erected which carry on briſkly the manufacture of pig, bar iron, &c. The firſt ſettlers here were Iriſh emigrants, who were afterwards joined by a number of Germans. In the town of Derry, on the bank of Swatara creek is a remarkable cavern; its entrance is under a high bank, and nearly 20 feet wide, and about 8 or 10 feet in height. It deſcends gradually nearly to a level with the creek. Its apartments are numerous, of different ſizes, and adorned with ſtalactites curiouſly diverſified in ſize and colour. Near the foot of Blue mountain is a mineral ſpring, much celebrated by the country people for its efficacy in removing rheumatic and other chronic diſorders.—*ib.*

DAVIDSON, a county in Mero diſtrict in Tenneſſee, bounded N. by the ſtate of Kentucky, E. by Sumner, and S. by the Indian territory. Its chief town Naſhville, lies on the great bend of Cumberland river.—*ib.*

DAVID's *Town*, on the Aſſanpink river, Hunterdon co. New-Jerſey, 10 or 12 miles from Trenton. Between theſe towns a boat navigation has lately been opened by the means of three locks, erected at a conſiderable expenſe. It is propoſed to render this river boatable 10 or 15 miles further, in which diſtance, no locks will be neceſſary.—*ib.*

DAVIS's *Strait*, a narrow ſea, lying between the N. main of America, and the weſtern coaſt of Greenland; running N. W. from Cape Farewell, lat. 60. N. to Baffin's Bay in 80. It had its name from Mr John Davis, who firſt diſcovered it. It extends to W. long. 75. where it communicates with Baffin's Bay, which lies to the N. of this ſtrait, and of the North Main, or James's Iſland.—*ib.*

DAWFUSKEE, an iſland on the coaſt of S. Carolina, which forms the N. E. ſide of the entrance of Savannah river, and S W. ſide of the entrance of Broad river, and admits of an inland communication between the two rivers.—*ib.*

DAXABON, *Dajabon*, or *Dahabon*, which the French call *Laxabon*, is a town and ſettlement of Spaniards on the line between the French and Spaniſh diviſions of the iſland of St Domingo. It was ſettled to prevent ſmuggling when the Spaniards had their ſhare of the iſland. It is bounded E. by the territory of St Yago, N. by the extremity of the bed of the Great Yaqui, and the bay of Mancenilla, W. by the river and little iſland of Maſſacre. It contains about 4000 perſons. The town ſtands 400 fathoms from the E. bank of Maſſacre river, more than 80 leagues N. W. of St Domingo, and 28 W. of St Yago. N. lat. 19. 32. W. long. from Paris 74. 9.—*ib.*

DAY's *Point*, on James river in Virginia. There is a plantation here of about a 1000 acres, which at a diſtance appears as if covered with ſnow; occaſioned by a bed of clam ſhells, which by repeated ploughing have become fine, and mixed with the earth.—*ib.*

DEAD CHEST *Iſland*, one of the ſmaller Virgin iſles, ſituated near the E. end of Peter's iſland, and W. of that of Cooper's.—*ib.*

DEADHAM, a poſt town, and the capital of Norfolk co. Maſſachuſetts, called by the aboriginals Tiot, and by the firſt ſettlers, Clapboard Trees. The townſhip was incorporated in 1637, is 7 miles in length, and 6 in breadth, and contains 1659 inhabitants. Its public buildings are 3 congregational churches, an epiſcopal church, and a court-houſe. It is pleaſantly ſituated, 11 miles S. W. of Boſton, on Charles river. A ſmall ſtream furniſhes water moſt part of the year to 2 griſt mills, 2 ſaw mills, 2 fulling mills and a leather mill, all in the ſpace of three quarters of a mile, and joins Neponſit river on the borders of Milton. A wire manufactory is erected here, for the uſe of the fiſh-hook and card manufacturers in Boſton.—*ib.*

DEADMAN's *Bay*, on the E. ſide of Newfoundland iſland, lies S. of St John's harbour, and N. W. of Cape Spear.—*ib.*

DEAL, in Monmouth co. New-Jerſey, about 7 miles ſouthward of Shrewſbury. This place is the reſort of great numbers of people from Philadelphia, in ſummer, for health and pleaſure.—*ib.*

DE BOIS BLANC, an iſland belonging to the N. W. territory, a voluntary gift of the Chipeway nation to the United States, at the treaty of peace concluded by gen. Wayne at Greenville, in 1795.—*ib.*

Circulating DECIMALS, called alſo *recurring* or *repeating decimals*, are thoſe in which a figure or ſeveral figures are continually repeated. They are diſtinguiſhed into *ſingle* and *multiple*, and theſe again into *pure* and *mixed*.

A *pure ſingle* circulate is that in which one figure only is repeated; as ·222 &c. and is marked thus $\cdot\dot{2}$.

A *pure multiple* circulate is that in which ſeveral figures are continually repeated; as ·232323 &c. marked $\cdot\dot{2}\dot{3}$; and ·524524 &c. marked $\cdot\dot{5}2\dot{4}$.

A *mixed ſingle* circulate is that which conſiſts of a terminate part, and a ſingle repeating figure; as 4.222 &c. or $4\cdot\dot{2}$. And

A *mixed multiple* circulate is that which contains a terminate part with ſeveral repeating figures; as $45\cdot\dot{5}2\dot{4}$.

That part of the circulate which repeats is called the *repetend*; and the whole repented, ſuppoſed infinitely continued, is equal to a vulgar fraction, whoſe numerator is the repeating number or figures, and its denominator the ſame number of nines: ſo $\cdot\dot{2} = \frac{2}{9}$; and $\cdot\dot{2}\dot{3} = \frac{23}{99}$; and $\cdot\dot{5}2\dot{4} = \frac{524}{999}$.

It ſeems it was Dr Wallis who firſt diſtinctly conſidered or treated of infinite circulating decimals, as he himſelf informs us in his Treatiſe of Infinites. Since his time many other authors have treated on this part of arithmetic; the principal of theſe, however, to whom the art is moſtly indebted, are Meſſrs Brown, Cunn, Martin, Emerſon, Malcolm, Donn, and Henry Clarke; in whoſe writings the nature and practice of this art may be fully ſeen, eſpecially in the laſt mentioned ingenious author.

DEEP *Spring*, in the ſtate of New-York, is a curioſity, and lies about 9 miles S. of Oneida lake, at the head of Chittenengo creek, and 10 miles S. W. of Oneida caſtle.—*Morſe.*

Deep *River*, in North Carolina, riſes in Wachovia, and unites with Haw river and forms the N. W. branch of Cape Fear river.—*ib.*

DEERFIELD, a townſhip in Cumberland co. New-Jerſey.—*ib.*

Deerfield *River*, or the *Pocomtic*, riſes in Stratton, in in Bennington co. Vermont, and after receiving a number of streams from the adjoining towns, unite on entering Massachusetts; thence winding in an E. direction, it receives North river and empties into Connecticut river, between the townships of Greenfield and Deerfield, where it is about 15 rods wide. Excellent tracts of meadow ground lie on its banks.—*ib.*

Deerfield, a very pleasant town in Hampshire co. Massachusetts, on the W. bank of Connecticut river, from which the compact part of the town is separated by a chain of high hills. It is in the midst of a fertile country, and has a small inland trade. The compact part of the town has from 60 to 100 houses, principally on one street, and a handsome congregational church. It was incorporated in 1681, and contains 1330 inhabitants; 17 miles N. of Northampton, and 109 N. by W. of Boston.

The house in which the Rev. Mr Williams and his family were captivated by the Indians in the early settlement of this town, is still standing, and the hole in the door, cut by the Indians with their hatchets, is still shewn as a curiosity. An academy, incorporated in 1797, by the name of "The Deerfield Academy," is established in this town.—*ib.*

Deerfield, a well settled agricultural town in Rockingham co. New-Hampshire, and was a part of the township of Nottingham, 19 miles S. E. of Concord, and 35 N. W. of Portsmouth. It contains 1619 inhabitants, and was incorporated in 1766.—*ib.*

DEER *Island*, an island and township in Penobscot bay, in Hancock co. district of Maine, containing 682 inhabitants. It was incorporated in 1789, and lies 305 miles N. E. of Boston.—*ib.*

DEERING, a township in Hillsborough co. New-Hampshire, incorporated in 1774. It contains 928 inhabitants, and lies 15 miles S. W. of Concord, and 54 miles W. of Portsmouth.—*ib.*

DEFERENS, or Deferent, in the ancient astronomy, an imaginary circle, which, as it were, carries about the body of a planet, and is the same with the eccentric; being invented to account for the eccentricity, perigee, and apogee of the planets.

DEFIANCE, a fort in the N. western territory, situated on the point of land formed by the confluence of the rivers of Au Glaize, and the Miami of the lake, nearly half way between Fort Wayne on the Miami, and lake Erie. N. lat. 41. 41. W. long. 84. 43. —*Morse.*

DEFLECTION, the turning any thing aside from its former course by some adventitious or external cause. The word is often applied to the tendency of a ship from her true course by reason of currents, &c. which turn her out of her right way. It is likewise applied by astronomers to the tendency of the planets from the line of their projection, or the tangent of their orbit. See Astronomy in this Supplement.

DEJECTION, in astrology, is applied to the planets when in their detriment, as astrologers speak, i. e. when they have lost their force or influence, as is pretended, by reason of their being in opposition to some others which check and counteract them. Or it is used when a planet is in a sign opposite to that in which it has its greatest effect or influence, which is called its *exaltation*. Thus, the sign Aries being the exaltation of the sun, the opposite sign Libra is its dejection.

DE LA MARCH, a western water of Illinois river in the N. W. territory. It is 30 yards wide, and navigable 8 or 9 miles.—*Morse.*

DE LA WAR, a town in King William's co. Virginia, situated on the broad peninsula formed by the confluence of the Pamunky and Mattapony. The united stream thence assumes the name of York river. It lies 20 miles N. by W. of Williamsburg in N. lat. 37. 31. W.—*ib.*

DELAWARE *Bay* and *River*. The bay is 60 miles long, from the cape to the entrance of the river, at Bombay Hook; and occupies a space of about 630,000 acres; and is so wide in some parts, as that a ship, in the middle of it, cannot be seen from the land. It opens into the Atlantic N. W. and S. E. between Cape Henlopen on the right, and Cape May on the left. These capes are 18 or 20 miles apart.

Delaware river was called Chihohocki by the aboriginals, and in an old Nurenberg map is named Zuydt river. It rises by two principal branches in New-York state. The northernmost of which, called the Mohawk's or Cookqugo branch, rises in lake Ustayantho, lat. 42. 25. and takes a S. W. course, and turning S. eastwardly, it crosses the Pennsylvania line in lat. 42.; about 7 miles from thence, it receives the Popachton branch from the N. E. which rises in the Kaats Kill mountains. Thence it runs southwardly, until it strikes the N. W. corner of New-Jersey, in lat. 41. 24.; and then passes off to sea through Delaware bay; having New-Jersey E. and Pennsylvania and Delaware W. The bay and river are navigable from the sea up to the great or lower falls at Trenton, 155 miles; and are accommodated with buoys and piers for the direction and safety of ships. A 74 gun ship may go up to Philadelphia, 120 miles by the ship channel from the sea. The distance across the land, in a S. E. course, to New-Jersey coast, is but 60 miles. Sloops go 35 miles above Philadelphia, to Trenton falls; boats that carry 8 or 9 tons, 100 miles farther, and Indian canoes 150 miles, except several small falls or portages.

It is in contemplation to connect the waters of Chesapeak bay with those of Delaware river by 4 different canals, viz. Elk river with Christiana creek—Broad creek, another branch with Red Lion creek—Bohemia, a third branch of the Elk, with Apoquinemy creek; and Chester river with Duck creek.—*ib.*

Delaware, a small river of East Florida.—*ib.*

Delaware *Co.* in Pennsylvania, is S. W. of Philadelphia co. on Delaware river. It is about 21 miles in length, and 15 in breadth, containing 115,200 acres, and subdivided into 19 townships; the chief of which is Chester. The number of inhabitants is 9,483. The lands bordering on the Delaware are low, and afford excellent meadow and pasturage; and are guarded from inundations by mounds of earth or dykes, which are sometimes broken down in extraordinary freshes in the river. If this happens before cutting the grass, the crop of hay is lost for that season, and the reparation of the breaches is expensive to the proprietors. Great numbers of cattle are brought here from the western parts of Virginia, and North-Carolina, to be fattened for supplying the Philadelphia market.—*ib.*

Delaware, a new county in the state of New-York, on the head waters of Delaware river, taken from Otsego county.—*ib.*

DELAWARES, an Indian nation formerly numerous and powerful, and who possessed part of Pennsylvania, New-Jersey and New-York. This name was doubtless given them by the Europeans; for they call themselves Lennilenape, that is, Indian men; or Woapanachky, which signifies a people living towards the rising sun. They now reside about half way between lake Erie and Ohio river. They are an ingenious and intelligent people; and like the Six Nations, are celebrated for their courage, peaceable disposition, and powerful alliances. Almost all the neighbouring nations are in league with them, especially the Mahikan, Swawanves, Cherokees, Twichtwees, Wawiachtanos, Kikapus, Moshkos, Tuckachshas, Chippeways, Ottawas, Putewoatamies, and Kaskaskias. The Delawares were lately hostile, but made peace with the United States in 1795, and ceded some lands. The United States, on the other hand, have engaged to pay them in goods, to the value of 1000 dollars a year forever. Twenty years ago, the Delawares could furnish 600 warriors; but their number is considerably decreased by war since that time.—*ib.*

DELIACAL Problem, a celebrated problem among the ancients, concerning the duplication of the cube.

DELIVERANCE, Cape, is the S. E. point of the land of Louisiade. Bougainville was here, and named it in 1768.—*Morse.*

DEL REY, a captainship in the southern division of Brazil, whose chief town is St Salvadore.—*ib.*

DEL SPIRITU SANTO, a river which falls into the gulf of Mexico, at the N. W. end of the peninsula of Florida.—*ib.*

DEMERARA, a river in Dutch Guiana, in S. America, is about two miles wide at its mouth, opposite the fort, on the E. bank of the river, and about 45 miles distant from Abary creek. It is scarcely a mile wide, 12 miles above the fort; and its course is from S. to N. It is navigable upwards of 200 miles for vessels which can pass the bar at its mouth, which is a mud bank, not having above 24 feet at the highest tides. The difference between high and low water mark, is from 10 to 12 feet. The fort, if properly supplied with men and ammunition, is able effectually to guard its entrance. Staebroeck, the seat of government, stands on the E. side of the river $1\frac{1}{2}$ miles above the fort.—*ib.*

Demerara, a district in Dutch Guiana, which, together with Essequebo, form one government, and have the same court of police, but each has a separate court of justice. The two districts contain about 3,000 whites and 40,000 slaves. Demerara river which gives name to the district, passes through it, and is usually visited by 40 or 50 large ships from Holland, who often make two voyages in a year, besides upwards of 250 smaller vessels, under the Dutch and other flags. The plantations are regularly laid out in lots along the sea-shore, called façades, about a quarter of a mile wide, and extending $\frac{3}{4}$ths of a mile back into the country. Each lot contains about 250 acres each; and when fully cultivated, the proprietor may obtain a similar tract back of the first, and so on in progression. Each lot will contain 120,000 cotton trees, averaging usually half a pound a tree. Such a plantation is reckoned well stocked to have 120 negroes. The shores of the rivers and creeks are chiefly planted with coffee, to the distance of about 30 miles from the sea; thence 30 miles further up, the soil becomes clayey and more fit for sugar canes. Beyond this, the finest kinds of wood, for building, furniture, &c. are cut.—*ib.*

DEMI-Bastion, in fortification, a bastion that has only one face and one flank.

DEMI-QUIAN, a river, swamp and lake on the western side of Illinois river in the N. W. territory. The river runs a S. S. E. course, is navigable 120 miles, and has the swamp of its name on the northern bank near its mouth; which last is 50 yards wide, 32 miles above Sagamond, and 165 miles above the Mississippi. The lake is of a circular form, 200 yards W. of the river, is 6 miles across, and empties into the Illinois by a small passage 4 feet deep, 171 miles from the Mississippi.—*Morse.*

DENDROMETER, in its usual acceptation, is the name of an instrument for measuring trees, of which the reader will find a description in the Encyclopædia. The same name has been lately given, by William Pitt, Esq; of Pendeford, near Wolverhampton, to an instrument proposed by him for measuring distances by one observation.

The idea of such an instrument is not new. It has been frequently discussed, both in conversation and upon paper; but has been generally treated by sound mathematicians with contempt, on the supposition of its being founded on false principles. Of all this our author is fully aware; but he, notwithstanding, strongly recommends it to the attention of the ingenious mathematical instrument-maker.

To determine distances by one observation, two methods may be proposed, founded on different principles; the one on the supposition of the observer being in the centre, and the object in the circumference, of a circle; the other, on the contrary supposition, of the observer being in the circumference, and the object in the centre.

To determine the distance of any object on the first supposition, the bulk or dimensions of such object must be known, either by measure or estimation, and the angle formed by lines drawn to its extremities being taken by an accurate instrument, the distance is easily calculated; and such calculations may be facilitated by tables or theorems adapted to that purpose. For this method our present instruments, with a nonius, and the whole very accurately divided, are sufficient; the only improvement wanting seems to be the application of a micrometer to such instruments, to enable the observer to read his angle with more minute accuracy, by ascertaining, not only the degrees and parts of a degree, but also the minutes and parts of a minute.

As in this method the bulk of inaccessible objects can only be estimated, the error in distance will be exactly in the proportion of the error in such estimation; little dependence can therefore be placed on distances thus ascertained. For the purposes of surveying, indeed, a staff of known length may be held by an assistant; and the angle from the eye of the observer to its two ends being measured by an accurate instrument, with a micrometer fitted to ascertain minutes and parts of a minute, distances may be thus determined with great accuracy; the application of a micrometer to the theodolite, if it could be depended upon, for thus determining

mining the minute parts of a degree, in ſmall angles, is very much a deſideratum with the practical ſurveyor.

This method of meaſuring diſtances, though plain and ſimple enough, our author illuſtrates by an example: Suppoſe A, fig. 1. (ſee Plate XXI.) the place of the inſtrument; BC the aſſiſtant's ſtaff, with a perpendicular pin at D, to enable the aſſiſtant to hold it in its right poſition; now, if the angle BAC could, by the help of a micrometer, be aſcertained to parts of a minute, the diſtance from A to B, or to C, might be eaſily calculated by the rules of plane TRIGONOMETRY; for which ſee that article in the Encyclopædia.

But this method of aſcertaining diſtances cannot be applied to inacceſſible objects, and it is moreover ſubject to the inconvenience of an aſſiſtant being obliged to go to the object whoſe diſtance is required (an inconvenience almoſt equal to the trouble of actual admeaſurment); therefore the perfection of the ſecond method propoſed, if attainable, is principally to be deſired; namely, that of conceiving the obſervation made on the circumference of a circle, whoſe centre is in the object whoſe diſtance is to be aſcertained; and, none of our inſtruments now in uſe being adapted to this mode of obſervation, a new conſtruction of a mathematical inſtrument is therefore propoſed, the name intended for which is the *dendrometer*.

Our author admits, that this name is not now uſed for the firſt time, though he thinks that the principle has never been applied in practice, for the familiar purpoſe of aſcertaining terreſtrial diſtances, in ſurveying, or otherwiſe, though the ſame principle has been ſo generally and ſucceſsfully applied in determining the diſtance of the heavenly bodies by means of their parallax.

The following principles of conſtruction are propoſed, which may perhaps be otherwiſe varied and improved. O, fig. 2. the object of whoſe diſtance is required: ABCDE the inſtrument *in plano;* BC a teleſcope, placed exactly parallel to the ſide AE; CE an arch of a circle, whoſe centre is at A, accurately divided from E in degrees, &c.; AD an index, moveable on the centre A, with a nonius ſcale at the end D, graduated to apply to the diviſions of the arch; alſo with a teleſcope, to enable the obſerver to diſcriminate the object, or any particular part or ſide thereof, the more accurately. The whole ſhould be mounted on three legs, in the manner of a plain table or theodolite, and furniſhed with ſpirit-tubes to adjuſt it to an horizontal poſition. The inſtrument being placed in ſuch poſition, the teleſcope BC muſt be brought upon the object O, or rather upon ſome particular point or ſide thereof; when, being there faſtened, the index AD muſt be moved till its teleſcope exactly ſtrikes the ſame point of the object; then the diviſions on the arch ED mark out the angle DAE, which will be exactly equal to the angle BOA, as is demonſtrated in the XV. and XXIX. propoſitions of Euclid, Book I.; and the ſide BA, as well as the angles ABO, and BAO, being already known, the diſtance BO or AO may be eaſily determined.

As the perfection of this inſtrument depends altogether upon its accuracy in taking ſmall angles, ſo that accuracy muſt depend, not only upon the inſtrument's being properly fitted with a micrometer, but alſo in ſome meaſure upon the length of the line BA in the figure. That line, therefore might be extended, by the inſtrument being conſtructed to fold or ſlide out to a greater length when in uſe; upon which principle, connected with the application of a micrometer, an accurate and uſeful inſtrument might certainly be conſtructed. To adjuſt ſuch inſtrument for uſe, let a ſtaff be held up at a diſtance, in the manner of fig. 1. exactly equal in length to the diſtance of the two teleſcopes, and the index AD being brought exactly upon the ſide AE, if the two teleſcopes accurately ſtrike either end of the ſtaff, the inſtrument is properly adjuſted.

The conſtruction of a ſimilar inſtrument on the principles of Hadley's quadrant, for naval obſervations, would alſo doubtleſs be an acceptable object in navigation, by enabling the mariner to aſcertain the diſtances of ſhips, capes, and other objects, at a ſingle obſervation; and that, perhaps, with greater accuracy than can be done by any method now in uſe.

For this purpoſe, the following conſtruction is propoſed: ABCDE, fig. 3. the inſtrument *in plano;* O the object whoſe diſtance is required; at A, at C, at E, and at 3, are to be fixed ſpeculums properly framed and fitted, that at 3 having only its lower part quickſilvered, the upper part being left tranſparent to view the object, the ſpeculum at A being fixed obliquely, ſo that a line A 1, drawn perpendicular to its ſurface, may biſect the angle BAC in equal parts; that at C being perpendicular to the line C 2; thoſe at E at 3 being perpendicular to the index E 3, and that at E being furniſhed with a ſight; the arch DC to be divided from D in the manner of Hadley's quadrant; the movement of the index to be meaſured as before by a micrometer; and as the length of the line AE would tend to the perfection of the inſtrument, it may be conſtructed to fold up in the middle, on the line C 2, into leſs compaſs when not in uſe. The inſtrument may be adjuſted for uſe by holding up a ſtaff at a diſtance, as before propoſed, whoſe length is exactly equal to the line AE.

To make an obſervation by this inſtrument, it being previouſly properly adjuſted, the eye is to be applied at the ſight in the ſpeculum E, and the face turned towards the object; when the object being received on the ſpeculum A, is reflected into that at C, and again into that at E, and that at 3 on the index; the index being then moved till the reflected object in the ſpeculum at 3 exactly coincides with the real object in the tranſparent part of the glaſs, the diviſions on the arch D 3, ſubdivided by the micrometer, will determine the angle DE 3 = the angle AOE; from which the diſtance O may be determined as before.

DENNEY's *River*, diſtrict of Maine, 22 miles E. of Machias. The country between this river and Machias, in 1794, was a wilderneſs. The banks of the river were at this time thinly ſettled by a regular and well diſpoſed people.—*Morſe.*

DENNIS, a part of Yarmouth in Barnſtable co. Maſſachuſetts, which was incorporated into a townſhip in 1793.—*ib.*

DENOMINATOR OF A RATIO is the quotient ariſing from the diviſion of the antecedent by the conſequent. Thus 6 is the denominator of the ratio 30 to 5, becauſe 30 divided by 5 gives 6. It is otherwiſe called the *exponent* of the ratio.

DENTON, the chief town of Caroline co. in Maryland; ſituated on the E. ſide of Choptank creek, the

E. main

E. main branch of Choptank river. It is laid out regularly, and has a few houses, and lies 7 miles S. of Greensborough, and 37 S. S. E. of Chester.—*Morse.*

DEPRESSION of a Star, or *Of the Sun*, is its distance below the horizon, and is measured by an arc of a vertical circle, intercepted between the horizon and the place of the star.

Depression of the Visible Horizon, or *Dip of the Horizon*, denotes its sinking or dipping below the true horizontal plane, by the observer's eye being raised above the surface of the sea; in consequence of which, the observed altitude of an object is by so much too great.

DERBY, a township in Orleans co. Vermont, on the N. line of the state, on the E. shore of lake Memphremagog.—*Morse.*

Derby, a town in New-Haven co. Connecticut, on the point of land formed by the confluence of Naugatuck and Housatonick rivers. This town was settled in 1665, under New-Haven jurisdiction, and is now divided into two parishes, and has an academy in its infancy. It has a considerable trade with the West-Indies for so small a town, and a number of mills on the falls of Naugatuck, and streams which fall into it, and iron and other works on Eight-mile river which falls into the Stratford. The Stratford or Housatonick river is navigable 12 miles to this town.—*ib.*

DEROOBUST, in Bengal, Entire; as an entire district, opposed to Kismut, which see.

DERRY, a township in Dauphin co. Pennsylvania, situated on the E. side of Swatara creek, 2 miles above its confluence with the Susquehannah, and celebrated for its curious cave.—*Morse.*

Derry, a township on Susquehannah river in Pennsylvania. There are two other townships of the same name in Pennsylvania; the one in Mifflin co. the other in that of Westmoreland.—*ib.*

DERRYFIELD, a township in New-Hampshire, on the E. bank of Merrimack river Hillsborough co. containing 362 inhabitants, and was incorporated in 1751; the soil is but indifferent. It is 42 miles W. of Portsmouth.—*ib.*

DESAQUADERO, a river in Peru, S. America, over which the Ynca Huana Capac built a bridge of flags and rushes, to transport his army to the other side, and which remained a few years since.—*ib.*

DESAULT (Peter Joseph), surgeon in chief to the Hospital of Humanity, formerly the *Hotel-Dieu*, at Paris, was born on the 6th of February, 1744 at Magny Vernois, a village in the neighbourhood of Lure, in the department of Haut Saone (formerly the province of *Franche Comté*) His father and mother were in that situation of life which is removed from want, and yet does not dispense with labour; he himself was the youngest child of a numerous family.

At Lure, under the direction of a private instructor, he was taught the first rudiments of the Latin tongue; his parents afterwards confided him to the care of the Jesuits, then almost exclusively entrusted with the education of youth in the public schools. This celebrated society, prompt in discovering, as expert at developing, and adroit in appropriating talents, soon distinguished the young student from the crowd; and he in his turn, was not displeased with the life he led in one of their seminaries.

On the completion of his studies his father, who had destined him for the church, intimated a wish that he should apply himself to theology; but his genius had taken a different direction, and he was averse to the profession of an ecclesiastic: in short, young Default declared that he was determined to betake himself to the study of the healing art, and, after a long and ineffectual resistance on the part of his family, he was sent to Béfort, in order to serve an *apprenticeship*, as it was then termed, in the military hospital of that place. He accordingly spent three years there, during which he acquired some knowledge of anatomy, attended to the dressing of the patients, and endeavoured to supply, by his own observations, what was wanting in his instruction.

In the midst of these professional labours, his mind frequently rambled towards another science but little connected with surgery: this was mathematics, the elements of which he had acquired among the Jesuits. His progress in this favourite study was rapid; but he fell into one of the many errors so common among the physicians of that day: this consisted in a false application of the rules of geometry to the laws of the animal economy.

He not only perused with avidity the treatise of Borelli *De Motu Animalium*, but actually translated the whole of it, and even added a commentary still more abundant in calculation than that of the celebrated professor of Naples.

His success in a branch of physiology so much cultivated at that time, attracted the attention of one of his superiors, a zealous partizan of the doctrine of the mechanicians who wished to attach him to his person; but his desire of fame required a more extensive theatre, and his love of study made him solicitous of better means of instruction. Paris presented both these advantages, and he accordingly repaired thither in 1764, at the age of nineteen, in search of them.

Surgery at that period flourished in the capital under the auspices of a Lafaye, a Morand, an Andouillet, and a Louis. The sight of such great masters excited the genius of those who aspired to emulate them: young Default deemed himself worthy of equalling men whom other students were content with only admiring. Animated by this sentiment, he entirely resigned himself to his ardour; anatomy became the special object of his labours, and his dissections were not confined to the human body; for he investigated by means of his knife, a prodigious number of animals of all kinds: at first, from a difficulty of procuring human subjects, and afterwards on account of the advantages which he experienced from this general method. In order to become intimately acquainted with our own organization, it is necessary to compare with it whatever has a resemblance to it in other bodies.

He accordingly spent the greater part of the day in the amphitheatres. The hours stolen from his favourite labours were employed in attending the hospitals; he was the first at the bed of the patient where an operation was to be performed, and was sure to be present at the dressings on purpose to examine the result. The infirmities of mankind, sterile in respect to the vulgar, served him as the best treatise for curing them; and the great surgeons of all nations have formed their mode of practice by contemplating the same book.

Default.

But he reckoned too much on a robuſt and vigorous temperament; for, after two years cloſe and aſſiduous application, he fell into a cachectical habit of body, which had nearly proved mortal, and which confined him for almoſt twelve months to his bed; but at length, owing partly to the vigour of his youth, and partly to the attention of his young friend Chopart, his inſeparable companion in his operations, who attended him alſo during his laſt illneſs, and only ſurvived him a few days, he was ſo fortunate as to recover.

Reſtored to life, he forgot that an exceſs of attention had conducted him to the very gates of death; a new career opened to his view, and required new efforts on his part. In the winter of 1766 he commenced a courſe of anatomy, and ſoon reckoned 300 pupils, moſt of them older than himſelf, who were attracted by the clearneſs of his demonſtrations, the methodical arrangement of his deſcriptions, and, above all, by his indefatigable zeal in the ſcience of inſtruction.

His ſucceſs inſpired the privileged profeſſors, whoſe ſchools became deſerted, with jealouſy and revenge; they employed the authority of the corporation againſt him, and would have nipped his efforts in the bud, had it not been for the protection of Louis and Lamartiniere, who were zealous of protecting a youth of talents, whoſe ſole reproach was that he had not wealth enough to purchaſe certain franchiſes, after all, had it not been for the permiſſion he obtained of borrowing the name of a celebrated phyſician, he muſt have actually deſiſted from his lectures.

Default's reputation now begun to be buzzed about, and a multitude of patients claimed his aſſiſtance; but he conſtantly refuſed to practiſe, until he ſhould be placed at the head of ſome great eſtabliſhment.

At length, at the repeated ſolicitations of his friends, he preſented himſelf as a candidate to the corporation of ſurgeons: and they, much to their honour, admitted him in 1776, on condition of paying the uſual fees when convenient. The following is the title of his theſis: "*De calculo veſicæ urinariæ, eoque extrahendo, prævià ſectione, ope inſtrumenti Haukenſiani emendati.*"

His public lectures were accompanied with as much celebrity as his private ones. Brilliant diſcoveries were not the object of his anatomical labours which were always connected with the art of healing: he was, however, the firſt man in France who taught ſurgical anatomy.

After becoming firſt a ſimple member, and then a counſellor, of the perpetual committee of the academy of ſurgery, he was appointed chief ſurgeon to the hoſpital of the college, and conſulting ſurgeon to that of St Sulpice: neither of theſe added any thing to his fortune, but they gave him a clear inſight into practice, and enabled him to judge of caſes by the inductions ariſing from his own experience.

In 1779 he invented the bandage now in uſe for fractures; by means of which, the fragments being kept in a ſtate of perpetual contact, become conſolidated, without the leaſt appearance of deformity, an almoſt inevitable conſequence of the former mode.

On his appointment to the place of ſurgeon major to the hoſpital *de la Charité*, in 1782, he introduced a new method of treatment in oblique fractures of the thigh bone; and he alſo healed, by means of a methodical compreſſion thoſe various ulcers whoſe cure had hitherto been attended with great difficulty. In addition to this, he ſubſtituted new bandages in fractures of the humerus and clavicle, and adopted a new mode of treating the hare-lip ſuperior to that uſed by Louis. He never recurred to amputation but in extreme caſes, when there was a certainty that diſſolution would have followed a neglect of the operation.

When a premature death carried off Ferrand, chief ſurgeon of the *Hotel-Dieu* in Paris, Default was conſidered as the moſt proper perſon to ſucceed him; and, on the demiſe of Moreau, the whole charge of the hoſpital devolved on him. After three years of ſolicitations and diſputes, he at length in 1788 proceeded in his long-projected ſcheme of eſtabliſhing a clinical ſchool; and a ſpacious amphitheatre was accordingly erected for that purpoſe. Scarcely had his firſt (A) courſe commenced, when the number of pupils who flocked around him was really aſtoniſhing. Foreigners repaired from all parts, and ſeveral of the neighbouring ſtates ſent ſtudents to Paris expreſsly for the purpoſe of aſſiſting at his demonſtrations. More than 600 auditors conſtantly attended, in order to learn a new ſyſtem, conſiſting of a ſimple mode of treatment diſengaged from ancient prejudices, and a complex incoherent practice.

A few of his improvements are here ſpecified.

1. The method of ligature employed by the ancients in the cure of umbilical hernias of children, having been generally omitted in the practice of the moderns, he again introduced and perfected this mode, and demonſtrated by his ſucceſs, its ſuperiority over compreſſive bandages.

2. He was one of the firſt men in France to extract the looſe cartilages *(cartilages flottans)* in joints.

3. He employed a new treatment, that of methodical compreſſion, in reſpect to ſchirroſities of the rectum; in order to which he introduced a candle or bougie, the ſize of which he gradually augmented.

4. He ſimplified, and rendered more commodious, the reduction of luxations of the humerus.

5. Fatal experience having pointed out the danger of employing the trepan in wounds of the head, he ſubſtituted another method of treatment *(l'uſage de l'emétique)* now adopted by many practitioners.

6. He made ſeveral very uſeful improvements on chirurgical inſtruments; ſuch as thoſe employed in the caſes

(A) The buſineſs of the day was conducted in the following routine: 1. A public conſultation concerning the indigent out-patients. 2. The young practitioners belonging to the hoſpital read a detailed account of all the intereſting caſes of ſuch patients as were to be diſcharged that day. 3. The operations: each of theſe was preceded by a diſſertation on the ſtate of the patient, who was then carried to the amphitheatre, where Default, attended by his aſſiſtants, performed the operation in preſence of all the pupils. 4. Argumentative details, by the profeſſor, either on the dangerous maladies exiſting in the hoſpital, or on the ſituation of the patients on whom operations had been performed during the preceding day. 5. The diſection of ſubjects. And 6. A lecture on ſome particular branch of pathology.

Default. cafes of polypus in the womb and noftrils *(la pince à gaîne et des porte-nœuds pour la ligature des polypes*, &c.); for cutting through obftructions in the different cavities*(le kiotome)*; and for the *fiftula in ano*. In cafes of incifion he introduced the ufe of the inftrument *(le gorgeret)* invented by Marchetti, well known among foreigners, but almoft totally neglected in France before this period.

He at the fame time retrenched the ufe of a great number of fuperfluous ones, and banifhed all practices attended with greater pains than utility. Avoiding every thing that was complex, he proved that the art of healing, in imitation of nature, ought to be fimple in its means, and fruitful in its refources.

In 1791 he publifhed his *Journal de Chirurgerie*, which was edited by his pupils, and deftined to defcribe the moft interefting occurrences in his fchool, and alfo extracts from his lectures, which were then dedicated to the inveftigation of the maladies incident to the urinary paffages. The treatment of thefe difeafes, hitherto the reproach of practitioners, had been much improved by the affiftance of the artift Bernard. The elaftic probes *(les fondes élaftiques)*, on their firft appearance, fixed the attention of all profeffional men; but none knew better than Default how to appretiate their advantages. By means of them, he introduced a novel mode of cure in contractions of the urethra, which faved a great number of lives every year in the *Hotel-Dieu*. But he did not confine their ufe to the difeafes of the urethra alone, for he employed them to remove the divers obftacles that impede deglutition or refpiration.

In the midft of fuch a multiplicity of labours, and although he was obliged to attend 400 fick twice a-day, Default neverthelefs employed more than four hours of his time in vifiting private patients.

Few furgeons ever enjoyed fuch an exclufive fhare of public confidence; few ever poffeffed fimilar means of enriching themfelves; and yet he neglected for a long time to take advantage of this. Had he been lefs ardent for glory, he would have been more favoured by fortune; but he facrificed all interefted views to the noble ambition of advancing his art. His clinical and anatomical courfes were gratuitoufly opened by him to the world after the year 1790; and while the public fchools languifhed in the midft of troubles, infeparable perhaps from a mighty revolution, he was forming the greater part of thofe furgeons employed at this prefent moment in the numerous armies of the republic. Confidered under this point of view alone, the fervices which he rendered to humanity are incalculable: too happy if perfecution had not been his fole reward!

While out of mere attachment to the public weal, he added to his various functions that of a member of the council of health, conferred on him in 1792 by the minifter Servan, he was denounced in the popular focieties as an *egotift*, an *indifferent*, &c. and became one of the firft victims of that profcription which, under Robefpierre, extended to nearly every man of talents.

Chaumette accufed him to the fections as having neglected the brave men wounded on the 10th of Auguft, while they themfelves were lavifhing their bleffings at the *Hotel-Dieu* on their faviour. Twice was he brought to the bar of a commune; defirous of difcovering a pretext for perfecution, the clamours of the people were unremittingly excited againft him. He was at length carried away from his amphitheatre, while in the very act of haranguing his pupils; and, in confequence of a *mandat d'arrêt* from the revolutionary committee, conducted by a body of armed men to the Luxembourg. From this horrid prifon few ever departed but to meet their fate; luckily, however, his name was not yet entered on that bloody lift, in which thofe of Malefherbes and Lavoifier were inferted. On the contrary, at the end of three days he was liberated, and inftantly refumed all his functions.

Default || Defeada.

On the eftablifhment of *L'Ecole de Santé*, Default was appointed clinical profeffor; and for external, maladies he foon after obtained from the government the converfion of the *Evechè* into an hofpital for furgical operations.

In the midft of thefe plans, the troubles that occurred in the month of May unfortunately affected his mind, and made him dread left the days of profcription fhould return. It was in vain that his friends attempted to foothe his fufferings; for on the night of the 29th of May, a malignant fever made its appearance, and a nearly continual delirium enfued until his death, which occurred on the 1ft of June 1795, on which day he breathed his laft, in the arms of his pupils, at the age of 51.

The populace were perfuaded that he was poifoned. This ridiculous opinion originated in confequence of the epoch of his death, which preceded but a fhort time that of the fon of Louis XVI. whom he had vifited during his illnefs in the prifon of the Temple. It is pretended that he fell a victim to his conftant refufal to yield to the criminal views entertained againft the life of that child.

Default was of a middling ftature. He was well proportioned, and poffeffed an open countenance. His temperament, naturally robuft, had been fortified by his early education, and was never fapped by an excefs of pleafures, for to them his heart was always indifferent. His ruling paffion was the love of glory; his favourite purfuit, the practice and advancement of his art. He was warm, nay fometimes violent; and his fcholars were not always inclined to praife the fweetnefs of his temper. On the other hand, his mind was noble, elevated, and great, even to excefs.

The French Republic, eager to pay homage to his memory, has prefented his widow with a penfion of 2000 livres per annum. A fon, Alexis Mathias Default, was the fole fruit of his marriage; and he has left but one work behind him, in which the name of his friend Chopart is joined with his own. It is entitled *Traité des Maladies Chirurgicales et des Operations qui leur conviennent*, 2 vols 8vo.

DESEADA, *Defirada* or *Defiderada*, the firft of the Caribbee iflands, difcovered by Columbus in his fecond voyage, anno 1494, when he gave it that name. It is fituated E. of Guadaloupe, and fubject to the French; and is of little confequence except in time of war, when it is the refort of a number of privateers. It is 10 miles long and 5 broad, and looks at a diftance like a galley, with a low point at the N. W. end. The Spaniards make this in their way to America, as well as Guadaloupe. N. lat. 16. 40. W. long. 61. 20.—*Morse*.

Deseada, or *Cape Defire*, the fouthern point of the

ftraits

straits of Magellan, in S. America, at the entrance of the South Sea. S. lat. 53. 4. long. 74. 18. W.—*ib.*

DESERT ISLAND, MOUNT, on the coast of the district of Maine, Massachusetts, contains about 200 families, divided into two different settlements, about 15 miles apart.—*ib.*

DETERMINATE PROBLEM, is that which has but one solution, or a certain limited number of solutions; in contradistinction to an indeterminate problem, which admits of infinite solutions.

DETERMINATE Section, the name of a tract or general problem written by the ancient geometrician Apollonius. None of this work has come down to us, excepting some extracts and an account of it by Pappus, in the Preface to the 7th book of his Mathematical Collections. He there says that the general problem was, "To cut an infinite right line in one point so, that, of the segments contained between the point of section sought, and given points in the said line, either the square on one of them, or the rectangle contained by two of them, may have a given ratio, either to the rectangle contained by one of them and a given line, or to the rectangle contained by two of them."

DETONATION (see that word *Encycl.).* The astonishing violence with which the oxy-muriat of potass, when mixed with various substances, detonates, has been already noticed in this Supplement under the article CHEMISTRY, n° 724, where the theory of these explosions is likewise given. But as several chemists seem to think that this salt, which decrepitates by friction, and spontaneously takes fire when mixed with sulphur, contains in itself the elements and phenomena of thunder, it will not probably be unacceptable to our readers to find, in this place, a distinct account of the various mixtures which produce its detonations. The following are the principal which have been discovered by Fourcroy and Vauquelin.

1. Three parts of the oxy-muriat of potass, and one part of powdered sulphur, rubbed together in a metal mortar, produce numerous successive explosions, resembling the smacking of a whip, or even as loud as the report of a pistol or a musket, according to the rapidity of the motion, and the force of the pressure made use of. A few grains of the same mixture, by being struck smartly upon an anvil with a hammer, occasion a report equal to that of a musket; and torrents of purplish light are seen about the anvil. If this mixture be thrown into concentrated sulphuric acid, it instantly takes fire, and burns, without noise, with a flame of a dazzling whiteness.

2. A mixture of three parts of this salt, half a part of sulphur, and half a part of charcoal, causes stronger explosions than the preceding when rubbed in a mortar, and a louder noise when struck upon an anvil. Its flame also, when the mixture is made to explode, or when it is thrown into sulphuric acid, is more rapid, more lively, and of a redder colour, than that of the preceding.

3. A mixture of equal parts of oxy-muriat of potass and antimony in powder explodes with noise by percussion; but produces only reddish sparks when thrown into sulphuric acid. If zinc be substituted in the place of antimony, a similar explosion takes place, accompanied with a white flame. Sulphuric acid has no effect upon this last mixture.

4. With regulus of arsenic, this salt explodes very violently by the stroke of a hammer; it inflames, with singular rapidity and brilliancy, by the contact of sulphuric acid. In this last experiment there arises a smoke, which in the air takes the form of a crown in the same manner as phosphorated hydrogenous gas does when it inflames spontaneously in a still atmosphere.

5. Sulphuret of iron or martial pyrites inflames rapidly, but without noise, when rubbed in a metal mortar with oxy-muriat of potass. This mixture, when struck upon an anvil, explodes violently, and with a red flame.

6. The red sulphuret of mercury or cinnabar, and the sulphurated calces of antimony, explode with the oxy-muriat of potass by percussion, but they do not inflame by sulphuric acid. The same thing happens when charcoal alone is mixed with this salt.

Any of the following substances, namely, sugar, gums, oils (both fixed and volatile), alcohol, ether, when mixed with oxy-muriat of potass, have the property of exploding very violently by the stroke of a hammer, and all of them send forth a brisk flame at the time of their explosion. The liquid combustible substances above-mentioned are to be mixed with the salt in such a manner as to form a kind of paste. None of these mixtures explode or inflame by being rubbed in a mortar; but some of them inflame by being mixed with concentrated sulphuric acid, their combustion being slow and progressive.

8. All the substances above-mentioned, which, being mixed with the oxy-muriat of potass, take fire and burn instantly, and with considerable noise, by the quick pressure of the strokes of a hammer, produce a much stronger explosion when they are so closely wrapped up in paper, two or three times doubled, as to be thereby compressed before they are struck.

9. An electric shock from a battery of large surface, charged by a strong electric machine, causes all the fore-mentioned mixtures to explode in the same manner as percussion, and their explosion is also accompanied by a bright light.

To the above-mentioned facts, the authors add, that it was already well known, that gunpowder would explode by a violent blow, or very strong pressure; but they observe, that the stroke which is necessary for that purpose must be much stronger than that which suffices to produce an explosion in the above-mentioned mixtures of combustible substances with the oxy-muriat of potass; and that its explosion is by no means so remarkable as that which is produced by the help of this new salt.

DETOUR DES ANGLOIS, or *English Turn*, is a circular direction of the river Mississippi, so very considerable, that vessels cannot pass it with the same wind that conducted them to it, and must either wait for a favourable wind, or make fast to the bank, and haul close; there being sufficient depth of water for any vessel that can enter the river. The two forts and batteries at this place on both sides the river, are more than sufficient to stop the progress of any vessel whatever. Dr. Cox, of New-Jersey, ascended the Mississippi to this place, anno 1698, took possession and called the country Carolina. It lies 18 miles below New-Orleans, and 87 above the Balize. The banks of the river are settled and well cultivated from this to New-Orleans, and there is a good road for carriages all the way.—*Morse.*

D'ETROIT,

D'ETROIT, one of the principal towns, and beſt fortified, in the N. W. territory; ſituated on the weſtern bank of the ſtrait St Clair, or D'Etroit river between lake Erie and lake St Clair; 18 miles N. of the W. end of the former, and 9 miles below the latter. Fort D'Etroit is of an oblong figure, built with ſtockades, and advantageouſly ſituated, with one entire ſide commanding the river. It is near a mile in circumference, and encloſes about 300 wooden houſes and a Roman Catholic church; built in a regular manner, with parallel ſtreets, croſſing each other at right angles. Its ſituation is delightful, and in the centre of a pleaſant and fruitful country. For 8 miles below, and the ſame diſtance above Fort D'Etroit, on both ſides of the river, the country is divided into regular and well cultivated plantations; and from the contiguity of the farmers houſes to each other, they appear as two long extended villages. The inhabitants, who were moſtly French, were about 2000 in number in 1778, 500 of whom were as good markſmen as the Indians themſelves; and as well accuſtomed to the woods. They raiſe large ſtocks of black cattle, and great quantities of corn, which they grind by wind mills, and manufacture into excellent flour. The chief trade of D'Etroit conſiſts in a barter of coarſe European goods with the natives for furs, deer ſkins, tallow, &c.

By the treaty of Greenville, Aug. 3, 1795, the Indians have ceded to the United States the poſt of D'Etroit, and all the land to the N. the W. and the S. of it, of which the Indian title has been extinguiſhed by gifts or grants to the French or Engliſh governments, and ſo much more land is to be annexed to D'Etroit as ſhall be comprehended between Roſine river on the S.; lake St Clair on the N.; and a line the general courſe whereof ſhall be 6 miles from the W. end of lake Erie and D'Etroit river. The fort, &c. was delivered up by the Britiſh in July 1796, according to treaty. It lies 18 miles N. of lake Erie, 724 N. W. by W. from Philadelphia. N. lat. 42. 40. W. long. 82. 56.—*ib.*

D'Etroit *River*, or *Strait of St Clair*, flows from lake St Clair into the W. end of lake Erie, forming part of the boundary between the United States and Upper Canada. In aſcending it, its entrance is more than 3 miles wide, but it perceptibly diminiſhes; ſo that oppoſite the fort, 18 miles from lake Erie, it does not exceed half a mile in width; from thence to lake St Clair it widens to more than a mile. The channel of the ſtrait is gentle, and wide and deep enough for ſhipping of great burden, although it is incommoded by ſeveral iſlands, one of which is more than ſeven miles in length. Theſe iſlands are of a fertile ſoil, and from their ſituation afford a very agreeable appearance. The length of the river is 28 miles; and ſeveral ſtreams fall into it chiefly from the N. W. viz. Bauche, Clora, Curriere, D'Etroit, and Huron rivers.—*ib.*

DEVIL's *Mouth*, a name given by ſailors to a frightful volcano, near Leon Nicaraguay, in New-Spain, ſeated near the lake. N. lat. 13. 10. W. long. 65. 10.—*ib.*

Devil's *Noſe*, a promontory on the S. ſide of lake Ontario, 16 miles E. of Fiſhing bay, and 23 N. W. of the mouth of Geneſſee river.—*ib.*

Devil's *Iſland*, on the E. ſide of Cheſapeak bay, is in Somerſet co. Maryland, between Fiſhing bay and Nanokin river.—*ib.*

DEWAN, under the Mogul government, the receiver general and civic governor of a province: in private life a ſteward.

DEWANNY, the revenue department of a province.

DEWEE, an iſland in South-Carolina, which forms one of the three harbors of Charleſton city.—*Morſe.*

DIABETES Mellitus (ſee Medicine, n° 318, &c. *Encycl.*), is ſo formidable a diſeaſe, though not very frequent, that it would be unpardonable in us not to mention every method of treating it ſucceſsfully which has come to our knowledge. Since our article Medicine was publiſhed, Dr Rollo, ſurgeon general to the royal artillery, has ſuggeſted a method of treating this diſeaſe, which in various inſtances has been crowned with ſucceſs.

The Doctor ſuppoſes, that in this complaint the vegetable matter taken into the ſtomach has not, from ſome defect in this organ, undergone a ſufficient change to form proper chyle: that in conſequence of this, much ſaccharine matter is evolved, which, when carried into the circulation, proves a general ſtimulus, producing head-aches and quickneſs of pulſe, but that it acts more remarkably on the kidneys, occaſioning a conſtant and copious ſecretion of ſweet urine. From this hypotheſis he was naturally led to adopt a plan of cure, which has proved completely ſucceſsful. The indication he lays down are: 1. To prevent the formation of ſaccharine matter in the ſtomach; and, 2. To remove the morbidly increaſed action of this organ, and reſtore it to a healthful condition. Theſe indications are to be anſwered by a complete diet of animal food, and by the uſe of ſuch medicines as ſhall diminiſh the action of the ſtomach, and at the ſame time counteract the formation of ſaccharine matter. The remedies employed for this purpoſe have been emetics, kali ſulphuratum, lime-water, hepatized ammonia, and vegetable narcotics. But the principal dependence is to be placed on a total abſtinence from all vegetable matter, which alone can ſupply the ſaccharine principle. By a regular perſeverance in this plan, the firſt of two patients was completely cured in four weeks, although the diſeaſe had been of ſeven months continuance. The urine, which at the commencement of the treatment was ſweet, and amounted to 24 pints daily, was at laſt reduced to 1½ pint, being at the ſame time free from any ſaccharine impregnation. The ſecond patient, from his age and other circumſtances, although relieved from the diabetic affection, did not regain his wonted ſtate of health; but even in this caſe, the effects produced by the treatment, when properly attended to, were moſt decidedly in confirmation of this plan of cure.

The Doctor has received ſeveral communications in conſequence of the diſperſion of the printed notes on the firſt caſe. The moſt important are the reſult of two caſes treated in this way by Dr Cleghorn of Glaſgow, and one by Drs Currie and Gerard at Liverpool; all of which afford the ſtrongeſt corroboration of the efficacy of this mode of treatment.

DIAMOND, the moſt precious of all the gems; for the nature of which ſee Chemistry, n° 33, &c. in this *Supplement*.

DICK's *River* in Kentucky, is a branch of Kentucky river which it joins in a N. W. direction. It is about 50 miles long, and 45 yards wide at the mouth, and has

Diderot. has a number of excellent mill feats, and runs through a body of firft rate land.—*Morse.*

DIDEROT (Dionyfius) of the academy of Berlin, the fon of a cutler, was born at Langres in 1713. The Jefuits, with whom he went through a courfe of ftudy, were defirous of having him in their order; and one of his uncles, defigning him for a canonry which he had in his gift, prevailed upon him to take the tonfure.

His father feems to have known him better; for perceiving that he was not inclined to be a Jefuit, nor fit to be a canon, he fent him to Paris to profecute the ftudy of the law. To the law, however, he paid very little attention, but devoted his time to fcience and general literature; which fo offended his father, that he ftopped the remittance of his pecuniary allowance, and feemed for fome time to have abandoned him.

The talents of young Diderot fupplied him with a maintenance, and drew him from obfcurity. According to his friends, his capacious mind embraced phyfics, geometry, metaphyfics, ethics, and the belles lettres, from the time that he began to read with reflection; and it is certain that he afpired at being a mafter in all thefe departments of literature. His bold and elevated imagination feemed to give him likewife a turn for poetry; but he neglected it for the fciences. He fettled at an early period at Paris, where the natural eloquence which animated his converfation procured him friends and patrons. What firft drew the attention of the public to him as an author, and gave him a high reputation among a certain clafs of readers, was a fmall volume written againft the Chriftian religion, and intitled *Penfées Philofophiques*; which was reprinted afterwards under the title of *Etrennes aux Efprits-forts.*

This book appeared in 1746, 12mo. The adepts of the new philofophy compared it, for perfpicuity, elegance, and force of diction, to the *Penfées de Pafcal.* But the aim of the two authors was widely different; Pafcal employed his talents and his erudition, which was profound and various, to fupport and illuftrate the great truths of our holy religion, which Diderot attacked by all the difingenuous arts of an unprincipled fophift. The *Penfées Philofophiques*, however, became popular. It contributed to promote the object of that confpiracy which had been for fome time formed againft every thing which ennobles human nature (fee Jacobins in this *Supplement).* It was therefore applauded by Voltaire and D'Alembert, and read, of courfe, by every man and woman of tafte in Paris.

Our author was more ufually employed in 1746, when, together with Meffrs *Eidous* and *Touiffant*, he publifhed a general Dictionary of Medicine, in fix volumes folio. This work, it muft be confeffed, has confiderable merit; for though there are in it feveral articles fuperficial and erroneous, there are many others or fuch deep and accurate difquifition, as defervedly recommend it to men of fcience.

It was about this time that an intimacy was formed between Diderot and D'Alembert, and that, under the direction of Voltaire, they formed the idea of a *Dictionaire Encyclopedique.* The great objects which they had in view when they entered upon this work are now univerfally known. D'Alembert was a profound mathematician, Diderot had confiderable knowledge in the phyfical fciences, more efpecially mechanical philofophy, and Voltaire was a mafter of the belles lettres.

It is not to be fuppofed that fuch men would publifh any thing very defective in thefe departments of fcience; but an *Encyclopedie* muft treat of *religion;* and to every kind of religion they were all fworn enemies. They engaged, however, a very worthy, though not very acute, clergyman, to furnifh the theological articles; and for other branches of knowledge, they were promifed the affiftance of feveral men of letters, and of a variety of artifts. Diderot.

Diderot took upon himfelf the defcription of arts and trades; one of the moft important departments of the work, and the moft acceptable to the public. To the particulars of the feveral proceffes of the workmen he fometimes added reflections, fpeculations, and principles, adapted to their elucidation. But befides his own department, he furnifhed articles on almoft every other fubject.

By thofe who knew not the great aim of the undertakers of this work, it has been regretted that Diderot was not lefs verbofe, lefs of the differtator, and lefs inclined to digreffions. He has alfo been cenfured for employing needlefsly a fcientific language, and for having recourfe to metaphyfical doctrines, frequently unintelligible, which occafioned him to be called the *Lycophron of philofophy;* for having introduced a number of definitions incapable of enlightening the ignorant, and which the philofopher feems to have invented for no other purpofe than to have it thought that he had great conceptions; while, in fact, he had not the art of expreffing perfpicuoufly and fimply the ideas of others. But thefe complaints arife from miftaking entirely the purpofe for which he wrote.

It has been completely proved, that one great object for which the philofophers, as they called themfelves, undertook the compilation of the *Encyclopedie* was to fap the foundation of all religion. This was to be attempted, not directly and avowedly; for bare-faced atheifm would not then have been fuffered in France. A cloak, therefore, was to be worn, and the poifoned dagger to be concealed under it. Whilft the well meaning divine was fupporting, by the beft arguments which he could devife, the religion of his country, Diderot and D'Alembert were overturning thofe arguments under titles which properly allowed of no fuch difquifitions. This neceffarily produced digreffions; for the greateft genius on earth could not, when writing on the laws of motion, attack the myfteries of Chriftianity without wandering from his fubject: but that the object of thefe digreffions might not pafs unnoticed by *any* clafs of readers, care was taken to refer to them from the articles where the queftion was difcuffed by the divine. That when employed in this way, Diderot feems to write obfcurely, is indeed true; but the obfcurity is not his. His atheifm was fo plain, that for the moft part D'Alembert, or fome other leader of the gang, had to retouch his articles, and throw a mift over them, to render their intention the lefs obvious.

Even with all this care and ftudied obfcurity, the defign of the *Encyclopedie* was too palpable not to be feen, and too wicked not to give offence. Certain wild pofitions on government and on religion occafioned the impreffion to be fufpended in 1752. At that time there were no more than two volumes of the dictionary publifhed; and the prohibition of the fucceeding ones was only taken off at the end of 1753. Five new volumes

Diderot. lumes then ſucceſſively appeared. But in 1757 a new ſtorm aroſe, and the book was ſuppreſſed. The remainder did not appear till about ten years after; and was then for a while only privately diſtributed; ſome copies having been ſeized by government, and the printers ſhut up in the baſtile. The merit, however, of ſome of the articles is confeſſedly great; and the firſt edition was quickly ſold off.

Thus was this great work in the preſs from 1751 to 1767; during which period, Diderot and D'Alembert were accuſtomed to frequent the coffee-houſes of Paris, and to enter with keenneſs into religious diſputes: the former attacking Chriſtianity; and the latter, under the maſk of piety, defending it; but always yielding to the arguments of his opponent. This practice was put a ſtop to by the police; and Diderot, when reproached by the lieutenant with preaching atheiſm, replied, "Cela eſt vrai, je ſuis athée, & m'en fai gloire."

Finding his impious converſations interrupted, and the publication of the *Encyclopedie* rendered tedious by the vigilance of government, he thought of propagating his notions by other vehicles. Alternately ſerious and ſportive, ſolid and frivolous, he publiſhed, at the very time he was working on the Dictionary of Sciences, ſeveral productions, which could ſcarcely have been expected from a man ſo completely employed. His *Bijoux Indiſcrets*, 2 vols 12mo, are of this number—a diſguſting work, even to thoſe young people who are unhappily too eager for following after licentious romances. Even here a certain philoſophical pedantry appears in the very paſſages where it is moſt miſplaced, and never is the author more aukward than where he intends to diſplay a graceful eaſe.

The *Fils Naturel*, and the *Pere de Famille*, two comedies in proſe, which appeared in 1757 and 1758, are not of the ſame kind with the *Bijoux Indiſcrets*. They are moral and affecting dramas, where we ſee at once a nervous ſtyle and pathetic ſentiments. The former piece is a picture of the trials of virtue, a conflict between intereſts and paſſions, wherein love and friendſhip play important parts. It has been ſaid, that Diderot borrowed it from Goldoni: but if that be the caſe, the copy does honour to the original; and, with the exception of a ſmall number of ſcenes, where the author mixes his philoſophical jargon with the ſentiments of the heart, and ſome ſentences out of place, the ſtyle is affecting and natural enough. In the ſecond comedy, a tender, virtuous, and humane father appears, whoſe tranquillity is diſturbed by the parential ſolicitudes, inſpired by the lively and impetuous paſſions of his children. This philoſophical, moral, and almoſt tragical comedy, has produced conſiderable effects on ſeveral theatres of Europe. The dedication, to the princeſs of Naſſau Saarbuck, is a little moral tract of a ſingular turn, without deviating from nature. This piece, written with a true dignity of ſtyle, proves that the author poſſeſſed a great fund of moral ſentiments and philoſophical ideas. At the end of theſe two pieces, publiſhed together under the title of *Theatre de M. Diderot*, are dialogues, containing profound reflections and novel views of the dramatic art. In his plays he has endeavoured to unite the characters of Ariſtophanes and Plato; and in his reflections he ſometimes diſplays the genius of Ariſtotle.

This ſpirit of criticiſm is exhibited, but with too much licence, in two other works, which made a great noiſe. The former appeared in 1749, 12mo. intitled *Letters on the Blind for the Uſe of thoſe who See.* The free notions of the author in this work coſt him his liberty. He underwent a ſix months impriſonment at Viorcennes. Having naturally ſtrong paſſions and a haughty ſpirit, and finding himſelf on a ſudden deprived of liberty and of all intercourſe with human beings, he was threatened with the loſs of his reaſon. The danger was great; and to prevent it, they were obliged to allow him to leave his room, to take frequent walks, and to receive the viſits of a few literary men; among whom J. J. Rouſſeau, at that time his friend, went and adminiſtered conſolation to him, which he ought not to have forgotten. Diderot.

The letter on the Blind was followed by another *On the Deaf and Dumb, for the Uſe of thoſe who can Hear and Speak*; 1751, 2 vols, 12mo. Under this title the author delivered reflections on metaphyſics, on poetry, on eloquence, on muſic, &c. In this eſſay there are ſome good things, among others abſurd and imperfect. Though he ſtrives to be perſpicuous, yet he is not always underſtood; and this is more his fault than that of his readers. Of what he has compoſed on abſtract ſubjects, it has been ſaid that it is a chaos on which the light ſhines only at intervals. The other productions of Diderot betray the ſame defect of clearneſs and preciſion, and the ſame uncouth emphaſis, for which he has always been blamed.

The principal of them are, 1. Principles of Moral Philoſophy, 1745, 12mo; of which the Abbé de Fontaine ſpeaks well, though it met with no great ſucceſs. It was our philoſopher's fate to write a great deal, and not to leave a good book, or at leaſt a book well compoſed. 2. Hiſtory of Greece, tranſlated from the Engliſh of Stanyan, 3 vols, 12mo; an indifferent tranſlation of an indifferent book. 3. Pieces on ſeveral Mathematical Subjects, 1748, 8vo. 4. Reflections on the Interpretation of Nature, 1754, 12mo. This interpreter is very obſcure. 5. The Code of Nature, 1755, 12mo; which is certainly not the code of Chriſtianity. 6. The Sixth Senſe, 1752, 12mo. 7. Of public Education; one of that ſwarm of publications produced by the appearance of Emilius, and the abolition of the Jeſuits. Though all the ideas of this author could not be adopted, yet ſome of them are very judicious, and would be highly uſeful in the execution. 8. Panegyric on Richardſon. Full of nerve and animation. 9. Life of Seneca. This is the laſt work which he acknowledged; and it is one of thoſe by Diderot that is peruſed with moſt pleaſure, even in rectifying the judgments he paſſes on Seneca and other celebrated men. The Abbé Barruel ſays, that he was the author of *Syſteme de la Nature*, which is uſually given to Robinet; and it is certain, that if he was not the author, he furniſhed hints, and reviſed the whole. Yet the junto of atheiſts were themſelves aſhamed of the firſt edition of that work; and after all Diderot's care to improve it, the ſubſequent editions are, notwithſtanding his boaſted knowledge of the laws of nature, contemptible in the eyes of a real mechanical philoſopher.

When a new edition of the *Encyclopedie* was reſolved on, Diderot, the editor of the former edition, thus addreſſes the bookſellers who had undertaken to republiſh it. "The imperfections (ſays he) of this work originated

nated in a great variety of caufes. We had not time to be very fcrupulous in the choice of our coadjutors. Among fome excellent perfons, there were others weak, indifferent, and altogether bad. Hence that motley appearance of the work, where we fee the rude attempt of the fchool-boy by the fide of a piece from the hand of a mafter; a piece of nonfenfe next neighbour to a fublime performance; fome working for no pay, foon loft their firft fervour; others, badly recompenfed, ferved us accordingly. The *Encyclopedie* was a gulpb into which all kinds of fcribblers promifcuoufly threw their contributions; their pieces ill conceived, and worfe digefted, good, bad, contemptible, true, falfe, uncertain, and always incoherent and unequal; the reference, that belonged to the very parts affigned to a perfon, never filled up by him. A refutation is often found where we fhould naturally expect a proof. There was no exact correfpondence between the text and the plates. To remedy this defect, recourfe was had to long explications. But how many unintelligible machines, for want of letters to denote the plates!" To this confeffion Diderot added particular details on various parts; fuch as proved that there were in the *Encyclopedie* fubjects to be not only retouched, but to be compofed afrefh: and this was what a new company of literati and artifts fet themfelves to work upon in the *Encyclopedie Methodique*.

This immenfe work is not yet completed; and therefore we cannot fpeak of it as a whole; but it it is furely not lefs verbofe than the former edition, nor do the aims of its editors appear to be purer. That it contains much valuable information in chemiftry, and indeed in every department of phyfical fcience, no candid man will controvert: but its articles on abftract philofophy are prolix and obfcure; and it betrays the fame impiety, the fame eager defire to corrupt the principles of the rifing generation, and the fame contempt for every thing which can make mankind happy here or hereafter, with the former edition.

Notwithftanding his numerous publications, Diderot was never rich. Soon after the publication of the laft volumes of the *Encyclopedie*, upon which he had been employed for upwards of twenty years, his circumftances were fo ftraitened, that an expedient was to be devifed for their improvement. He had long correfponded with the late Emprefs of Ruffia, whom he perfuaded to confider him as the greateft, or *one* of the greateft economifts in France. In the courfe of the correfpondence he had mentioned his own library as one of the moft valuable in Europe; and when Catharine wanted to purchafe it and make him librarian, he faid that his conftitution could not fupport the cold climate of St Peterfburg. She offered to let him keep it during his lifetime in Paris; and the library was fold for an immenfe price. When her ambaffador wanted to fee it, after a year or two's payments, and the vifitation could be no longer put off, Diderot was obliged to run in a hurry through all the bookfellers fhops in Germany to fill his empty fhelves with old volumes. He had the good fortune to fave appearances; but the trick took air, becaufe he had been niggardly in his attention to the ambaffador's fecretary. This, however, did not hinder him from vifiting his imperial pupil, to whom he told a poor ftory, in hopes of getting his daughter married with parade, and patronized by her majefty; but it was feen through, and he was difappointed.

In the year 1784 Diderot's health began vifibly to decline, and one of his domeftics, perceiving that his death was at no great diftance, acquainted him with his apprehenfions, and addreffed him on the importance of preparing for another world. He heard the man with attention, thanked him kindly, acknowledged that his fituation required ferioufnefs, and promifed to weigh well what he had faid. Some time after this converfation he defired that a prieft might be brought; and the fame domeftic introduced to him M. de Farfac, Curé de St Sulpice. Diderot faw this ecclefiaftic feveral times, and was preparing to make a public recantation of his errors. Condorcet and the other adepts now crowded about him, perfuaded him that he was cheated, that his cafe was not fo dangerous as it was faid to be, and that he only wanted the country air to reftore him to health. For fome time he refifted their attempts to bring him back to atheifm, but was at laft prevailed upon to try the effect of the country air. His departure was kept fecret, and he was concealed in the country till the 2d of July, when he died. His dead body was fecretly brought back to Paris, and a report was fpread and believed, that he died fuddenly on rifing from the table, without remorfe, and with his atheifm unfhaken.

To draw a formal character of this wretch is furely fuperfluous. His friends extol his franknefs, his difintereftednefs, and his integrity; but except his grofs avowal of atheifm, which may in France be called franknefs, this character is belied by every tranfaction of his life. He married, and had a daughter, as has been already mentioned. M. Bauzé, referred to by Abbé Barruel, coming one day into Diderot's houfe, found him explaining to this daughter a chapter of the gofpel. When he expreffed fome furprife at this conduct, Diderot faid: "J'entends ce que vous voulez dire; mais au fond, quelles meilleures leçons pourrois-je lui donner, ou trouverai-je mieux?" It was a common affertion of Diderot's, that between him and his dog "il n'y avoit de difference que habit." In uttering this fentiment, he refembled not Pope's Indian with untutored mind,

"Who thinks, admitted to that equal fky,
"His faithful dog fhall bear him company."

The Indian hopes to carry his dog with him to heaven; but Diderot hoped to die like a dog, and to be as if he had never been.

DIFFERENTIAL METHOD, is the art of working with the differences of quantities. By this method any term of a feries may be found from the feveral orders of differences being given; or *vice verfa*, any difference may be found from having the terms of the feries given: it likewife fhews how to find the fum of fuch a feries. And it gives rules to find by interpolation any intermediate term, which is not expreffed in the feries, by having its place or pofition given.

When any feries of quantities is propofed, take the firft term from the fecond, the fecond from the third, the third from the fourth, &c. then all thefe remainders make a new feries, called the *firft order of differences*. In this new feries take the firft term from the fecond, the fecond from the third, the third from the fourth, &c. as before; and thefe remainders make another feries, called the *fecond order of differences*. In like manner, in this feries, take the firft term from the fecond, the second from the third, &c.; and these will make a series called the *third order of differences*; and after this manner you may proceed as far as you will. Thus in the following proposition A, b, c, d, e, &c. is the series; B, B^2, B^3, B^4, &c. the first order of differences; C, C^2, C^3, &c. the second order of differences; D, D^2, &c. the third order; E, &c. the fourth order, and so on. But the first terms of these several orders of differences, as B, C, D, E, &c. are those that are principally made use of in calculations by this method.

Prop. I. If there be any series, A, b, c, d, e, &c. and if there be taken the first differences B, B^2, B^3, &c. the second differences C, C^2, C^3, &c. the third differences D, D^2, D^3, &c. and so on.

Then if T stand for the first term of the nth differences, $\pm T = A - nb + n \times \frac{n-1}{2} c - n \times \frac{n-1}{2} \times \frac{n-2}{3} d + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} e -$ &c. that is, $+T$, when n is even, and $-T$ when n is odd.

The several orders of differences being taken as before directed, will stand thus. Then,

$$\begin{array}{ccccc} A & & & & \\ & B & & & \\ b & & C & & \\ & B^2 & & D & \\ c & & C^2 & & E \\ & B^3 & & D^2 & \\ d & & C^3 & & \\ & B^4 & & \&c. & \\ e & & & & \end{array}$$

series	A	b	c	d	e, &c.
1st diff.	$b-A$	$c-b$	$d-c$	$e-d$, &c.	
2d diff.	$c-2b+A$	$d-2c+b$	$e-2d+c$, &c.		
3d diff.	$d-3c+3b-A$	$e-3d+3c-b$, &c.			
4th diff.	$e-4d+6c-4b+A$, &c.				

That is, $B = b - A$, $C = c - 2b + A$, $D = d - 3c + 3b - A$, $E = e - 4d + 6c - 4b + A$, &c. or $-B = A - b$, $+C = A - 2b + c$, $-D = A - 3b + 3c - d$, $+E = A - 4b + 6c - 4d + e$, &c. where, putting T successively equal to B, C, D, E, &c. and $n = 1, 2, 3, 4$, &c. the prop. will be evident.

Cor. Hence

$A = A$, the first term.

$B = -A + b$, the first difference.

$C = A - 2b + c$, the 2d difference.

$D = -A + 3b - 3c + d$, the 3d difference.

$E = A - 4b + 6c - 4d + e$, the 4th difference.

$F = -A + 5b - 10c + 10d - 5e + f$, the 5th difference, &c.

Prop. II. If A, b, c, d, e, &c. be any series, and there be taken B, C, D, E, &c. the first of the several orders of differences;

Then, the nth term of the series will be $= A + \frac{n-1}{1} B + \frac{n-1}{1} \times \frac{n-2}{2} C + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} D + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} E +$, &c.

For from the equations in the last Prop. viz. $B = b - A$, $C = c - 2b + A$, &c. we have, by transposing, $b = A + B$, $= -A + 2b + C = -A + 2A + 2B + C$ (expunging b); that is,

$c = A + 2B + C$, $d = A - 3b + 3c + D = A - 3A - 3B + 3A + 6B + 3C + D$ (expunging b and c); that is, $d = A + 3B + 3C + D$. Also $e = -A + 4b - 6c - 4d + E =$ (expunging b, c, d,) $- A + 4A + 4B - 6A - 12B - 6C + 4A + 12B + 12C + 4D + E$; that is $e = A + 4B + 6C + 4D + E$, &c.

Then putting A, b, c, d, &c. for the nth term, and n successively $= 1, 2, 3, 4$, &c. the series will be evident.

Cor. 1. If d', d'', d''', &c. be the first of the first, second, third order, &c. of differences; then

The nth term of the series A, b, c, d, &c. will be $= A + \frac{n-1}{1} d' + \frac{n-1}{1} \times \frac{n-2}{2} d'' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} d''' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} d'''' +$ &c.

For $B = d'$, $C = d''$, $D = d'''$, &c. And the coefficients are the unciæ of the $\overline{n-1}$th power.

Cor. 2. Hence also it follows, that any term of a given series may be accurately determined, if the differences of any order happen at last to be equal.

Cor. 3 Hence

$A = A$, the first term.

$b = A + B$, the 2d term.

$c = A + 2B + C$, the 3d term.

$d = A + 3B + 3C + D$, the 4th term.

$e = A + 4B + 6C + 4D + E$, the 5th term.

$f = A + 5B + 10C + 10D + 5E + F$, the 6th term.

$g = A + 6B + 15C + 20D + 15E + 6F + G$, the 7th term, &c.

Prop. III. If a, b, c, d, e, &c. be any series, and d' d'', d''', &c. the first of the several orders of differences; then

The sum of n terms of the series is $= na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} d''' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} \times \frac{n-4}{5} d'''' +$, &c.

For in the series of quantities,

	o	a	$a+b$	$a+b+c$	$a+b+c+d$	&c.
1st diff. are		a	b	c	d	&c.
2d diff.			d'	$d'2$	$d'3$	&c.
3d diff.				d''	$d''2$	&c.
4th diff.					d'''	&c.

Therefore (by Cor. 1. Prop. II.) the $\overline{n+1}$th term of the series o, a, $a+b$, $a+b+c$, $a+b+c+d$, &c. or the nth term of the series, a, $a+b$, a, $+b+c$, $a+b+c+d$, &c. is $= o + na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' +$ &c. But the nth term of the series a, $a+b$, $a+b+c$, &c. is the sum of n terms of the series, a, b, c, d, &c. and therefore equal to $na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' +$ &c.

For a fuller account of this method and its application to curves, we refer the reader to Emerson's works, from which these three propositions are taken.

DIFFRACTION, a term first used by Grimaldi, to denote that property of the rays of light, which others have called inflection; the discovery of which is attributed by some to Grimaldi, and by others to Dr Hook.

DIGBY, situated on the S. E. side of Annapolis bay, 18 miles S. W. of Annapolis, and 53 N. by E. of of Yarmouth, is one of the moft confiderable of the new fettlements in Nova-Scotia.—*Morse.*

DIGGES (Leonard), an eminent mathematician of the 16th century, was defcended from an ancient family, and born at Digges-court, in the parifh of Barham in Kent; but we know not in what year. He was fent to Univerfity-college in Oxford, where he laid a good foundation of learning and fcience, and retiring thence without a degree, profecuted his ftudies, and compofed the following works: 1. "Tectonicum: briefly fhewing the exact Meafuring, and fpeedy Reckoning of all manner of Lands, Squares, Timber, Stones, Steeples, &c. 1556," 4to. Augmented and publifhed again by his fon Thomas Digges, 1592, 4to, and reprinted in 1647, 4to. 2. "A geometrical practical Treatife, named *Pantometria*, in three books." This he left in manufcript; but after his death his fon fupplied fuch parts of it as were obfcure and imperfect, and publifhed it in 1591, folio; fubjoining, "A Difcourfe geometrical of the five regular and platonical bodies, containing fundry theoretical and practical propofitions, arifing by mutual conference of thefe folids, infcription, circumfpection, and transformation." 3. "Prognoftication everlafting of right good Effect: or, Choice Rules to judge the Weather by the Sun, Moon, and Stars, &c." 1555, 1556, and 1564, 4to, corrected and augmented by his fon, with divers general tables, and many compendious rules, 1592, 4to. He died about 1574.

Digges (Thomas), only fon of Leonard Digges, after a liberal fchool education, went and ftudied for fome time at Oxford; and by the improvements which he made there, and the inftructions of his learned father, became one of the greateft mathematicians of his age. When Queen Elizabeth fent fome forces to affift the oppreffed inhabitants of the Netherlands, Digges was appointed mufter mafter-general of them; by which he had an opportunity of becoming fkilled in the art of war. Befides revifing, correcting, and enlarging fome pieces of his father's already mentioned, he wrote and publifhed the following learned works himfelf, namely, 1. "*Alæ five fcalæ Mathematicæ*; or, Mathematical Wings or Ladders, 1573," 4to. This book contains feveral demonftrations for finding the parallaxes of any comet or other celeftial body, with a correction of the errors in the ufe of the *radius aftronomicus*. 2. "An arithmetical military Treatife, containing fo much of Arithmetic as is neceffary towards military Difcipline, 1579," 4to. 3. "A geometrical Treatife, named *Stratioticos*, requifite for the perfection of foldiers, 1579," 4to. This was begun by his father, but finifhed by himfelf. They were both reprinted together in 1590, with feveral amendments and additions under this title, "An arithmetical warlike Treatife, named *Stratioticos*, compendioufly teaching the fcience of numbers, as well in fractions as integers, and fo much of the rules and equations algebraical, and art of numbers coeffical, as are requifite for the profeffion of a fouldier. Together with the moderne militarie difcipline, offices, lawes, and orders in every well-governed campe and armie, inviolably to be obferved." At the end of this work there are two pieces; the firft intitled, "A briefe and true report of the proceedings of the Earle of Leycefter, for the reliefe of the towne of Sluce, from his arrival at Vlifhing, about the end of June 1587, untill the furrendrie thereof 26 Julii next enfuing. Whereby it fhall plainelie appear, his Excellencie was not in anie fault for the loffe of that towne"—The fecond, "A briefe difcourfe what orders were beft for repulfing of foraine forces, if at any time they fhould invade us by fea in Kent, or elfewhere." 4. "A perfect defcription of the celeftial orbs, according to the moft ancient doctrine of the Pythagoreans, &c." This was placed at the end of his father's "Prognoftication everlafting, &c." printed in 1592, 4to. 5. "A humble motive for affociation to maintain the religion eftablifhed, 1601," 8vo. To which is added, his "Letter to the fame purpofe to the Archbifhops and Bifhops of England." 6. "England's Defence: or, a Treatife concerning Invafion." This is a tract of the fame nature with that printed at the end of his *Stratioticos*, and called, "A briefe Difcourfe, &c." It was written in 1599, but not publifhed till 1686. 7. "A Letter printed before Dr John Dee's *Parallaticæ Commentationis praxeofque nucleus quidam*, 1573," 4to. Befides thefe and his *Nova Corpora*, he had by him feveral mathematical treatifes ready for the prefs; which, by reafon of law-fuits and other avocations he was hindered from publifhing. He died in 1595, but we know not at what age.

DIGHTON, a poft town in Briftol co. Maffachufetts, 7 miles from Taunton, and 20 from Warren, in Rhode-Ifland. There are 236 houfes in the townfhip, and 1793 inhabitants.—*Morse.*

DIMINUTION, in mufic, is the abating fomething of the full value or quantity of any note.

DINWIDDIE, a co. in Virginia, S. of Appamattox river, which divides it from Chefterfield. It is about 30 miles long, and 20 broad, and its chief town is Peterfburg.—*Morse.*

DIOPHANTUS, a celebrated mathematician of Alexandria, has been reputed to be the inventor of algebra; at leaft his is the earlieft work extant on that fcience. It is not certain when Diophantus lived. Some have placed him before Chrift, and fome after, in the reigns of Nero and the Antonines; but all with equal uncertainty. It feems he is the fame Diophantus who wrote the Canon Aftronomicus, which Suidas fays was commented on by the celebrated Hypatia, daughter of Theon of Alexandria. His reputation muft have been very high among the ancients, fince they ranked him with Pythagoras and Euclid in mathematical learning. Bachet in his notes upon the 5th book De Arithmeticis, has collected, from Diophantus's epitaph in the Anthologia, the following circumftances of his life, namely, that he was married when he was 33 years old, and had a fon born five years after; that this fon died when he was 42 years of age, and that his father did not furvive him above four years; from which it appears that Diophantus was 84 years old when he died.

DIOPTER or Dioptra, the fame with the index or alhidade of an aftrolabe or other fuch inftrument.

Dioptra was an inftrument invented by Hipparchus, which ferved for feveral ufes; as, to level water-courfes; to take the height of towers, or places at a diftance; to determine the places, magnitudes, and diftances of the planets, &c.

DIRECT, in arithmetic, is when the proportion of any terms, or quantities, is in the natural or direct order in which they ftand; being the oppofite to inverfe which

which considers the proportion in the inverted order of the terms. So, 3 : 4 : : 6 : 8 directly ; or 3 : 4 : : 8 : 6 inversely.

DIRECTION, in Astronomy, the motion and other phenomena of a planet when direct.

DIRECTION, in astrology, is a kind of calculus, by which they pretend to find the time in which any notable accident shall befal the person whose horoscope is drawn.

DISCRETE QUANTITY, is such as is not continued and joined together. Such, for instance, is any number.

DISMAL, a swamp in the township of Milton, Lincoln co. district of Maine.—*Morse.*

DISMAL *Swamp*, called the *Great Dismal*, to distinguish it from another swamp called Dismal, in Curri-tuck co. is a very large bog extending from N. to S. near 30 miles, and from E. to W. at a medium about 10 miles: partly in Virginia, and partly in North-Carolina. No less than 5 navigable rivers, besides creeks, rise out of it; whereof two run into Virginia, viz. the S. branch of Elizabeth, and the S. branch of Nansemond river, and 3 into North-Carolina, namely, North river, North-West river and Perquimons. All these hide their heads, properly speaking, in the Dismal, there being no signs of them above ground. For this reason there must be plentiful subterraneous stores of water to feed so many rivers, or else the soil is so replete with this element, drained from the high-lands that surround it, that it can abundantly afford these supplies. This is most probable, as the ground of the swamp is a mere quagmire, trembling under the feet of those that walk upon it, and every impression is instantly filled with water. The skirts of the swamp, towards the E. are overgrown with reeds, 10 or 12 feet high, interspersed every where with strong bamboo briers. Among these grow here and there a cypress or white cedar, which last is commonly mistaken for the juniper. Towards the S. end of it is a large tract of reeds, which being constantly green, and waving in the wind, is called the green sea. In many parts, especially on the borders, grows an ever green shrub, very plentifully, called the gall bush. It bears a berry which dies a black color like the gall of an oak, whence it has its name. Near the middle of the Dismal the trees grow much thicker, both cypress and cedar. These being always green, and loaded with very large tops, are much exposed to the wind and easily blown down, the boggy ground affording but a slender hold to the roots. Neither beast, bird, insect or reptile, approach the heart of this horrible desert; perhaps deterred by the everlasting shade, occasioned by the thick shrubs and bushes, which the sun can never penetrate, to warm the earth: nor indeed do any birds care to fly over it, any more than they are said to do over the lake Avernus, for fear of the noisome exhalations that rise from this vast body of filth and nastiness. These noxious vapours infect the air round about, giving agues and other distempers to the neighboring inhabitants. On the western border of the Dismal is a pine swamp, above a mile in breadth, great part of which is covered with water knee deep; the bottom, however, is firm, and the pines grow very tall, and are not easily blown down by the wind. With all these disadvantages, the Dismal is, in many places, pleasing to the eye, though disagreeable to the other senses.

This dreadful swamp was judged impassable, till the line, dividing Virginia from N. Carolina, was carried through it, in N. lat. 36. 28. in the year 1728, by order of king George II. Although it happened then to be a very dry season, the men who were employed in pushing the line were not altogether free from apprehensions of being starved; it being 10 whole days before the work was accomplished, though they proceeded with all possible diligence and resolution, and besides had no disaster to retard them.

This swamp is chiefly owned by two companies. The Virginia company, of which General Washington is one, owns 100,000 acres: the North-Carolina company owns 40,000 acres. In the midst of the swamp is a lake, about 7 miles long, called Drummond's pond, whose waters discharge themselves to the S. into Pasquotank river, which empties into Albemarle sound; on the N. into Elizabeth and Nansemond rivers, which fall into James river. A navigable canal is now digging to connect the navigable waters of the Pasquotank and Elizabeth rivers. The distance about 14 miles. This canal will pass about a mile E. of Drummond's pond, and will receive water from it. The Canal company are incorporated by the concurring laws of Virginia and North-Carolina. This canal, when finished, will open an inland navigation from the head of Chesapeak bay, including all the rivers in Virginia, to Georgetown in South-Carolina; and when the short canal from Elk river to Christiana creek is opened, the communication will extend to Philadelphia and the other ports connected with Delaware river. Such an extensive inland communication must be beneficial in time of peace, and in time of war will be essentially serviceable.—*ib.*

DITTON (Humphry) an eminent mathematician, was born at Salisbury, May 29, 1675. Being an only son, and his father observing in him an extraordinary good capacity, determined to cultivate it with a good education. For this purpose he placed him in a reputable private academy, upon quitting of which he, at the desire of his father, though against his own inclination, engaged in the profession of divinity, and began to exercise his function at Tunbridge in the county of Kent, where he continued to preach some years; during which time he married a lady of that place.

But a weak constitution, and the death of his father, induced Mr Ditton to quit that profession. And at the persuasion of Dr Harris and Mr Whiston, both eminent mathematicians, he engaged in the study of mathematics; a science to which he had always a strong inclination. In the prosecution of this science, he was much encouraged by the success and applause he received: being greatly esteemed by the chief professors of it, and particularly by Sir Isaac Newton, by whose interest and recommendation he was elected master of the new mathematical school in Christ's Hospital; where he continued till his death, which happened in 1715, in the 40th year of his age, much regretted by the philosophical world, who expected many useful and ingenious discoveries from his assiduity, learning, and penetrating genius.

Mr Ditton publifhed feveral mathematical and other tracts, as below.—1. Of the Tangents of Curves, &c. Philof. Tranf. vol. 23.

2. A Treatife on Spherical Catoptrics, publifhed in the Philof. Tranf. for 1705; from whence it was copied and reprinted in the Acta Eruditorum 1707, and alfo in the Memoirs of the Academy of Sciences at Paris.

3. General Laws of Nature and Motion; 8vo, 1705. Wolfius mentions this work, and fays that it illuftrates and renders eafy, the writings of Galileo, Huygens, and the Principia of Newton. It is alfo noticed by La Roche in the Memoirs de Literature, vol. 8. page 46.

4. An Inftitution of Fluxions, containing the firft Principles, Operations and Applications, of that admirable Method, as invented by Sir Ifaac Newton, 8vo, 1706. This work, with additions and alterations, was again publifhed by Mr John Clarke, in the year 1726.

5. In 1709 he publifhed the Synopsis Algebraica of John Alexander, with many additions and corrections.

6. His Treatife on Perfpective was publifhed in 1712. In this work he explained the principles of that art mathematically; and befides teaching the methods then generally practifed, gave the firft hints of the new method, afterwards enlarged upon and improved by Dr Brook Taylor; and which was publifhed in the year 1715.

7. In 1714, Mr Ditton publifhed feveral pieces both theological and mathematical; particularly his Difcourfe on the Refurrection of Jefus Chrift; and The New Law of Fluids, or a Difcourfe concerning the Afcent of Liquids, in exact Geometrical Figures, between two nearly contiguous Surfaces. To this was annexed a tract, to demonftrate the impoffibility of thinking or perception being the refult of any combination of the parts of matter and motion: a fubject much agitated about that time. To this work alfo was added an advertifement from him and Mr Whifton concerning a method for difcovering the longitude, which it feems they had publifhed about half a year before. This attempt probably coft our author his life; for although it was approved and countenanced by Sir Ifaac Newton, before it wat prefented to the Board of Longitude, and the method has been fuccefsfully put in practice in finding the longitude between Paris and Vienna; yet that board then determined againft it: fo that the difappointment, together with fome public ridicule (particularly in a poem written by Dean Swift), affected his health fo that he died the enfuing year, 1715.

In an account of Mr Ditton, prefixed to the German tranflation of his Difcourfe on the Refurrection, it is faid that he had publifhed, in his own name only, another method for finding the longitude; but which Mr Whifton denied. However, Raphael Levi, a learned Jew, who had ftudied under Leibnitz, informed the German editor, that he well knew that Ditton and Leibnitz had correfponded upon the fubject; and that Ditton had fent to Leibnitz a delineation of a machine he had invented for that purpofe; which was a piece of mechanifm conftructed with many wheels like a clock, and which Leibnitz highly approved of for land ufe; but doubted whether it would anfwer on fhip-board, on account of the motion of the fhip.

DIVING Bell has been already defcribed in the *Encyclopædia*; but in that work was given no account of its antiquity or its invention. In the works of Ariftotle we read of a kind of kettle ufed by divers to enable them to remain for fome time under water; but the manner in which thofe kettles were employed is not clearly defcribed. "The oldeft information (fays Profeffor Beckmann) which we have of the ufe of the diving bell in Europe, is that of John Taifnier, who was born at Hainault in 1509, had a place at court under Charles V. whom he attended on his voyage to Africa. He relates in what manner he faw at Toledo, in the prefence of the emperor and feveral thoufand fpectators, two Greeks let themfelves down under water, in a large inverted kettle with a burning light, and rife up again without being wet. It appears that this art was then new to the emperor and the Spaniards, and that the Greeks were caufed to make the experiment in order to prove the poffibility of it."

When the Englifh, in 1588, difperfed the Spanifh fleet, called the Invincible Armada, part of the fhips went to the bottom near the ifle of Mull, on the weftern coaft of Scotland; and fome of thefe, according to the account of the Spanifh prifoners, contained great riches. This information excited, from time to time, the avarice of fpeculators, and gave rife to feveral attempts to procure part of the loft treafure. In the year 1665, a perfon was fo fortunate as to bring up fome cannon, which, however, were not fufficient to defray the expences. Of thefe attempts, and the kind of diving bell ufed in them, the reader will find an account in a work printed at Rotterdam, in 1669, and entitled *G. Sinclari Ars nova et magna gravitatis et levitatis*. In the year 1680, William Phipps, a native of America, formed a project for fearching and unloading a rich Spanifh fhip funk on the coaft of Hifpaniola; and reprefented his plan in fuch a plaufible manner, that King Charles II. gave him a fhip, and furnifhed him with every thing neceffary for the undertaking. He fet fail in the year 1683, but being unfuccefsful, returned again in great poverty, though with a firm conviction of the poffibility of his fcheme. By a fubfcription promoted chiefly by the Duke of Albemarle, the fon of the celebrated Monk, Phipps was enabled, in 1687 to try his fortune once more, having previoufly engaged to divide the profit according to the twenty fhares of which the fubfcription confifted. At firft all his labour proved fruitlefs; but at laft, when his patience was almoft entirely exhaufted, he was fo lucky as to bring up from the depth of fix or feven fathoms, fo much treafure, that he returned to England with the value of two hundred thoufand pounds fterling. Of this fum he himfelf got about fixteen, others fay twenty thoufand, and the duke ninety thoufand pounds. After he came back fome perfons endeavoured to perfuade the king to feize both the fhip and the cargo, under a pretence, that Phipps, when he folicited for his majefty's permiffion, had not given accurate information refpecting the bufinefs. But the king anfwered, with much greatnefs of mind, that he knew Phipps to be an honeft man, and that he and his friends fhould fhare the whole among them had he returned with double the value. His majefty even conferred upon him the honour of knighthood, to fhew how much he was fatisfied with his conduct. We know not the conftruction of Phipps's apparatus; but of the old figures of a diving machine,

machine, that which approaches neareſt to the diving-bell is in a book on fortification by Lorini; who deſcribes a ſquare box bound round with iron, which is furniſhed with windows, and has a ſtool affixed to it for the diver. This ingenious contrivance appears, however, to be older than that Italian; at leaſt he does not pretend to be the inventor of it.

In the year 1617, Francis Keſsler gave a deſcription of his water-armour intended alſo for diving, but which cannot really be uſed for that purpoſe. In the year 1671, Witſen taught, in a better manner than any of his predeceſſors, the conſtruction and uſe of the diving-bell; but he is much miſtaken when he ſays that it was invented at Amſterdam. In 1679 appeared, for the firſt time, Borelli's well known work *de motu animalium*, in which he not only deſcribed the diving-bell, but alſo propoſed another, the impracticability of which was ſhewn by James Bernoulli. When Sturm publiſhed his *Collegium curioſum* in 1678, he propoſed ſome hints for the improvement of this machine, on which remarks were made in the *Journal des ſçavans*. To him ſucceeded Dr Halley, whoſe bell is well known.

DIXON's *Sound*, on the N. W. coaſt of N. America, is the paſſage into the ſound between the main land and Waſhington's or Queen Charlotte's iſlands, from the N. W. This ſeems to be what is called in America *Barrell's Sound*.—*Morse.*

DOBB's *Ferry*, on Hudſon river, is 26 miles above New-York city —*ib.*

Dobb's *Co.* in Newbern diſtrict, N. Carolina, has been divided into two counties, viz. Glaſgow and Lenoir, ſince the cenſus of 1790, and the name no longer exiſts. It contained 6893 inhabitants, of whom 1915 were ſlaves.—*ib.*

DODECATEMORY, the 12 houſes or parts of the zodiac of the primum mobile. Alſo the 12 ſigns of the zodiac are ſometimes ſo called, becauſe they contain each the 12th part of the zodiac.

DOG-RIBBED *Indians*, inhabit round lake Edlande, in the N. W. part of N. America They are often at war with the Arathapeſcow Indians Both theſe tribes are among the moſt ſavage of the human race. They trade with the Hudſon bay company's ſettlements. Edlande lake lies N. of the Arathapeſcow ſea, or lake, and near the arctic circle.—*Morse.*

DOME, See Arch in this Supplement.

DOMINGO, or St Domingo. See Hispaniola, both in *Encycl.* and in this Supplement.

Domingo, St, an iſland in the Atlantic ocean, at the entrance of the gulf of Mexico, is one of the four great Antilles, the largeſt of them all, except the iſland of Cuba, and proved the cradle of European power in the new world. Chriſtopher Columbus landed on it the 6th of Dec. 1492. The natives called it *Hayti*, ſignifying high or mountainous land. Charlevoix ſays it was called *Quiſqueya*, that is, great country, or mother of countries. Others ſay it had the name of *Bohio*, which means, a country full of habitations and villages. Columbus called it *Hiſpaniola*, or Little Spain, which name the Spaniards ſtill retain, though St Domingo is the name commonly uſed by other nations; ſo called from *St Domingo*, the capital of the Spaniſh part; which was thus named by Columbus in honor of his father. St Domingo is ſituated between 17. 55. and 20. N. latitude, and between 71. and 77. W. longitude from Paris. It lies 45 leagues E. N. E. of Jamaica, 22 S. E. of Cuba, and 20 N. W. by W. of Porto Rico; and is, not including the ſmall dependent iſlands that ſurround it, 160 leagues long from E. to W. and from 60 to 70 broad from N. to S. When the Spaniards diſcovered the iſland, there were on it at leaſt a million of happy inhabitants, and Bartholomew de las Caſas ſays there were three millions. Such, however, were the cruelties of the Spaniards, and to ſuch an infamous height did they carry their oppreſſion of the poor natives, that they were reduced to 60,000 in the ſhort ſpace of 15 years! It formed five kingdoms, each governed by ſovereigns called caciques. The names of theſe kingdoms were *Maqua*, *Marien*, *Higuay*, *Maguana*, and *Xaraguay*. The Spaniards had poſſeſſion of the whole of the iſland for 120 years. At laſt, about the year 1630, a handful of Engliſh, French, and other Europeans, came and forced them to fight in its defence, and after repeated wars for 50 years, they were forced to divide the iſland with the French. Theſe latter, being the only ſurvivors of the firſt free-booters or buccaniers, or having inſenſibly acquired an aſcendancy among them, had, ſo early as 1640, formed this aſſembly of individuals, born under the domination of almoſt all the powers of Europe, into a French colony, under the direction of the general government, firſt eſtabliſhed at St Chriſtophers, and afterwards at Martinico. The Spaniſh part is by far the moſt extenſive and the moſt fertile; that of the French the beſt cultivated. The whole iſland now belongs to the French republic, the Spaniards having ceded their part of it to that power in the treaty of 1795.

The Spaniards, however ungrateful to the diſcoverer of the new world during his life, would not leave his duſt out of their territories. The remains of Columbus, who died the 20th of May, 1506, were firſt depoſited in Seville, afterwards removed to the cathedral in the city of St Domingo, and laſtly conveyed to the Havannah in a 74 gun ſhip; and on the 19th of January, 1796, all that was mortal of that great man, was committed to the earth the third time, with great parade and ceremony.

The following particulars relating to this famous iſland are founded on the beſt authority, and many circumſtances require a ſeparate view of the two artificial diviſions of the iſland, viz. the French and Spaniſh territories, before they were united under one head. They are both alike in poſſeſſing the various productions common to the W. Indies. The European cattle are ſo multiplied here that they run wild in the woods; few of theſe are in the French part in compariſon with the Spaniſh.

The two great chains of mountains, which extend from E. to W. and their numerous ſpurs, give the iſland an aſpect, at a diſtance, not ſo favourable as it deſerves. They are, however, the cauſe of the fertility of the iſland. They give ſource to innumerable rivers, repel the violence of the winds, vary the temperature of the air, and multiply the reſources of human induſtry. They abound with excellent timber, and mines of iron, lead, copper, ſilver, gold, ſome precious ſtones, and even mercury.—With reſpect to the vegetable claſs in this iſland, it would be difficult, even in a work devoted to the ſubject, to expreſs or paint all their

their majefty. Here are the mountains of *Cibao*, *Selle*, and *Hotte*, reckoned 1000 fathoms above the level of the fea. In the bowels of the firft, the cruel Spaniards condemned thoufands of the natives, to facrifice their lives, in fearch of gold. The mines are not now worked, although Valverde thinks they might be to advantage. In the plains, in the Spanifh part, the heat is nearly uniform, but varies in proportion to their diftance from the mountains. In the plains, the thermometer is fometimes at 99. In the mountains it rarely raifes above 72. or 77. There the nights are cool enough to render a blanket not unwelcome; and there are mountains where even a fire is a very agreeable companion in fome evenings. The contraft of violent heats and heavy rains renders St Domingo humid; hence the tarnifhed appearance of almoft all metals, however brilliant the polifh they may originally have had. This is particularly obfervable on the fea fhore, which is more unhealthy than the interior parts of the ifland. The fouthern part of the ifland is pretty much fubject to hurricanes, called here fouthern gales, becaufe they are not attended with fuch dreadful confequences as the hurricanes in the windward iflands.

The Spanifh part is computed to contain about 90 leagues in its greateft length from E. to W. 60 leagues in its greateft breadth; having a furface of about 3,200 fquare leagues. About 400 fquare leagues of this furface is in mountains, which are generally more capable of cultivation than thofe in the French part, and have fometimes a foil that difputes the preference with that of the valleys. There remains therefore a fine fertile furface of more than 2,700 fquare leagues, divided into valleys and plains of various lengths and breadths.

Many circumftances confpired to render this ifland a place of importance to the Spaniards. It was a key to the gulf of Mexico, a convenient place for their fhipping to touch at, an excellent rendezvous for their fquadrons and fleets, and an important hold for naval operations of all forts; but from the impolitic meafures of the government, and the reftraints on commerce, it proved rather a burden than an advantage to the mother country.

The cantons or jurifdictions, beginning at the wefternmoft point of the Spanifh frontiers, on the fouthern coaft or narrows, are, *Baharuco*, (poffeffed by the brigands or fugitive Spanifh and French negroes, who inhabit the mountain of Bahoruco), *Neybe*, *Azua*, *Bani* or Vani, the city of *St Domingo*, and territory dependent thereon, *St Laurent des Mines*, *Samana*, *Cotuy*, *La Vega*, *St Yago*, *Daxabon*, *St Raphael*, *Hinche*, *Banique*, and *St John of Maguana*. Over the whole of the Spanifh part of the ifland, mountains and plains, are fpread 125,000 inhabitants; of whom 110,000 are free, and 15,000 flaves; which does not amount to 40 individuals to one fquare league. The Spanifh creoles are infenfible of all the treafures which furround them, and pafs their lives without wifhing to change their lot; while the French portion furnifhes three fifths of the produce of all the French Weft-India colonies put together; or more than 10 millions fterling. The drefs and mode of living of the Spanifh creoles indicate pride, lazinefs, and poverty. A capital, which of itfelf indicates decay, little infignificant towns here and there, a few colonial fettlements, for which the name of manufactories would be too great an honor, immenfe poffeffions called *Hattes*, where beafts and cattle are raifed with little care, in different grades of domeftication; as the domeftic, the gentle, and the fhy. Thofe called wild or mountaineers, as alfo the fhy, coft the herdfmen, called pioneers and lancers, immenfe labor and danger in the chafe. The hattes are the moft numerous fort of Spanifh fettlements, and of an extent far difproportioned to their utility. Some are feveral fquare leagues, and do not contain above 500 head of cattle, great and fmall. Some are called horfe-hattes, others cattle-hattes, according to the name of the animals they contain; others ufed in breeding pigs are called corails. A fmall piece of woodland, called venerie, frequently ferves as a boundary between the hattes, common to thofe on both fides of it, and alfo fhelters the cattle from the heat of the fun. The woodland likewife attracts the wild animals, and leffens the labors of the huntfman. In thefe hattes, the people lodge miferably, and have but poor fubfiftence. The fmall provifion farms called *Conacos*, fall generally to the lot of the poorer colonifts, or moft commonly people of color, or freed people.

The fupply of horned cattle to the French part of the ifland cannot be eftimated at lefs than 15,000 head annually; of which the Spaniards furnifh four fifths. Thefe at 30 dollars a head, and bringing them by the Spaniards, cannot be lefs than 450,000 dollars. This forms three quarters of the produce of the colony; and the impoft paid to government is 10 per cent. The number of 200,000 head of cattle is the number in the general cenfus taken by order of the prefident in 1780, and if we count the cattle exempted from the tribute, they may amount to 250,000; without comprehending horfes, mules and affes, which, with an augmentation eftimated fince 1780, would make a ftock of 300,000 head, and an annual production of 60,000; and fuppofe a fifth part of the young ones perifh accidentally, there ftill remains 48,000. The refources of the colonifts are very confined, and their few eftablifhments are all below mediocrity. There are but 22 fugar manufactories of any confequence; the reft being not worth naming; and even thefe 22 have altogether but about 600 negroes. Of thefe 6 produce firup, and fome fugar; but the others, which are called trapachies, where animals are employed to turn the mills and prefs the canes, without fhelter, in the open air, make nothing but firup. The whole of which produce is generally ufed in the colony; fmall quantities are fometimes fent to Porto Rico, or to Old Spain; and the goodnefs of the fugar has proved that of the foil, but nothing in favor of the manufacturer. The coffee raifed here is excellent; each tree in a ftate of bearing will produce on an average a pound weight, and is fometimes of a quality equal to that of Mocha, yet chocolate is preferred to it. Cotton grows naturally at St Domingo, of an excellent quality, even without care, in ftony land, and in the crevices of the rocks. The numerous roots of indigo are only obftacles to the feeble cultivation of the fields, where it grows fpontaneoufly. All thefe valuable productions have fhared the fate of depopulation. Tobacco, fays Valverde, has here a larger leaf than in any other part of America; it grows every where, and equals fometimes that of Cuba or the Havannah.

nah. It is as much esteemed as this latter, in the manufactures of Sevelle, and is even preferable to it in segars. Its cultivation has lately become more general. The kernel of the cocoa nut of St Domingo is more acidulated than that of the cocoa nut of Venezuela and Caraca, to which it is not inferior; and experience proves, that the chocolate made of the two cocoas has a more delicate flavor than that made of the cocoa of Caraca alone. Achiote, ginger, and cassia have shared the fate of the other productions.

The population of the Spanish part is composed of whites, freed people, and slaves. There are also a few creoles resembling the Indians, having long, straight and black hair, who pretend to be descendants of the ancient natives. They are, however, thought to be descended from a mixture of the aborigines and the Spaniards. There were, however, in 1744, several Indians at Banique, who proved their descent from the subjects of the unfortunate cacique *Henri;* although historical authority affirms that the whole race was exterminated.

The freed people are few in number, if compared with the whites, but considerable in proportion to the number of slaves. The people of color are excluded from almost all employments, civil as well as military, as long as the color of the skin betrays its origin; but the political constitution of the country admits of no distinction between the civil rights of a white inhabitant and those of a free person. Indeed the major part of the Spanish colonists are of a mixed race: this an African feature, and sometimes more than one, often betrays; but its frequency has silenced a prejudice that would otherwise be a troublesome remembrancer. People of color are admitted to the priesthood without difficulty; but the Spaniards have not yet brought themselves to make negro priests and bishops like the Portuguese. Slaves are treated with extreme mildness, and are usually fed as well as their masters. A religious principle and an illicit affection tend to their emancipation. A slave can redeem himself at a price fixed by law. Thus the fate of the slave is softened by the hope of freedom, and the authority of the master by the habit of being confounded, in some sort, with those who were the other day in slavery. The laws against slaves are much neglected; those in their favor are very exactly observed.

Few of the creoles can either read or write; hence the want of social intercourse, which is also augmented by the badness of the roads. The roads are nothing but paths passable only on foot and on horseback; and 8 leagues a day is very great work, in which space the traveller often does not meet with a single habitation, and must consequently carry with him every necessary for nourishment and lodging. Such is the low state of commerce in the Spanish part, that Don Antonio de Valverde, a native creole, goes so far as to assert, in his account of the territory, that the commerce in cattle, with the French part, is its only support.

The whole island is in general well watered by rivers and brooks without number, but certain spaces are deprived of this advantage. From the formation of the island, their courses are but short, and few of them navigable to any distance. It is generally impossible to conceive, from the tranquil aspect that these rivers usually wear, what they become when they overflow their banks. A river that but now hardly covered the pebbles on its bed, or wet the foot of the traveller, is changed by one tempestuous shower into a flood, menacing all that it approaches; and should its banks give way, it spreads its watery devastation over the plains. Many of these are infested with alligators. The only lakes or ponds worth notice are those of Henriquelle and Salt pond; the former is a great curiosity.

The chief of the islands which surround St Domingo, part of which belonged to the Spanish part, are Altavele, Saone, Beate, St Catherine, on the S. side, from W. to E. Mone, and Monique on the S. E. Caymite, and Gonave on the W. between the two peninsulas, and La Tortue, on the N. side, towards the W. end of the island, and that of Avache on the S. side of the southern peninsula.

The ancient division line which separated the French from the Spanish part of the island extended from the river des Anses a Pitre or Pedernales, on the S. side, to that of Massacre, on the N. side, at the head of the bay of Mancenille, which, together with the large bay which sets up from the westward, between Cape St Nicholas and Cape Dame Marie, S. W. of the former, and 43 leagues apart, moulds this division of the island into such a figure, as can be best comprehended by a view of the map; suffice it to say, that it contains 2,500,000 acres of land, of an extremely fertile soil, presenting an agreeable variety of hills, vallies, woods and streams.

The French part of St Domingo, containing 2,500,000 acres, of which 1,500,000 were under high cultivation in 1789, was then divided into 10 jurisdictions, which were subdivided into 52 parishes. West jurisdictions, Port au Prince, St Mark, Le Petit Goave, and Jeremie—in the north, Cape François, Fort Dauphin, and Port de Paix—those in the south, Les Cayes, St Louis, and Jacmel. Before the late revolution, there were in these parishes about 42,000 white people, 44,000 free people of color, and 600,000 slaves. Other accounts make them considerably less; the above, however, is from good authority. The number of deaths, during 1789, according to the bills of mortality, 7121—the number of births the same year, 4232. The excess of deaths, 2889, will be the less astonishing, when it is considered, that in the year 1787, and 1788, there had been imported into the colony nearly 60,000 new negroes. The exports from Jan. 1, 1789, to Dec. 31, of the same year, were 47,516,531 lbs. white sugar, 93,573,300 brown sugar; 76,835,219 lbs. coffee; 7,004,274 lbs. cotton; 758,628 lbs. indigo; and other articles, as tanned hides, molasses, spirits, &c. to the value of 46,873 livres. The total value of duties on the above exportations, amounted to 770,801 dollars, 3 cents. Port au Prince is the seat of the French government in this island, in time of peace, and a place of considerable trade. Cape François exceeds Port au Prince in the value of its productions, the elegance of its buildings, and the advantageous situation of its port. It is the governor's residence in time of war. The Mole, though inferior to these in other respects, is the first port in the island for safety in time of war, being by nature and art strongly fortified. The other towns and ports of any note, are Fort Dauphin, St Mark, Leogane, Petit Goave, Jeremie, Les Cayes, St Louis, and Jacmel.

The most ancient town in this island, and in all America, built by Europeans, is St Domingo; of which an account is given below. To these particular observations, we add the following, of a more general nature: The sugar and indigo plantations were in the flat, the coffee in the mountainous lands. The plantations were for the most part enclosed with live hedges, straight and well dressed; the dwelling and manufactory houses were built and laid out with great neatness and taste; every habitation possessed a private hospital for the accommodation of its sick negroes, who were parentally dealt with; the roads were excellent; and from the general hospitality and cheerfulness of its former inhabitants, it was considered as one of the most enviable spots on earth. Such was the French part of St Domingo in 1789; but, alas! it is no more: the destructive ravages of an unrelenting insurrection, of frightful massacres and conflagrations, have laid waste all those beautiful settlements, reduced the buildings to ashes, and laid low in dust or scattered in exile, its wretched inhabitants.

The first interference of the National Assembly, in the affairs of the colonies, was by a decree of the 8th of March, 1790, which declared, "That all free persons, who were proprietors and residents of two years standing, and who contributed to the exigencies of the state, should exercise the rights of voting, which constitute the quality of French citizens." This decree, though in fact it gave no new rights to the people of color, was regarded with a jealous eye by the white planters; whose pride and resentment dictated to them to repel the people of color from their assemblies. This seems to be the true source of their calamities; to develope which, and the dreadful consequences, belong to the professed historian.—*Morse.*

Domingo, St, the capital of the Spanish part of the island of St Domingo or Hispaniola, is situated on the W. bank of the Ozama, a league below the mouth of Isabella river, in which distance it is 24 feet deep, having a bottom of mud or soft sand, and banks 20 feet perpendicular height; but N. of the city this height is reduced to 4 feet. The Ozama is navigable for 9 or 10 leagues, and has several sugar manufactories, tile kilns, and provision farms on its banks. The road before the mouth of the Ozama is very indifferent, and lies exposed from W. S. W. to E. It is impossible to anchor in it in the time of the south winds; and the north winds drive the vessels from their moorings out into the sea, which here runs extremely high. The port of St Domingo is magnificent in every respect; a real natural bason, with a great number of careenings for the vessels that can get at them. There is a rock at the entrance, which will only admit vessels drawing 18 or 20 feet water; which it is asserted might be removed without great difficulty.

The city of St Domingo was originally founded on the E. side of the Ozama, in 1494, by Bartholomew Columbus, who gave it the name of New-Isabella. Authors assert that Christopher Columbus gave it the name of his father, and that the inhabitants of Isabella on the N. coast of the island, founded by Christopher Columbus in 1493, removed to New-Isabella in 1496. In 1502 a hurricane destroyed most of its buildings, which induced Ovando to remove the inhabitants to the W. side of the river. The new city was soon built, and that with a grandeur of design not unworthy of the first metropolis of the New World. The plan of the city is a trapezium of about 540 fathoms on the E. side, along the Ozama; near 500 fathoms on the S. bordering on the sea; and of about 1800 fathoms in circumference. To the W. and to the N. of the city, the land is rough and rocky for about half a league, but after that it becomes good, and the country delightful. Towards the sea the scite of the city lies very high, which forms an insurmountable dyke against the fury of the waves. It is surrounded with a rampart 8 feet in diameter, and about 10 feet high. There is a great deal of ordnance at St Domingo, particularly cast ordnance, but the fortifications are not strong; and the height of the Ileignes commands it entirely; and its crown is not more than 250 fathoms from the ditch. The streets are spacious, and straight as a line, which gives it a pleasing appearance. Ten of these streets run from N. to S. and 10 others from E. to W. The greatest part of the houses, first built, are of a sort of marble found in the vicinity, and in the style of the ancient towns of Spain and Italy: those of a more recent construction are of tapia, a sort of pise. To erect these buildings, a case is made of planks, between pillars of masonry: this case is filled by degrees with a reddish clay, which is rammed down as it is thrown in, until it forms a solid, or sort of wall, between the pillars. The clay thus pressed together, acquires an amazing hardness, and the walls are sometimes so solid and strong, that the pillars of masonry are useless. The houses of St Domingo are tolerably handsome, in a simple style, and nearly uniform. A considerable part of these, built within these 15 years, are of wood, covered with the leves or taches of palm trees. The roofs are generally platformed, being shaped so as to conduct the rain-water to the cisterns. The climate of the capital is, happily, very temperate. The nights of those months which answer to the winter in Europe, are even found to be cold.

Among a number of public edifices that merit attention, in this declining city, we may reckon the ruins of the house that Diego, son of Christopher Columbus, had begun, entirely of hewed stone. The walls are yet remaining, and some of the sculpture round the windows. The roof and ceilings are fallen in, the lower floor is become a pen for cattle; and a Latin inscription over the portal, is now hidden by the hut of a herdsman. The cathedral, of the same sort of stone as the house of Diego Columbus, stands on the S. E. Opposite its entrance is a fine spacious oblong square, at the S. W. end of which is the town house. The cathedral is a noble Gothic pile begun in 1512, and finished in 1540, and was constructed after the model of a church at Rome. It merits admiration on account of the boldness of its vault, which, notwithstanding the ravages of earthquakes in its neighbourhood, has never, till within these 15 or 20 years, had a single flaw. The dust of Columbus rested within this pile until the year 1796, when it was removed. Here are 3 convents for men; which have increased in importance since 1782; 2 nunneries, 3 hospitals, a college, and a gaol. The convent of the Cordeliers was built by Ovando in 1503, on a little hill containing a mine of mercury. All the 3 parochial churches of St Domingo, are beautiful, rich in ornaments, in vases

Domingo ‖ Dominica.

vases of gold and silver set with precious stones, in pictures, in statues of marble and of metal; but the cathedral surpasses the others in every respect. The population of the city of St Domingo is not very considerable; yet it is extraordinarily augmented since the year 1780. The census lately taken, amounted to 20,000, of every age and sex. But this is far below the exact number. The census is taken by the Spanish priests or vicars, and who go from house to house to verify those who do not perform their paschal duties. This list does not comprehend children under 7 years of age, nor heads of families absent from their home or from the city. But the principal cause of the inexactness, is, one half of the parochial territory of the city is on the outside of the walls.

This territory comprehends the part called the Plains, a great part of the Monte-de-Plate, and again as well to the E. as to the W. of the city, a very considerable number of country seats and provision habitations, where there are a great many families of blacks, of people of color, and white cultivators; so that there are always 5 or 6000 not included in the census.

Notwithstanding the declining situation of the Spanish territory of the island, it is far more prosperous than it was 60 years ago. A census even of 1737 shows, that the total population at that time did not surpass 6000 souls, and the capital contained hardly 500.

The Spanish capital is 70 leagues E. by S. of Port au Prince, the road runs half the way along the sea coast, through Bany, Azua, and Neybe, and thence by the lakes Henriquelle and Brackish-pond. In this route you have to cross two large rivers, Nisai and Neybe, besides 11 smaller streams. It is 90 leagues S. E. of Cape François, going by the road through St Raphael, Azua, &c.; and about 100 leagues by that of Dahabon, St Yague, and La Vega. N. lat. 18. 19. 30. W. long. from Paris 72. 37.—*ib.*

DOMINICA, the last of the leeward Charaibee or Caribbee islands, taking them from N. W. to S. E.; but the Spaniards call it the last of the windward islands. It is situated about half way betwixt Guadaloupe on the N. W. and Martinico on the S. E. 15 leagues from each, between 15. 20. and 15. 44. 30. N. lat. and between 61. 17. and 61. 30. W. long. being about 29 miles in length from Crab-Point S. to the N. W. cape of Agusha bay on the N.; and nearly 16 miles broad from Raymond bay E. to Coulihaut on the W.; and contains 186,436 acres of land, and is divided into 10 parishes, viz. St John, St Andrew, St Peter, St Joseph, St Paul, St David, St George, St Patrick, St Luke, and St Martin. The island contains many high and rugged mountains, interspersed with fertile vallies, and is watered by upwards of 30 rivers, beside a number of rivulets. Several of the mountains contain unextinguished volcanoes, which frequently discharge vast quantities of burning sulphur. Here are several hot springs, esteemed efficacious in removing tropical disorders. Some of the waters are said to be hot enough to coagulate an egg. Here are vast swarms of bees, which produce a great quantity of wax and honey; they hive in the trees, and are thought to have been transported from Europe: the native bee of the West-Indies being a smaller species, unprovided with stings, and very different in its manners from the European. The forests afford an inexhaustible quantity of rose wood, so esteemed by cabinet makers. The fruits and other productions are similar to those in the neighboring islands; but the soil being generally thin, is more adapted to the rearing of cotton than sugar. The best eye-stones that are known, are found on the shores of this island. They have their name from the use which is made of them, for clearing the eyes of any dirt. They are shaped like a lentil, smooth and sleek, but much smaller, and of a grey color. The value of exports, according to the current London prices in 1788, amounted to £. 302,987-15 sterling including exports to the American states, value £. 7,164-5. The cargoes, in 162 vessels, consisted of 71,302 cwt. 1 qr. 21 lbs. of sugar—63,392 gall. of rum—16,803 gall. molasses—1,194 cwt. 3 qrs. 2lbs. cacao—18,149 cwt. 3 qrs. 6lbs. coffee—11,250 lbs. indigo—970,816lbs. cotton—161 cwt. ginger, besides hides, dying woods, &c. The number of inhabitants, in the same year, appears to have been 1236 whites—445 free negroes, &c. and 14,967 slaves. There are also about 30 families of Charaibes, the remains of the ancient natives. The only towns here of any note are Charlotte town, the capital and the seat of government, formerly called Rosseau, on the S. W. side of the island, and Portsmouth, situated at the head of Prince Rupert's bay.

Dominica ‖ Don Martin de Mayorga.

Dominica, from its local situation, between Martinico and Guadaloupe, is the best calculated of all the British possessions in that part of the world, for securing to her the dominion of the Charaibbean sea. A few ships of war in Prince Rupert's bay would effectually stop all intercourse of the French settlements with each other, as not a vessel can pass but is liable to capture, by ships cruising off that bay, and to windward of the island. It is a separate government and a free port. The anchorage is good all round the coast of Dominica; but it has no port or bay for retiring into; but the vessels have the advantage of shelter behind many of its capes.

It was discovered by Christopher Columbus, Nov. 3, 1493; and had its name from being discovered on a Sunday. It was taken by the French in the late war, and restored to Britain at the peace of 1783.—*ib.*

DOMINICA, LA, one of the Marquesa islands, called by the natives *Heevaroa*, is the largest of them all, extending E. and W. 6 leagues; is about 16 leagues in circuit, full of rugged hills, and of a barren aspect; but is inhabited. S. lat. 9. 44. The long. of the W. end from Greenwich is 139. 13. W.—*ib.*

DON CHRISTOPHER's *Cove*, lies on the N. side of the island of Jamaica, having St Anne's bay on the W. and Mammee bay on the S. E. It is remarkable for having given shelter to the discoverer of America, during a storm, in 1503, and for being the scite of the old town of Sevilla de Nueva.—*ib.*

DON MARTIN DE MAYORGA, the name given by the Spaniards to a cluster of islands in the South Sea, discovered on the 27th of February 1781, by Don F. A. Maurelle, a celebrated pilot of that nation.

Those islands are described by him as abounding with tropical fruits and roots, as highly cultivated, and as inhabited by a people considerably polished. The fertility

tility of the land, fays he, is fuch, that its cultivation cannot fail to promife a favourable harveft. Every where are feen an endlefs number of cocoa-nut trees, beautiful banana trees, ranged in lines with the greateft order, and numerous plantations of potatoes, of which he defcribes fome as fifteen feet in length, and of the thicknefs of a man's thigh. He admired the order with which every thing was difpofed. No weeds were fuffered to grow between the plants; and their roads were kept in repair with a diligence deferving imitation by the moft civilized nations.

Their government appears from his account to be defpotic. The fovereign, who is called the *Tubou*, is held in the higheft veneration by his fubjects, whofe lives and properties are at his difpofal. Under him there is an order of nobles called *Equis*, who, though they fhrink into infignificance in the prefence of the *Tubou*, have great authority over the people. Thefe people are faid by Maurelle to be of great mufcular ftrength and large ftature, the ordinary height of the men being fix feet or fix feet four inches, while many of them are much taller. It would appear, too, that they delight in gymnaftic exercifes; for when the *Tubou*, by whom he had been treated with great hofpitality, wifhed to amufe him and his fhip's company, he exhibited to them feats of wreftling and boxing, and that as well by the women as by the men.

Though thefe people put the greateft confidence in the Spaniards, and frequently ftaid whole nights on board the frigate, they had yet the common inclination of favages to fteal. "Every time they came on board (fays our author), clothes, iron-work, whatever fell in their way, they confidered as lawful prize. They drew out through the port holes, or the windows, whatever was within their reach. They thieved even to the very chain of the rudder. I made my complaints to the king; he gave me permiffion to kill whomfoever I fhould detect in the act; and I was affured he had himfelf difcovered and punifhed with death the authors of the complained of theft. Our vigilance was neceffarily called into action. We furprifed the iflanders ftriving to tear away the new rudder chains; we fired a piftol at them, one of them fell dead on the occafion, and this was an awful leffon for thofe who were either on board or alongfide of the frigate; they faid to themfelves, or to one another *chito* (robber) *fama* (death)."

They make of the bark of trees a kind of cloth not unlike that which has been brought from other iflands in the South Sea; and our author defcribes the women as being peculiarly neat both in their drefs and in their perfons. They had their mantles or loofe garments adjufted in neat plaits and folds, and becomingly attached by a knot over the left fhoulder. They wore garlands or wreaths on the head, and chaplets of large glafs beads round their necks; the hair was pleafingly difpofed in treffes, and the whole perfon perfumed with an oil of an agreeable odour; above all, the fkin was fo exquifitely clean, that they would not have fuffered the fmalleft particle of duft to remain upon it a moment.

In this archipelago Don Maurelle found a fafe harbour, to which he gave the name of El Refugio, and which he places in South Lat. 18°. 36′. and W. Lon. 177°. 47′. 45″. of Greenwich.

DONDON, an interior fettlement in the French part of the ifland of St Domingo, 3 leagues N. W. of St Raphael in the Spanifh part, and 13 leagues E. by N. of Les Gonaives.—*Morse.*

DONEGAL. There are 3 townfhips in Pennfylvania of this name; the one in Lancafter co. the other in that of Weftmoreland, and the third in Wafhington co.—*ib.*

DOOBOUNT *Lake*, newly difcovered, about 60 or 70 miles long, and 20 or 30 broad; lies fouth-eaft of the head of Chefterfield inlet, in New South Wales.—*ib.*

DORCHESTER, a townfhip in Grafton co. New-Hampfhire, incorporated in 1761. In 1790 it contained 175 inhabitants. It lies N. E. of Dartmouth College about 17 miles.—*ib.*

DORCHESTER, an ancient and thriving townfhip in Norfolk co. Maffachufetts, fettled as early as 1630. A number of towns have been taken off from it fince its firft fettlement. It is fituated 2 miles S. by E. of Bofton, and is now about 6 miles long and 3½ broad. The chief manufactures here are paper, chocolate, fnuff, leather, and fhoes of various forts. It has a handfome church, 256 houfes, and 1722 inhabitants. The N. E. point of the peninfula, called Dorchefter neck, approaches within half a mile of Caftle ifland, and its N. W. point within half a mile of the S. part of Bofton. Forts were erected on the heights in the late war; and this town and its vicinity fuffered much during the early part of the war.—*ib.*

DORCHESTER, in Cumberland co. New-Jerfey, lies on the E. fide of Morris river, about 5 miles from its mouth in the bay, and 17 eaftward of Fairfield.—*ib.*

DORCHESTER *Co.* in Maryland, lies on the E. fide of Chefapeak bay; on the S. fide of Choptank river, which feparates it from Talbot co. It has feveral iflands on its coaft. The chief of thefe, from the mouth of Hudfon river, are, James, Taylor's, Barren, Hooper's, and Goldfborough's, which laft lies between Hungary river and Fifhing bay. The length of the county from E. to W. is about 33 miles, and its breadth from N. to S. 27 miles. The number of its inhabitants 15,875, of whom 5337 are flaves. The lands in the northern parts are fomewhat elevated, but in the fouthern parts low and marfhy, particularly along Fifhing bay, and up its waters, Tranfquaking, Blackwater, and Fearim creek, and along Hungary river an arm of the Chefapeak. The produce is chiefly wheat, corn and lumber. Its chief town is Cambridge.—*ib.*

DORCHESTER, a fmall town of Charlefton diftrict, South-Carolina, feated on the N. E. bank of Afhley river, 18 miles W. N. W. of Charlefton city.—This place was fettled and named as early as 1700, by a colony from Dorchefter and its vicinity in Maffachufetts; and a part of its inhabitants, about the year 1750, left it and fettled Midway, in Georgia.—*ib.*

DORLACH, a townfhip in Otfego co. New-York. By the ftate cenfus of 1796, 433 of its inhabitants are electors.—*ib.*

DORSET, a townfhip in Bennington co. Vermont, having Rupert W. Manchefter S. and Danby N.; and contains 958 inhabitants, 27 miles N. by E. of Bennington.—*ib.*

DOUGLASS, a townfhip, the fouthernmoft in Worcefter co. Maffachufetts, having the ftate of Rhode-Ifland on the S. and that of Connecticut on the S. W. and

and through it passes the middle road from Boston to New-York. It is a very rocky township, and contains 1080 inhabitants. It lies 16 miles S. of Worcester, and 47 S. W. of Boston. It was incorporated anno 1746, and received its name in honor of William Douglass, M. D. of Boston, a native of Scotland, and a considerable benefactor to the town.—*ib.*

Douglass, a township in Montgomery co. Pennsylvania.—*ib.*

Douglass, a cape on the N. W. coast of N. America, which forms the W. side of the entrance into Cook's river, opposite Point Bede, which forms the E. side. It is a very lofty promontory, whose elevated summit appears above the clouds, forming two exceeding high mountains. Lat. 58. 56. N. long. 206. 10. E.—*ib.*

DOUTY'*s Falls*, in York co. Maine, a place where a post office is kept; 7 miles from Berwick, and 8 from Sanford.—*ib.*

DOVER, a township in Norfolk co. Massachusetts, incorporated anno 1650. It contains 485 inhabitants, and lies 15 miles southward of Boston.—*ib.*

Dover, a considerable township in Strafford co. New-Hampshire, and the shire town of the county; situated on the southern side of Cochecho river, about 4 miles above its junction with Salmon Fall river, which together form the Piscataqua; 10 miles S. by E. of Rochester, 6 from Berwick, in Maine, and 12 N. W. by N. from Portsmouth. The Indians named it Winichahanat and Cochecho; by the first settlers, it was called Northam. It was incorporated in 1633, and contains 1998 inhabitants. The public buildings are a Congregational church, court-house and gaol. At Dover is a high neck of land, between the main branch of Piscataqua and Back river, about two miles long, and half a mile wide, rising gently along a fine road and declining on each side, like a ship's deck. It commands an extensive and variegated prospect of the rivers, bays, adjacent shores, and distant mountains. It has often been admired by travellers as an elegant situation for a city, and by military gentlemen for a fortress. The first settlers pitched here, but the trade has long since been removed to Cochecho falls; and this beautiful spot is almost deserted of inhabitants. N. lat. 43. 11. W. long. 70. 50.—*ib.*

Dover, a township in Monmouth co. New-Jersey, between Shrewsbury and New-Stafford, and extends from the sea to the county line. Although a large township, it contains only 910 inhabitants, who live mostly upon the sea-shore. There is but one church, the property of a generous and benevolent individual; who gives liberty to ministers of all denominations to preach in it whenever they please.—*ib.*

Dover, the metropolis of Delaware state, in Kent co. on the S. W. side of Jones creek, about 4½ miles N. W. from its mouth, in the Delaware; 12 miles from Duck creek, 48 from Wilmington, and 76 S. S. W. of Philadelphia. It contains about 100 houses, built principally of brick. There are 4 streets, which intersect each other at right angles, in the centre of the town. The area included within these intersections extends into a spacious parade; on the E. side of which is an elegant state-house. The town has a lively appearance, and drives on a considerable trade with Philadelphia, chiefly in flour. N. lat. 39. 10. W. long. 75. 34.—*ib.*

Dover, a town in York co. Pennsylvania, on Fox Run, which falls into Conewago creek, near its mouth, in the Susquehanna. It contains a German Lutheran and Calvinist church, united; and about 40 houses.—*ib.*

DOWNE, or *Downs*, a township in Cumberland co. New-Jersey.—*ib.*

DOWNINGS, a post town of Pennsylvania, in Chester co. on the E. side of Brandywine creek; 33 miles W. by N. of Philadelphia, and near 7 N. W. of Westchester.—*ib.*

DOYLSTOWN, a village in Bucks co. Pennsylvania, 10 miles S. W. of Howell's ferry, on Delaware river, 15 N. W. of Newton, and 33 W. by N. of Philadelphia.—*ib.*

DRACŒNA Draco (see Dracoena, *Encycl.*), is a native of Madeira, though it is there becoming scarce. The following account of it is by La Martiniere, naturalist in the last voyage of discovery by La Perouse. "The idea of the dracœna draco (says he) given by the shabby specimens cultivated in our hot-houses, is far inferior to that we entertain of it when we have an opportunity of seeing it in its native soil. I met with three in particular, of which the trunk was six or seven feet high, and four and a half or five in diameter. The principal branches, 12 or 15 in number, and as thick as a man's body, shoot out a little obliquely, dividing themselves generally into two, and now and then into three, to the height of 40 or 50 feet including the seven feet of the trunk. The leaves are all at the extremity of the branches, where they are placed in alternate order, and form a cluster. This tree presents the most perfect regularity to the eye, and tempts the spectator to think, that the most skilful gardener makes it the object of his daily care."

DRACUT, a township in the northernmost part of Middlesex co. on the northern bank of Merrimack river opposite Patucket Falls. It contains 1217 inhabitants, and lies 30 miles N. by W. of Boston, and 28 S. W. of Exeter, in New-Hampshire.—*Morse.*

DRAINS. Under this word in the Encyclopædia we published Mr Bayley of Hope's method of draining land; and by a letter from the author, we have since learned, that experience, the best guide, has fully proved the usefulness and durability of his *drains*. With a candour, however, worthy of a man who writes not for fame, but for the good of the public, he informs us of a mistake into which he had led us; and requests us to correct it in this Supplement.

"I wish (says he) that, in the Supplement to the Encyclopædia, due notice may be taken of a very great error into which I was led in my scheme of making the *main drains*. I conjectured, that where the bottom of the trench was of a hard or solid body, as *clay* or *marl*, it might not be necessary to lay it with bricks or stones; but in this I was quite wrong. By the runs of water, the alternate changes from wet to dry, and the access of air, these hard bottoms have been rendered friable; they have crumbled away, and let in all my drains which were not supported by a bottom laid with brick or stone." For this information we request the author to accept of our thanks, and we are persuaded we may add, the thanks of the public.

As the draining of land is a matter of great importance in agriculture, and as the subject has been again brought before us, we imagine that our agricultural readers will be glad to find here the substance of a paper on this subject, for which the author received the silver medal of the *Society* instituted for the encouragement of Arts, Manufactures, and Commerce. That author is Mr John Wedge, of Bickenhill near Coventry, who is not only a great farmer himself, but had likewise been employed by the Earl of Alesford in the management of several estates. Encouraged by his lordship's liberality, Mr Wedge informs the society, that he had been employed for some years in draining large portions of land, of which part was in the Earl's occupation, and part in his own, as tenant to his lordship. The principles upon which he proceeded, as well as his mode of procedure, he states in the following terms:

In every country there are large portions of land that, in wet seasons, have always what may be called a *dry surface*, and other portions of land that have always a *moist* or *wet surface*; the former of these admitting all the water which falls upon them to sink freely through their pores to various depths, till falling on clay, or some other unctuous earth, whose pores will not permit it to pass through, it is there held up to a height proportioned to the quantity of water which comes upon it, and the facility with which that water is discharged. Thus, held up to various heights, it serves as a fountain to distribute its water (either by veins of sand, pebbles or rock), according to the formation of the different under strata on the neighbouring lands, and there forms bogs and other varieties of wet surface, on a basis that will be always found to consist of marl, or clay, or some mixture thereof. The effect of water thus distributed may be divided into two classes. The first class, where the water is thrown out by a body of marl or clay, &c. upon the surface of descending ground, and in the valley (there held up by clay also) forms bogs or swamps. The second class, where the water is held up by marl or clay, as before, having above that marl or clay a stratum of sand, or pebbles, through which the water passes; and above those sands or pebbles another stratum of marl or clay, through the weakest parts of which, the water, by a continual pressure from its fountain, forces a passage upwards; and thus, through the weakest parts of the marl or clay, furnishes a continual supply of water on the surface, for the formation or growth of bogs, &c. in proportion as this water is more or less abundantly supplied by its fountain or head, namely, the higher lands, into which rain-water freely passes, as before described. There are also different soils under different circumstances, which may form a third class of land for draining; such as strong deep soils, or open light soils, having near the surface a body of marl or clay. In either of these cases, the water which falls on the surface must, for reasons which are self evident, keep such lands, in rainy seasons, constantly wet and cold; and it should be observed, that a mixture of all the three before-described classes of wet land sometimes occur in one field, by sudden alterations of the under strata, and thereby perplex the operator, by requiring all the different modes of draining in the same field.

If it be admitted that bogs are thus formed and fed, their cure may be effected with certainty. The first class, by cutting through the stratum (be it sand, pebbles, or rock,) that conveys the water to the bog, and carrying off that water by a close drain to some proper place, where the level admits of its discharge. The second class, by sinking a drain to any convenient depth in the upper clay; and then digging or boring with a large auger, at a small distance on one side of this drain, through the remaining part, be it (the upper clay) ever so deep, into the under stratum of sand, pebbles, or rock, through which the water passes; which will then rush up into the drain so made, with a velocity proportioned to the height of the land or fountain whence it is supplied. As this drain advances through the land, holes must be dug or bored, as before, every seven yards, or at such distance as the strength of the springs may require; and the whole of the water thus brought up by tapping the springs, is carried off by the drain made in the upper clay, which must be a close one, to its proper level, and there discharged.

By both these methods of draining, large tracts of land, under favourable circumstances, may be cured with one drain. The best place for fixing these drains is where the stratum that conveys the water comes nearest to the surface; and the best method of ascertaining that, is to bore or dig in different parts through the different under strata.

The third class may be easily cured by close drains, at such distances and depths as will best carry off the surface-water. It may not be improper to observe that where the different strata or measures crop out, that is, become gradually more and more shallow in some certain direction (as is often the case, till, one after the other, they all present themselves in succession on the surface of the earth), draining may often be much more easily and better effected by crossing with the drain the different strata or measures where the levels and other circumstances will admit.

Some of the land drained was part of a common, in the parish of Church Bickenhill, in the county of Warwick; part of it was covered with moss and ling, had a peaty surface about six inches deep, and produced little or no grass: in all wet seasons it was filled quite to the surface, and often overflowed, with water. Some of the land was much more unsound, deeper of peat, and covered with moss, in most parts nine inches long; another part was an absolute bog in all seasons.

Having dug or bored with a large auger into several parts of the land, Mr Wedge found peat, gravel, and sand mixed, and a quick-sand almost uniformly. The quick-sand in every part, after getting an inch or two into it, seemed almost as fluid as water. Judging from this, that no materials for a drain could be laid in the quick-sand, but what it would immediately bury, he dug a trench almost to the quick-sand, leaving gravel, &c. of sufficient strength to bear up the materials for a hollow drain; these materials were two sides and a coverer of stone, with a peat-turf on the top to keep out the soil. At every seven yards forward, by the side of this drain, he dug a hole in the quick-sand as deep as it would permit. From these holes the water rose freely into the hollow drain, and was by it discharged at a proper level. It may be proper to remark, that the stone made use for this drain, and all others here mentioned, was a red sand and rag-stone, which easily split into proper sizes for the purpose, and is very durable; it cost about sixpence per ton getting, exclusive of carriage. The drain thus formed ran on the whole rather freely, and made the land dry for a few yards on each

each fide thereof, but was far from having the effect he improperly expected; for it evidently appears that the drain could only take a very fmall portion of the water from fo large a quick-fand, which it did not penetrate more than two inches; and that it could drain only to its own depth, or at moft, to that depth in the fountain which fupplied the quick-fand. His purpofe was then defeated; and his motive for mentioning this error cannot, he hopes, be miftaken.

He now did what he fays he ought to have done before, that is, examined the different ftrata to a greater depth, particularly on the bog, and at the upper edges thereof, and found the bog to be what has been defcribed under the firft clafs. He therefore determined to attempt the cure in the manner before prefcribed for that clafs, namely, to cut through the whole of the ftratum (in this inftance, of quick-fand), through which he found the water pafs. This he effected as follows: The fummer being dry, and favourable for the purpofe, and having previoufly made his main open drain, he began his main clofe drain the firft week in June 1791, three feet wide, on the declivity near the edge of the great bog. In the firft operation he dug through the peat, the hard fand, and gravel, and one fpade's graft (about nine inches deep, and feven inches wide) into the quick-fand the whole length of this drain, which was 73 perches, of eight yards to the perch, in length. The drain thus dug ran copioufly, not lefs than 60 gallons per minute. In this ftate he left it about nine days: the effect of it was rapid, both above the drain and on the bog below. Upon examination, he now found about three inches on the top of the fpade's graft, which had been made into the quick-fand, perfectly dry. He then dug out thefe three inches of dry fand, to nearly the whole width of the drain, three feet; and at the fame time dug out, as before, another fpade's graft from the top of the quick-fand, as near the middle of the drain as poffible. This was left to run a few days, as before, and had the fame effect, namely, three or four inches more of the top of the quick-fand became dry and hard. The fame operation was repeated again and again with the fame effect, till the purpofe of getting through this quick-fand was completed, fo far at leaft as the level of the main open drain would permit. The ftream of water continued increafing during the whole operation; the bog below the drain was quite dry, and the land above perfectly fo. The drain which was firft made, and continued running for fome time during the progrefs of the main clofe drain, became gradually dry; and has not, fince that drain was finifhed, difcharged one fingle drop of water. Great care was neceffary, in making the main clofe drain, to keep the ftream of watar in the middle of it, otherwife the current would have undermined the fides, as it fometimes had done, and caufed them to fall in. For this reafon it was neceffary, when the dry fand was taken from the top of the quick-fand, immediately to take out a fpade's graft from the middle thereof, in order to divert the current from the fides.

The main clofe drain thus made was three feet wide at top, about nine feet deep on the average, and, bevelling a little from the top, it was about one foot ten inches wide at the bottom. The ftone and other materials were put into this drain in the following manner:

Where the drain went through the quick-fand into the ftratum of clay below it, as in moft places it did, the bottom, and in fome inftances the fides, wanted no particular fecurity (A); but where it did not go quite through the quick-fand, which the level of his main open drain in fome places would not admit, the bottom of the drain was covered half an inch thick with ling; then peat-turfs, one foot wide and three or four inches thick, were cut in convenient lengths, and placed on their edges on each fide of the bottom of the drain, forming two fides of a trough of peat; then fide ftones about eight inches high, and a ftone coverer, were put in upon the ling between the peat-turfs; a large peat-turf, near two feet wide and four inches thick, was then cut and firmly placed over the whole; this left in the bottom of the drain an open fpace, of more than fix inches fquare, for the water to pafs. The whole was then completed by filling in the upper part of the drain.

In this way the author drained, for about L. 80, thirty acres of land, which, from being of no value whatever, became worth at leaft 14 fhillings per acre of yearly rent. He likewife hollow drained nine acres by the method prefcribed for the third clafs of wet land. Thefe drains were made a few yards below that part of each field where the dry and wet land feparate, about 22 inches deep, with fides and a coverer of ftone, and ling on the top of it, to keep the earth from running in. The length of thefe drains was 880 yards, and the expence of labour and materials three halfpence per yard. The drains, in wet weather, difcharge a large quantity of water; and will, he has no doubt, anfwer the intended purpofe. Thus far relates to land in his own occupation.

Nine acres of the land in the earl of Aylesford's occupation was almoft an entire pulp. This bog was of the fecond clafs, namely, water paffing through a quick-fand, and confined by a ftratum of clay below, and another ftratum of clay above it. The water thus confined, being preffed by its fountain, and forced up thro' the weakeft parts of the clay, had formed a bog of irregular thicknefs on the furface, in fome places fix feet deep, in others not more than two. As there is a confiderable fall in this land from eaft to weft, he thought it expedient to put two drains into it; and this appears to him to have been neceffary, from a confideration that both thefe drains continue to run in the fame proportions as when firft opened. The manner in which thefe drains were executed was, by digging through the different upper ftrata, and as deep into the clay as the main open drain would admit; then digging or boring through the remaining part of that clay into the quick-fand, at the diftance of about fix yards, in a progreffive manner.

The water rifing rapidly through thefe holes into the clofe drains, has effected a complete cure of this land, every part of which will now bear a horfe to gallop upon it. Thefe drains difcharge 3660 gallons an hour; which

(A) He will probably find in time that he was under the fame miftake with Mr Bayley, and we hope that with Mr Bayley's candour he will acknowledge it.

which is much less than they did at first, as must be the case in all bogs. This land will be worth twenty shillings per acre. The draining cost twenty-five pounds; and the length of the under-ground drains is eight hundred and fourteen yards.

Mr Wedge had just finished (January 1792) draining another piece of land, about forty-three acres. As this was intended to answer two purposes, one, to drain the land, the other, to give an additional supply of water to a mill-pool, and as a circumstance arose in the execution of the work which frequently happens in draining land, namely, a sudden alteration in the position of the under strata—a description thereof will not, we hope, be thought tedious. This draining was begun at the level of a mill pool, and continued, without any great difficulty, to the distance of about thirty-two chains, in the manner before described as a cure for the second class of boggy land; but at or near that place the under strata altered their position; the quick-sand which conveyed the water now became of twice its former thickness; and the clay, which had hitherto been above that quick-sand, for some distance disappeared. From the quick-sand thus becoming so much deeper, he could not, with the level of the mill-pool, cut through it; nor indeed, from the wetness of the season, would such an operation have been proper. He therefore continued a shallow drain to some distance, making side-holes into the quick-sand, which ran freely; but as this could not cure the whole of the bog below, he branched out another drain (which was made by the method described for curing the second class of wet or boggy land), by sinking a close drain through the upper strata into the upper clay, and then, at a small distance on one side of this close drain, boring a hole with an auger through the remaining part of that clay into the quick-sand; and at every eight yards, as this close drain advanced, still boring other holes, in the manner before described: through many of these holes the water rushed with great rapidity. The water discharged by these drains into the mill-pool is 168 gallons per minute, or 3780 hogsheads in a day; which is after the rate of 1,379,700 hogsheads in a year.

About six acres of this land were always found; about twelve acres on the north side were an absolute pulp, and the remaining twenty-six acres very unsound. The whole is now sound, and will when cultivated be worth sixteen shillings per acre. This land would have been drained at a much less expence into the main open drain; but then the water, which was much wanted for the mill, would have been lost. These close drains are in length 1452 yards, and cost L. 100, of which about L. 30 ought to be charged to the mill.

Important as this subject is, we must not enlarge this article, or we should make large extracts from Dr Anderson's *Practical Treatise on Draining Bogs and Swampy Grounds*, lately published. It is proper, however, to inform the public, that the author puts in his claim for being the first discoverer of that mode of draining for which Mr Elkington has obtained from parliament a premium of L. 1000; and the reader who shall turn to the article DRAINS in the Encyclopædia, will perceive that his claim is well-founded.

DRAKE, a harbour in California, so called after the celebrated Sir Francis Drake, who discovered and took possession of the peninsula of California, for his mistress, Queen Elizabeth. N. lat. 28. 15. W. long. 111. 39.—*Morse.*

DRAKE, SIR FRANCIS, or *Drake's Bay*, a bason in the middle of the Virgin isles, in the West-Indies, 3 or 4 leagues broad, and 6 or 7 long, the finest that can be imagined; and in which ships may anchor, landlocked, and sheltered from all winds.—*ib.*

DRESDEN, a township in Lincoln co. district of Maine, situated 9 miles from Wiscasset Point, 15 from Fort Weston, at Hallowell, and 180 N. by E. of Boston. Swan Island is in this township.—*ib.*

DROMORE, a township in Lancaster co. Pennsylvania.—*ib.*

DROSSERA ANGLICANA, or the SUNDEW (see DROSSERA, *Encycl.*), is a very minute villous plant, usually growing entangled with moss on peat bogs; the leaves are curiously fringed with numerous strong reddish hairs, terminated by small pellucid globules of viscous liquor, which occasion, by the reflection of the sun, that peculiar lustre from which its name is derived. It is in these hairs that the essential properties of the plant reside; for if a small insect should fix itself on one of the leaves, these hairs immediately begin to close, one by one, till the insect is wholly environed by them, and then the leaf in which it is imprisoned gradually bends inwards, so as to reach the base: in this state the insect is killed by the operation of the acrimonious juice exuding from the ends of the hairs. Rothius (as quoted by Withering, in his Arrangement of British Plants,) mentions the effects of this singular plant, occasioned by the irritation of an ant, which he placed on the centre of one of the leaves with a pair of pincers. The ant, in endeavouring to escape, was held fast by the viscous juice of the smaller hairs till the large ones, together with the edges of the leaf, closed in and imprisoned it. The ant died in fifteen minutes; but he observes, that the effects followed sooner or later, in different experiments, according to the state of the weather. Dr Withering has published a similar account of the sensitive properties of the Sundew, which was communicated to him by two of his botanical friends, and which he has made very entertaining and interesting. The same thing is confirmed by a writer in the Monthly Magazine for August 1797; who says, that whenever he made experiments on the drossera with ants and other diminutive insects, he commonly found them perish in a shorter time than fifteen minutes. His experiments were made on the drossera rotundifolia. Rothius, however, observes, that the longifolia produces the same effects, but with greater rapidity. In concluding his account, Dr Withering suggests this enquiry: "Whether this destruction of insects be not necessary to the welfare of the plant?" And it is surely worth some botanist's while to take some pains to answer the question.

DRUGS (see *Encycl.*) are so commonly counterfeited, or at least adulterated, that in London, the royal college of physicians, it is well known, has long ago appointed a court of examiners to investigate the goodness of drugs and medicines in the different chemists and apothecaries shops. The counterfeit, however, is made up with such dexterity, that not only the merchant and drug-broker, but even the man of skill is sometimes deceived: and indeed nothing can detect this imposition but a practical knowledge of chemistry. We therefore recommend it to every father of a family to to ſtudy our Supplementary article CHEMISTRY with this view, if with no other; for whatever be the faults of that article, we have loſt much labour if it be not ſufficiently perſpicuous to enable every man not an abſolute ſtranger to phyſical ſcience in all its branches, to detect the common impoſtures of drug-ſellers.

DRUMMOND, or Accomac court-houſe, in Virginia, is on the poſt road from Philadelphia to Norfolk, 20 miles from Belhaven, and 194 from Philadelphia.—*Morſe.*

DRYDEN, a military townſhip in the ſtate of New-York, having Ulyſſes W. and Virgil on the E.; and on the S. the town of Owego, in Tioga co. The centre of the town lies 8 miles E. of the S. end of Cayuga Lake.—*ib.*

DUANESBURGH, a townſhip in Albany co. New-York, containing 1470 inhabitants; of whom 260 are electors, and 5 ſlaves.—*ib.*

DUBLIN, a townſhip in Cheſhire co. New-Hampſhire, on a branch of Aſhuclot river, and N. of the Great Monadnock, containing 901 inhabitants. It is 28 miles S. E. of Charleſtown, and 63 W. of Portſmouth. Incorporated in the year 1771.—*ib.*

DUBLIN, a pleaſant town in Philadelphia co. Pennſylvania, 10 miles N. E. of Philadelphia, and as far S. W. of Briſtol. Alſo a townſhip in Huntingdon co. in Pennſylvania.—*ib.*

DUCK, a river in Tenneſſee, which riſes on the N. W. ſide of the Cumberland mountain. It runs a N. W. courſe, and empties into the Tenneſſee in N. lat. 36. W. It is 200 yards wide 5 miles from its mouth, which is 57 miles weſterly of Naſhville; and is boatable 90 miles.—*ib.*

DUCK-CREEK-CROSS-ROADS, or *Saliſbury*, a conſiderable and thriving poſt town in the ſtate of Delaware, ſituated on Duck-Creek, which in part divides Kent and Newcaſtle counties. It contains about 90 houſes in one ſtreet, and carries on a conſiderable trade with Philadelphia, and is one of the largeſt wheat markets in the ſtate. It lies 12 miles N. by W. of Dover, and 36 from Wilmington.—*ib.*

DUCKTRAP, a village in the diſtrict of Maine, where a poſt office is kept, in Hancock co.; containing 278 inhabitants; 12 miles from Belfaſt and 32 from Penobſcot.—*ib.*

DUDLEY, a townſhip in Worceſter co. Maſſachuſetts, containing 1114 inhabitants. It is 18 miles ſouthward of Worceſter, and 55 miles S. W. of Boſton. —*ib.*

DUFTER, in Bengal, an office or department.

DUFTER-Cana, the place where the office is kept.

DUKE'*s Co.* in Maſſachuſetts, comprehends Martha's Vineyard iſland, Chabaquiddick iſland, Noman's iſland, and the Elizabeth iſlands; ſituated on the S. E. coaſt of the ſtate. The number of inhabitants is 3265. They ſend 3 repreſentatives, and, in conjunction with Nantucket iſland, one ſenator to the General Court. Theſe iſlands are deſcribed ſeparately. Chief town, Edgarton.—*Morſe.*

DUMFRIES, a port of entry and poſt town in Virginia, and chief town of Prince William co. It lies on the N. ſide of Quantico creek, 4 miles above its entrance into the Potowmack, and 10 miles from Colcheſter. Its public edifices are an Epiſcopal church, a court-houſe and gaol. The exports from this port for one year ending the 30th of Sept. 1794, amounted in value to 85,635 dollars. It lies 28 miles N. by E. of Fredericksburg, and 185 S. W. of Philadelphia.—*ib.*

DUMMER *Fort*, is ſituated on Connecticut river in the town of Cheſterfield, New-Hampſhire.—*ib.*

DUMMER, a townſhip in Grafton co. New-Hampſhire, incorporated 1773. It is to the S. W. of lake Umbagog, on the waters of Upper Amonooſcuk and of Androſcoggin rivers.—*ib.*

DUMMERSTON, a townſhip in Windham co. Vermont, N. of Brattleborough, containing 1501 inhabitants.—*ib.*

DUNBARTON, a townſhip in Hillſborough co. New-Hampſhire, incorporated in 1765, and containing 917 inhabitants; 9. miles S. of Concord, and 36 W. of Portſmouth.—*ib.*

DUNCANSBOROUGH, a townſhip of Vermont, on the W. ſide of lake Memphremagog.—*ib.*

DUNCARD'S *Bottom*, a tract of fine lands on the E. ſide of Cheat river in Virginia, about 22 miles from its mouth, and 49 W. S. W. from Fort Cumberland. —*ib.*

DUNDERBERG, in Engliſh, *Thunder hill*, is ſituated on the W. ſide of Hudſon river, at the S. E. entrance of the high-lands, oppoſite Peek's Hill; and is remarkable for its echoes.—*ib.*

DUNLOPE, a fort on the W. bank of Little Miama river, about 12 miles above Columbia, in the N. W. territory.—*ib.*

DUNSTABLE, a townſhip in Hillſborough co. New-Hampſhire, on the W. ſide of Merrimack river below the town of Merrimack, and ſeparated by the ſtate line from Pepperel and Dunſtable in Middleſex co. Maſſachuſetts. It was incorporated in 1746, contains 632 inhabitants, and lies about 40 miles N. W. of Boſton.—*ib.*

DUNSTABLE, a townſhip of Maſſachuſetts, in the northern part of Middleſex co. and on the ſouthern bank of Merrimack river. It contains 380 inhabitants, and lies 37 miles N. weſterly of Boſton.—*ib.*

DUPAGE, a circular lake on the S. E. ſide of Plein river, or rather an enlargement of the channel of that river, 5 miles from its mouth. Plein and Theakiki there form the Illinois.—*ib*

DUPLIN *Co.* in Wilmington diſtrict, North-Carolina, is bounded E. by Onflow, and S. W. by Sampſon. The number of inhabitantants is 5662, of whom 1383 are ſlaves. The chief town is Sarecto, on the N. E. branch of Cape Fear.—*ib.*

DURANGO, a town in the province of Zacatecas, and audience of Guadalaxara, in New-Spain, 10 leagues from Nombre de Dios, and is a biſhop's ſee, at the confluence of ſeveral rivers which render it convenient for trade.—*ib.*

DURHAM, a townſhip in Cumberland co. diſtrict of Maine, on the S. W. bank of Androſcoggin river which ſeparates it from Bowdoin on the N. E. It was incorporated in 1789, contains 724 inhabitants, and lies 145 miles N. eaſterly of Boſton. N. lat. 43. 55. —*ib.*

DURHAM, a poſt town in Strafford co. New-Hampſhire on Oyſter river, near where it joins the Piſcataqua;

12 miles W. of Portſmouth. It was incorporated in 1633, and contains 1247 inhabitants. It was formerly a part of Dover, which adjoins it on the N. and was called Oyſter river. On the top of a hill in this town is a rock, computed to weigh 60 or 70 tons, ſo exactly poiſed on another rock as to be eaſily moved by one's finger. Its ſituation appears to be natural. —*ib.*

Durham, a townſhip in New-Haven co. Connecticut, ſettled from Guildford in 1698, and incorporated in 1708. It is about 22 miles S. W. of Hartford and 18 miles N. E. of New-Haven. It was called *Chogingchague* by the Indians; which name a ſmall river that chiefly riſes here, ſtill bears.—*ib.*

Durham, a townſhip in Bucks co. Pennſylvania. —*ib.*

DUTCHESS *Co.* in New-York, is on the E. ſide of Hudſon river. It has the ſtate of Connecticut on the E. Weſt-Cheſter on the S. and Columbia co. on the N. It is about 48 miles long and 23 broad, and contains 15 townſhips, of which Poughkeepſie and Fiſh-Kill are the chief. It contains 45,266 inhabitants; of theſe 6013 are qualified to be electors, and 1856 are ſlaves. Dutcheſs co. ſends 7 repreſentatives to the aſſembly of the ſtate. In the year 1792, a remarkable cavern was diſcovered in this county, at a place called by the Indians Sepaſcot, at Rhynbeck. A lad, by chance, paſſing near its entrance, which lies between two huge rocks, on the declivity of a ſteep hill, on prying into the gloomy receſs, ſaw the top of a ladder, by which he deſcended about 10 feet, and found himſelf in a ſubterraneous apartment, more capacious than he choſe to inveſtigate. He found, however, that it had been the abode of perſons, who probably during the war, had taken ſhelter here, as bits of cloth and pieces of leather were ſcattered about its floor. It ſince appears to be divided by a narrow paſſage into two apartments; the firſt being about 17 feet in length, and ſo low that a child of eight years old could but juſt walk upright in it; the breadth is about 8 or 10 feet. The ſecond between 12 and 14 feet in length, but much higher and broader than the firſt. Like many other caverns in the United States, it poſſeſſes a petrifying quality; and the water, which is conſtantly percolating through the roofs of its apartments, has formed a variety of tranſparent and beautiful ſtalactites. They have the appearance of icicles, and may be broken off by the hand, if not more than two inches in circumference.

But what is moſt to be admired is the ſkeleton of a large ſnake, turned into ſolid ſtone by the petrifying quality of the water before-metioned. It was with ſome difficulty torn up with an axe from the rock it lay upon, and is now in poſſeſſion of the gentleman who explored the cavern. A want of free air was experienced in the inmoſt receſſes of the cavern, by a difficult reſpiration, though the candles burnt very clear. The air was alſo very warm.—*ib.*

DUTCHMAN's *Point*, a point of land on the Vermont ſide of lake Champlain, about 16 miles S. of the Canada line. The Britiſh held a ſtockaded hut here, garriſoned by ſix ſoldiers, ſince the peace of 1783. It has ſince been delivered up to the United States. —*ib.*

DUXBOROUGH, a maritime townſhip in Plymouth co. Maſſachuſetts, incorporated in 1637. 20 veſſels, the greater part from 60 to 90 tons, are owned here. It is a healthy town, and contains 1460 inhabitants; not a greater number than it contained 50 years ago. It lies S. by E. of Plymouth, 3 miles acroſs Plymouth bay by water, and 8 round by land, and 38 S. E. by S. of Boſton. Within the harbour are Clarke's iſland conſiſting of about 100 acres of excellent land, and Sauquiſh iſland which was formerly joined to the Gurnet, by a narrow piece of land; but the water has inſulated it. The Gurnet is an eminence at the ſouthern extremity of the beach, on which is a light-houſe built by the ſtate. The Indian name of the town was Mattakeeſet, or Namakeeſet. It was ſettled by capt. Standiſh and his aſſociates. The captain came to Plymouth with the firſt ſettlers in 1620.—*ib.*

DUXBURY, a townſhip in Hillſborough co. New-Hampſhire, incorporated in 1763; firſt called Dantzick, joined with Sutton in the enumeration of 1775. It has only 169 inhabitants.—*ib.*

Duxbury, a townſhip in Chittenden co. Vermont, about 20 miles S. E. of Burlington, and contains 39 inhabitants.—*ib.*

DWARFING of Vegetables, an art invented by the Chineſe, to which the attention of Sir George Staunton was attracted on the following occaſion:

When the embaſſy was at Chuſan (See Chusan in this Supplement) the gentlemen who went on ſhore were introduced to the governor in his hall of audience, where on ſeveral tables were placed, in frames filled with earth, dwarf pines, oaks, and orange trees, bearing fruit. None of them exceeded in height two feet. Some of thoſe dwarfs bore all the marks of decay from age: and upon the ſurface of the ſoil were interſperſed ſmall heaps of ſtones, which, in proportion to the adjoining dwarfs might be termed rocks. Theſe were honey-combed and moſs-grown, as if untouched for ages, which ſerved to maintain the illuſion, and to give an antique appearance to the whole. This kind of ſtunted vegetation ſeemed to be much reliſhed by the curious in China, and ſpecimens of it were to be found in every conſiderable dwelling. To produce them formed part of the gardener's ſkill, and was an art invented in that country. Beſide the mere merit of overcoming a difficulty, it had that of introducing vegetables into common apartments, from which their natural ſize muſt otherwiſe have excluded them.

The general method of obtaining vegetable dwarfs is ſaid to be the following: A quantity of clay or mould is applied to the upper part of the trunk of a tree, from which a dwarf is intended to be taken, and cloſe to its diviſion into branches. The mold is to be confined to the ſpot by coarſe hempen or cotton cloth, and to be carefully kept moiſt by water. In conſequence of this application, continued ſometimes above a twelvemonth, ſmall tender fibres ſhoot down like roots from the wood into the mould. The part of the trunk emitting thoſe new fibres, together with the branch riſing immediately above it, is then to be carefully ſeparated from the reſt of the tree, and planted in new earth, in which the fibres become new roots, while the former branch is now the ſtem of the vegetable thus transformed in ſome meaſure. This operation does not deſtroy or alter the productive

Dwarfing ‖ Dyeing.

productive faculty which thoſe parts enjoyed before their ſeparation from their parent root. That which, while a branch of the original tree bore flowers and fruit, continues to produce the ſame, though no longer ſupported upon any ſtock. The terminal buds of ſuch branches of trees as are meant to become dwarfs are torn off; which circumſtance prevents the further elongation of thoſe branches, and forces other buds and branchlets from the ſides. Theſe branchlets are bent by wires to whatever form the operator wiſhes: and when the appearance of age and decay is meant to be given to a dwarf tree, it is repeatedly ſmeared with treacle or molaſſes, which attracts multitudes of ants, who, in purſuit of thoſe ſweet juices, attack the bark, and, by a gradual corroſion of it, produce the deſired effect. Theſe different proceſſes are ſometimes attempted to be kept ſecret by the gardeners, and they vary deſignedly in the mode of carrying them on; but the principle on which they are founded is ſufficiently apparent from what is related here, and the contrivance argues ingenuity and perſeverance, rather than the practice does true taſte, which conſiſts in aſſiſting nature in its moſt favourite works—not in counteracting its operations or diſtorting its productions.

DYEING is an art, into which, ſince the article in the Encyclopædia was publiſhed, improvements have been introduced of ſuch importance, that it would be unpardonable not to notice them in this Supplement. We accordingly agreed for a new article with a teacher of chemiſtry, ſtrongly recommended to us as a man who had long directed his attention to that ſubject; and he ſolemnly engaged to have the article ready for the preſs before the 1ſt of November 1798. It is now the 20th of February 1799; and after amuſing us from week to week, and from day to day, till our patience is quite exhauſted, he finds himſelf unable (for we will not attribute his conduct to a worſe motive) to fulfil his engagement. In this ſtate of things what are we to do? The ſubject muſt not be relinquiſhed, and our numerous preſſes can no longer ſtand unemployed. It is fortunate that, by following the arrangement of Chaptal, ſo well known for the clearneſs of his method, we have yet an opportunity of treating of dyeing under the article *Animal and Vegetable* SUBSTANCES referred to from CHEMISTRY. Such of our readers as are acquainted with the buſineſs of the preſs will deem this ſhort narrative a ſufficient apology for our conduct; and even thoſe of them who are in a great meaſure ſtrangers to that buſineſs, will not think us, circumſtanced as we are, deſerving of much cenſure for delaying a ſubject, which we pledge ourſelves not to omit under the article to which we have referred.

Dyeing.

D Y N A M I C S.

1 Definition.

THIS name marks that department of phyſico-mathematical ſcience which contains the abſtract doctrine of MOVING FORCES; that is, whatever neceſſarily reſults from the relations of our ideas of motion, and of the immediate cauſes of its production and changes.

2 Object of dynamics is change of that condition of a thing which we call its *motion.*

All *changes* of motion are conſidered by us as the indications, the characteriſtics, and the meaſures of changing cauſes. This is a phyſical law of human thought, and therefore a principle to which we may refer, and from which we muſt derive all our knowledge of thoſe cauſes. When we appeal to our own thoughts or feelings, we do not find in ourſelves any diſpoſition to refer mere exiſtence to any cauſe, although the beginning of exiſtence certainly produces this reference in an inſtant. Had we always obſerved the univerſe in motion, it does not appear that we ſhould have aſcribed it to a cauſe, till the obſervation of relative reſt, or ſomething leading to it, had enabled us to ſeparate, by abſtraction, the notion of matter from that of motion. We might then perceive, that reſt is not incompatible with matter; and we might even obſerve, by means of relative motions, that abſolute reſt might be produced by the concourſe of equal and oppoſite motions. But all this requires reflection and reaſoning; whereas we are now ſpeaking of the firſt ſuggeſtions of our minds.

3 We cannot have any notion of motion *in abſtracto*, without conſidering it as a ſtate or condition of exiſtence, which would remain if not changed by ſome cauſe. It is from changes alone, therefore, that we infer any agency in nature; and it is in theſe that we are to find all that we know of their cauſes.

When we look around us, we cannot but obſerve, that the motions of bodies have, in moſt caſes, if not always, ſome relation to the ſituation, the diſtance, and the diſcriminating qualities of other bodies. The motions of the moon have a palpable relation to the earth; the motions of the tides have as evident a relation to the moon; the motions of a piece of iron have a palpable dependence on a magnet. The vicinity of the one ſeems to be the occaſion at leaſt of the motions of the other. The cauſes of theſe motions have an evident connection with or dependence on the other body. We are even diſpoſed to imagine that they are inherent in that body, and that it poſſeſſes certain qualities which are the cauſes of thoſe modifications of motion in other bodies. Theſe ſerve to diſtinguiſh ſome bodies from others, and may therefore be called PROPERTIES; and, ſince the condition of other bodies ſo evidently depends on them, theſe properties expreſs very intereſting relations of bodies, and are chiefly attended to in the enumeration of the circumſtances which aſcertain what we call the *nature* of any thing. We do not mean to ſay, that theſe inferences are always juſt; nay, we know that many of them are ill-founded: but they are real, and they ſerve abundantly for informing us what we may expect from any propoſed ſituation of things. It is enough for us to know that when a piece of iron is ſo and ſo ſituated in relation to a magnet, it will move in a certain manner. 4 Mechanical relation, what.

This mutual relation of bodies is differently conſidered, according to the intereſt that we chance to take in the phenomenon. The cauſe of the approach of the iron to a magnet is generally aſcribed to the magnet, which is ſaid to attract the iron, becauſe we commonly employ the magnet in order that theſe motions may take place. The ſimilar approach of a ſtone to the earth is aſcribed to the ſtone, and we ſay that it tends to the earth. In all probability, the procedure of nature is the ſame in both; for they are obſerved, in every inſtance, to be mutual between the related bodies. As iron approaches a magnet, ſo the magnet approaches the iron. The ſame thing is obſerved in the motions of electrified bodies; alſo in the caſe of the ſtone and the earth. Therefore the cauſe of the motions may be conceived as inherent in either, or in both.

Force and *Action* are figurative terms when uſed in mechaniſm;

The qualities thus inherent in bodies, conſtituting their mechanical relations, have been called the MECHANICAL AFFECTIONS OF MATTER. But they are more commonly named POWERS or FORCES; and the event which indicates their preſence, is conſidered as the effect and mark of their agency. The magnet is ſaid to ACT on the iron, the earth is ſaid to ACT on the ſtone; and the iron and the ſtone are ſaid to ACT on the magnet and on the earth.

All this is figurative or metaphorical language. All languages have begun with ſocial union, and have improved along with it. The firſt collections of words expreſſed the moſt familiar and the moſt intereſting notions. In the proceſs of ſocial improvement the number of words did not increaſe in the ſame proportion with the notions that became intereſting and familiar in their turn: for it often happened that relations of certain ideas ſo much reſembled the relations of certain other ideas, that the word expreſſing one of them ſerved very well for expreſſing the other; becauſe the diſſimilar circumſtances of the two caſes prevented all chance of miſtake. Thus we are ſaid to *ſurmount* a difficulty, without attaching to the word the notion of *getting over* a ſteep hill. Languages are thus filled with figurative expreſſions.

5
But the analogy is not in the force, but in the effect.

POWER, FORCE, and ACTION, are words which muſt have appeared in the language of the moſt ſimple people; becauſe the notions of perſonal ability, ſtrength, and exertion, are at once the moſt familiar and the moſt intereſting that can have a place in the human mind. Theſe terms, when uſed in their pure primitive ſenſe, expreſs the notions of the power, force and action of a ſentient, active, being. Such a being only is an agent. The exertion of his power or force is (excluſively) action: But the relation of cauſe and effect ſo much reſembles in its reſults the relation between this force and the work performed, that the ſame term may be very intelligibly employed for both. Perhaps the only caſe of pure unfigurative action is that of the mind on the body. But as this is always with the deſign of producing ſome change on external bodies, we think only of them; the inſtrument or tool is overlooked, and we ſay that we act on the external body. Our *real* action therefore is but the firſt movement in a long train of ſucceſſive events, and is but the remote cauſe of the intereſting event. The reſemblance to ſuch actions is very ſtrong indeed in many caſes of mechanical phenomena. A man throws a ball by the motion of his arm. A ſpring impels a ball in the ſame manner by unbending. Theſe two events reſemble each other in every circumſtance but the action of the mind on the corporeal organ—the reſt of it is a train of pure mechaniſm. In general, becauſe the ultimate reſults of the mutual influence of bodies on each other greatly reſemble the ultimate reſults of our actions on bodies, we have not invented appropriated terms, but have contented ourſelves with thoſe already employed for expreſſing our own actions, the exertions of our own powers or forces. The relation of phyſical cauſe and effect is expreſſed metaphorically in the words which belong properly to the relation of agent and action. This has been attended by the uſual conſequences of poverty of language, namely, ambiguity, and ſometimes miſtake, both in our reflections, (which are generally carried on by mental diſcourſe), our reaſonings, and our concluſions. It is neceſſary to be on our guard againſt ſuch miſtakes; for they frequently amount to the confounding of things totally different. Many philoſophers of great reputation, on no better foundation than this metaphorical language, have confounded the relations of activity and of cauſation, and even denied that there is any difference; and they have affirmed, that there is the ſame invariable relation between the determinations of the will and the inducements that prompt them, as there is between any phyſical power and its effect. Others have maintained, that the firſt mover in the mechanical operations, and indeed through the whole train of any complicated event, is a percipient and intending principle in the ſame manner as in our actions. According to theſe philoſophers, a particle of gravitating matter perceives its relation to every other particle in the univerſe, and determines its own motion according to fixed laws, in exact conformity to its ſituation. But the language, and even the actions of all men ſhew, that they have a notion of the relation of an agent to the action, eaſily diſtinguiſhable (becauſe all diſtinguiſh it) from the relation between the phyſical cauſe and its effect. The proofs of this fact have been adduced in other parts of the Encyclopædia, as, for example, in the article PHILOSOPHY, n° 42. and in this Supplement in the article ACTION.

Theſe remarks are not made in this place for any philological purpoſe, ſuch as the mere improvement of language, but becauſe this metaphorical language has affected the doctrines of mechanical philoſophy, and has produced a diſpute about ſome of its firſt principles; and becauſe we find, that the only way to decide this diſpute is to avoid, moſt ſcrupulouſly, all metaphorical language, though at the expence of much circumlocution. 6

Directions for the ſafe employment of this analogy.

When we ſpeak of powers or forces as reſiding in a body, and the effect as produced by their exertion, the body, conſidered as poſſeſſing the power, is ſaid to ACT on the other. A magnet is ſaid to act on a piece of iron; a billiard ball in motion is ſaid to act on one that is hit by it: but if we attempt to fix our attention on this action, as diſtinct both from the agent and the thing acted on, we find no object of contemplation.—The exertion or procedure of nature in producing the effect does not come under our view. When we *ſpeak* of the action as diſtinct from the agent, we find that it is not the action, properly ſpeaking, but the act that we ſpeak of. In like manner, the action of a mechanical power can be conceived only in the effect produced. 7

Action implies change; and mere motion is not action.

A man is not ſaid to act unleſs he produces ſome effect. Thought is the act of the thinking principle; motion of the limb is the act of the mind on it. In mechanics,

mechanics, alfo, there is action only in fo far as there is mechanical effect produced. I muft act violently in order to begin motion on a flide: I muft exert force, and this force exerted produces motion. I conceive the production of motion, in all cafes, as the exertion of force; but it requires no exertion to continue the motion along the flide; I am confcious of none, therefore I ought to infer that no force is neceffary for the continuation of any motion. The continuation of motion is not the production of any new effect, but the permanency of an effect already produced. We indeed confider motion as the effect of an action; but there would be no effect if the body were not moving. Motion is not the action, but the effect of the action.

8 *Preffion, impulfion.*

Mechanical actions have been ufually claffed under two heads: they are either PRESSURES or IMPULSIONS. They are generally confidered as of different kinds; the exertions of different powers. PRESSURE is fuppofed to differ effentially from IMPULSE.

Inftead of attempting to define, or defcribe, thefe two kinds of forces and actions, we fhall juft mention fome inftances. This will give us all the knowledge of their diftinctions that we can acquire.

Examples of preffion.

When a ball lies on a table, and I prefs it gently on one fide, it moves toward the other fide of the table. If I follow it with my finger, continuing my preffure, it accelerates continually in its motion. In like manner, when I prefs on the handle of a common kitchen jack, the fly *begins* to move. If I continue to urge or prefs round the handle, the fly accelerates continually, and may be brought into a ftate of very rapid motion. Thefe motions are the effects of genuine preffure. The ball would be urged along the table in the fame manner, and with a motion continually accelerated, by the unbending of a fpring. Alfo, a fpring coiled up round the axis of the handle of the jack would, by uncoiling itfelf, urge round the fly with a motion accelerating in the fame way. The more I reflect on the preffure of my finger on the ball, and compare it with the effect of the fpring on it, the more clearly do I fee the perfect fimilarity; and I call thefe influences, exertions, or actions, by one name, PRESSURE, taken from the moft familiar inftance of them.

Again, the very fame motion may be produced in the ball or fly, by pulling the ball or the machine by means of a thread, to which a weight is fufpended. As both are motions accelerated in the fame manner, I call the influence or action of the thread on the ball or machine by the fame name PRESSURE, and WEIGHT is confidered as a preffing power. Indeed I feel the fame compreffion from the real preffure of a man on my fhoulders that I would feel from a load laid on them. But the weight in our example is acting by the intervention of the thread. By its preffure it is pulling at that part of the thread to which it is faftened; this part is pulling at the next by means of the force of cohefion; and this pulls at a third, and fo on, till the moft remote pulls at the ball or the machine. Thus may elafticity, weight, cohefion, and other forces, perform the office of a genuine power; and fince their refult is always a motion beginning from nothing, and accelerating by perceptible degrees to any velocity, this refemblance makes us call them by one familiar name.

But farther, I fee that if the thread be cut, the weight will fall with an accelerated motion, which will increafe to any degree if the fall be great enough. I afcribe this alfo to a preffing power acting on the weight. Nay, after a very little refinement, I confider this power as the caufe of the body's weight; which word is but a diftinguifhing name for this particular inftance of preffing power. Gravitation is therefore added to the lift of preffures; and for fimilar reafons, the attractions and repulfions of magnets or electric bodies may be added to the lift. For they produce actual compreffions of bodies placed between them, and they produce motions gradually accelerated, precifely as gravitation does. Therefore all thefe powers may be diftinguifhed by this defcriptive name *preffures*, which, in ftrict language, belongs to one of them only.

Gravity, attractions, and repulfions, are confidered as preffions.

Several writers, however, fubdivide this great clafs into preffions and folicitations. Gravity is a folicitation *ab extra*, by which a body is urged downward. In like manner, the forces of magnetifm and electricity, and a vaft variety of other attractions and repulfions, are called *folicitations*. We fee little ufe for this diftinction, and the term is too like an affection of mind.

9 Examples of impulfion.

IMPULSION is exhibited when a ball in motion puts another ball into motion by hitting, or (to fpeak metaphorically) by ftriking it. The appearances here are very different. The body that is ftruck acquires, in the inftant of impulfe a fenfible quantity of motion, and fometimes a very rapid motion. This motion is neither accelerated nor retarded after the ftroke, unlefs it be affected by fome other force. It is alfo remarked, that the rapidity of the motion depends, *inter alia* on the previous velocity of the ftriking body; for inftance, if a clay ball, moving with any velocity, ftrike another equal ball which is at reft, the ftruck ball moves with half the velocity of the other. And it is farther remarkable, that the ftriking body always lofes as much motion as the ftruck body gains. This univerfal and remarkable fact feems to have given rife to a confufed or indiftinct notion of a fort of transference of motion from one body to another. The phrafeology in general ufe on this fubject expreffes this in the moft precife terms. The one ball is not faid to caufe or produce motion in the other, but to *communicate* motion to it; and the whole phenomenon is called the *communication of motion*. We call this an *indiftinct* notion; for furely no one will fay that he has any clear conception of it. We can form the moft diftinct notion of the communication of heat, or of the caufe of heat; of the communication of faltnefs, fweetnefs, and a thoufand other *things*; but we cannot conceive how part of that identical motion which was formerly in A, is now infufed into B, being given up by A. It is in our attempt to form this notion that we find that motion is not a *thing*, not a fubftance which can exift independently, and is fufceptible of actual transference. It appears in this cafe to be a ftate, or condition, or mode of exiftence, of which bodies are fufceptible, which is producible, or (to fpeak without metaphor) caufable in bodies, and which is the effect and *characteriftic* of *certain* natural qualities, properties or powers. We are anxious to have our readers impreffed with clear and precife notions on this fubject, being confident that fuch, and only fuch, will carry them through fome intricate paths of mechanical and philofophical refearch.

Communication of motion, not a good expreffion.

10 *Inherent force* is the diftinctive character of the impulfion,

The remarkable circumftance in this phenomenon is, that a rapid motion, which requires for the effecting it

the

the action of a preſſing power, continued for a ſenſible, and frequently a long time, ſeems to be effected in an inſtant by impulſion. This has tended much to ſupport the notion of the actual transference of ſomething formerly poſſeſſed excluſively by the ſtriking body, inhering in it, but ſeparable, and now transfuſed, into the body ſtricken. And now room is found for the employment of metaphor, both in thought and language. The *ſtriking* body affects the body which it thus impels: It therefore poſſeſſes the *power* of impulſion, that is, of *communicating* motion. It poſſeſſes it only while it is in motion. This *power*, therefore, is the efficient diſtinguiſhing cauſe of its motion, and its only office muſt be the continuation of this motion. It is therefore called the INHERENT FORCE, the force inherent in a moving body VIS INSITA *corpori moto*. This force is transfuſed into the body impelled, and *therefore* the transference is inſtantaneous, and the impelled body continues its motion till it is changed by ſome other action. All this is at firſt ſight very plauſible; but a ſcrupulous attention to thoſe feelings which have given riſe to this metaphorical conception, ſhould have produced very different notions. I am conſcious of exertion, in order to begin motion on a ſlide; but if the ice be very ſmooth, I am conſcious of no exertion in order to ſlide along. My power is felt only while I am conſcious of exerting it: Therefore I have no primitive feeling or notion of power while I am ſliding along. I am certain that no exertion of power is neceſſary here. Nay, I find that I cannot think of my moving forward without effort otherwiſe than as a certain mode of my exiſtence. Yet we imagine that the partiſans of this opinion did really deduce it in ſome ſhape from their feelings. We muſt continue the *exertion* of walking in order to walk on; our power of walking muſt be continually exerted, otherwiſe we ſhall ſtop. But this is a very imperfect, incomplete, and careleſs obſervation. Walking is much more than mere continuance in progreſſive motion. It is a continually repeated lifting our body up a ſmall height, and allowing it to come down again. This renewed aſcent requires repeated exertion.

11 And ſaid to be infinitely greater than preſſion.

We have other obſervations of importance yet to make on this force of moving bodies, but this is not the moſt proper occaſion. Meanwhile we muſt remark, that the inſtantaneous production of rapid motion by impulſe has induced the firſt mechanicians of Europe to maintain, that the power or force of impulſe is unſuſceptible of any compariſon with a preſſing power. They have aſſerted, that impulſe is infinitely great when compared with preſſure; not recollecting that they held them to be things totally diſparate, that have no proportion more than weight and ſweetneſs. But theſe gentlemen are perpetually enticed away from their creed by the ſimilarity of the ultimate reſults of preſſure and impulſe. No perſon can find any difference between the motion of two balls moving equally ſwift, in the ſame direction, one of which is deſcending by gravity and the other has derived its motion from a blow. This ſtruggle of the mind to maintain its faith, and yet accommodate its doctrines to what we ſee, has occaſioned ſome other curious forms of expreſſion. Preſſure is conſidered as an *effort* to produce motion. When a ball lies on a table, its weight, which they call a *power*, continually and repeatedly *endeavours* (mark the metaphorical word and thought) to move the ball downward. But theſe efforts are ineffectual. They ſay that this ineffectual power is *dead*, and call it a VIS MORTUA: but the force of impulſion is called a VIS VIVA, a living force. But this is very whimſical and very inaccurate. If the impelling ball falls perpendicularly on the other lying on the table, it will produce no motion any more than gravity will; and if the table be annihilated, gravity becomes a *vis viva*.

Arguments indiſtinct and inconcluſive.

We muſt now add, that in order to prove that impulſe is infinitely greater than preſſure, theſe mechanicians turn our attention to many familiar facts which plead ſtrongly in their favour. A carpenter will drive a nail into a board with a very moderate blow of his hammer. This will require a preſſure which ſeems many hundred times greater than the impelling effort of the carpenter. A very moderate blow will ſhiver into pieces a diamond which would carry the weight of a mountain. Seeing this prodigious ſuperiority in the impulſe, how ſhall they account for the production of motion by means of preſſure? for this motion of the hammer might have been acquired by its falling from a height; nay, it is actually acquired by means of the continued preſſure of the carpenter's arm. They conſider it as the aggregate of an infinity of ſucceeding preſſures in *every* inſtant of its continuance; ſo that the inſignificant ſmallneſs of each effort is compenſated by their inconceiveable number.

No difference between preſſion and impulſion.

On the whole, we do not think that there is clear evidence that there are two kinds of mechanical force eſſentially different in their nature. It is virtually given up by thoſe who ſay that impulſe is infinitely greater than preſſure. Nor is there any conſiderable advantage to be obtained by arranging the phenomenon under thoſe two heads. We may perhaps find ſome method of explaining ſatisfactorily the remarkable difference that is really obſerved in the two modes of producing motion: namely, the gradual production of motion by acknowledged preſſure, and the inſtantaneous production of it by impulſe. Indeed, we ſhould not have taken up ſo much of our readers attention with this ſubject, had it not been for ſome inferences that have been made from theſe premiſes, which meet us in our very entry on the conſideration of firſt principles, and that are of extenſive influence on the whole ſcience of mechanical philoſophy, and, indeed, on the whole ſtudy of nature.

12 Is impulſion the ſole cauſe of motion?

Mechanicians are greatly divided in their opinion about the nature of the ſole moving force in nature. Thoſe whom we are now ſpeaking of, ſeem to think that all motion is produced by preſſure: For when they conſider impulſe as equivalent to the aggregate of an infinity of repeated preſſures, they undoubtedly ſuppoſe any preſſure, however inſignificant, as a moving force. But there is a party, both numerous and reſpectable, who maintain that impulſion is the ſole cauſe of motion. We ſee bodies in motion, ſay they, and we ſee them impel others; and we ſee that this production of motion is regulated by ſuch laws, that there is but one abſolute quantity of motion in the univerſe which remains unalterably the ſame. It muſt therefore be transfuſed in the acts of colliſion. We alſo ſee, with clear evidence, in ſome caſes, that motion can produce preſſure. Euler adduces ſome very whimſical and complicated caſes, in which an action, preciſely ſimilar to preſſure, may be produced by motion. Thus, two balls connected by a thread, may be ſo ſtruck that they ſhall move forward, and at the ſame time wheel round. In this caſe the connecting thread will be ſtretched between them. Now, ſay the philoſophers, ſince we ſee motion, and ſee that preſſure may be produced by motion, it is prepoſterous to imagine that it is any thing elſe than a reſult of certain motions; and it is the buſineſs of a philoſopher to inquire and diſcover what motions produce the preſſures that we obſerve.

They then proceed to account for thoſe preſſing powers, or ſolicitations to motion, which we obſerve in the acceleration of falling bodies, the attractions of magnetiſm and electricity, and many other phenomena of this kind, where bodies are put in motion by the vicinity of other bodies, or (in the popular language) by the action of other bodies at a diſtance. To ſay that a magnet can act on a piece of remote iron, is to ſay that it can act *where* it is not; which is as abſurd as to ſay, that it can act *when* it is not. *Nihil movetur*, ſays Euler, *niſi a contiguo et moto.*

How does it produce preſſure?

The bulk of theſe philoſophers are not very anxious about the way in which theſe motions are produced, nor do they fall upon ſuch ingenious methods of producing preſſure as the one already mentioned, which was adduced by Euler. The piece of iron, ſay they, is put in motion when brought into the neighbourhood of a magnet, becauſe there is a ſtream of fluid iſſuing from one pole of the magnet, which circles round the magnet, and enters at the other pole: This ſtream impels the iron, and arranges it in certain determined poſitions, juſt as a ſtream of water would arrange the flote graſs. In the ſame manner, there is a ſtream of fluid continually moving towards the centre of the earth, which impels all bodies in lines perpendicular to the ſurface; and ſo on with regard to other like phenomena. Theſe motions are thus reduced to very ſimple caſes by impulſion.

Incompatible with the rules of philoſophiſing.

It is unneceſſary to refute this doctrine at preſent; it is enough that it is contrary to all the dictates of common ſenſe. To *ſuppoſe* an agent that we do not ſee, and for whoſe exiſtence we have not the ſmalleſt argument; with equal propriety we might ſuppoſe miniſtering ſpirits, or any thing that we pleaſe.

13 Others maintain that preſſure is the ſole moving force.

Other philoſophers are ſo diſſatisfied with this notion of the production of preſſure, that they, on the other hand, affirm that preſſure is the only moving force in nature; not according to the popular notion of preſſure, by the mutual contact of ſolid bodies, but that kind of preſſure which has been called *ſolicitation*; ſuch as the power of gravity. They affirm, that there is no ſuch thing as contact on inſtantaneous communication of motion by real colliſion. They ſay (and they prove it by very convincing facts (ſee Optics, nº 63—68. *Encycl.*), that the particles of ſolid bodies exert very ſtrong repulſions to a ſmall diſtance; and therefore, when they are brought by motion ſufficiently near to another body, they repel it, and are equally repelled by it. Thus is motion produced in the other body, and their own motion is diminiſhed. And they then ſhew, by a ſcrupulous conſideration of the ſtate of the bodies while the one is advancing and the other retiring, in what manner the two bodies attain a common velocity, ſo that the quantity of motion before colliſion remains unchanged, the one body gaining as much as the other loſes. They alſo ſhew caſes of ſuch mutual action between bodies, where it is evident that they have never come into contact; and yet the reſult has been preciſely ſimilar to thoſe caſes where the motion appeared to be changed in an inſtant. Therefore they conclude, that there is no ſuch thing as inſtantaneous *communication*, or transfuſion of motion, by contact in colliſion or impulſe. The reaſon why previous motion of the impelling body is neceſſary, is not that it may have a *vis inſita corpori moto*, a force inherent in it *by its being in motion*, but that it may continue to follow the impelled and retiring body, and exert on it a force inherent in itſelf, whether in motion or at reſt.—According to theſe philoſophers, therefore, all moving forces are of that kind which has been named *ſolicitation*; ſuch as gravity. We ſhall know it afterwards by the more familiar and deſcriptive name of Accelerating or Retarding force.

14 Action, Reſiſtance, Reaction.

The exertions of mechanical forces are differently termed, according to the reference that we make to the reſult. If, in boxing or wreſtling, I ſtrike, or endeavour to throw my antagoniſt. I am ſaid to act; but if I only parry his blows, or prevent him from throwing me, I am ſaid to resist. This diſtinction is applied to the exertions of mechanical powers. When one body A changes the motion of another B, we may conſider the change in the motion of B either as the indication and meaſure of A's power of producing motion, or as the indication and meaſure of A's reſiſtance to the being brought to reſt, or having its motion any how changed. The diſtinction is not in the thing itſelf, but only in the reference that we are diſpoſed, by other conſiderations, to make of its effect. They may be diſtinguiſhed in the following manner: If a change of motion follow when one of the powers ceaſes to be exerted, that power is conceived as having reſiſted. The whole language on this ſubject is metaphorical. Reſiſtance, effort, endeavour, &c. are words which cannot be employed in mechanical diſcuſſions without figure, becauſe they all expreſs notions which relate to ſentient beings; and the unguarded indulgence of this figurative language has ſo much affected the imagination of philoſophers, that many have almoſt animated all matter. Perhaps the word Reaction, introduced (we think) by Newton, is the beſt term for expreſſing that mutual force which is perceived in all the operations of nature that we have inveſtigated with ſucceſs. As the magnet attracts iron, and in ſo doing is ſaid to *act* on it; ſo the iron attracts the magnet, and may be ſaid to *react* on it.

15 We need not ſuppoſe action at a diſtance. Tendency.

With reſpect to the difficulty that has been objected to the opinion of thoſe who maintain that all the mechanical phenomena are produced by the agency of attracting or repelling forces; namely, that this ſuppoſes the bodies to act on each other at a diſtance, however ſmall thoſe diſtances may be, which is thought to be abſurd, we may obſerve, that we may aſcribe the mutual approaches or receſſes to tendencies to or from each other. What we call *the attraction of the magnet* may be conſidered as a tendency of the iron to the magnet, ſomewhat ſimilar to the gravitation of a ſtone toward the earth. We ſurely (at leaſt the unlearned) can and do conceive the iron to be affected by the magnet, *without thinking* of any intermedium. The thing is not therefore inconceivable; which is all that we know

know about absurdity: and we do not know any thing about the nature or essence of matter which renders this tendency to the magnet impossible. That we do not see intuitively any reason why the iron should approach the magnet, must be granted; but this is not enough to intitle us to say, that such a thing is impossible or inconsistent with the nature of matter. It appears, therefore, to be very hasty and unwarrantable, to suppose the impulse of an invisible fluid, of which we know nothing, and of the existence of which we have no proof. Nay, if it be true that bodies do not come into contact, even when one ball hits another, and drives it before it, this invisible fluid will not solve the difficulty; because the same difficulty occurs in the action of any particle of the fluid on the body. We are obliged to say, that the production of motion without any *observed* contact, is a much more familiar phenomenon than the production of motion by impulsion. More motion has been produced in this way by the gravitation of a small stream of water, running ever since the creation, than by all the impulses in the world twice told. We do not mean by this to say, that the giving to this observed mutual relation between iron and a loadstone the name tendency makes it less absurd, than when we say that the loadstone attracts the iron; it only makes it more conceivable: It suggests a very familiar analogy; but both are equally figurative expressions; at least as the word tendency is used at present. In the language of ancient Rome, there was no metaphor when Virgil's hero said, *Tendimus in Latium. Tendere versus solem* means, in plain Latin to *approach the sun*. The safe way of conceiving the whole is to say, that the condition of
16 the iron depends on the vicinity of the magnet.

Attraction, Repulsion, are figurative terms.

When the exertions of a mechanical power are observed to be always directed toward a body, that body is said to attract. But when the other body always moves off from it, it is said to repel. These also are metaphorical expressions. I attract a boat when I pull it toward me by a rope; this is purely ATTRACTION: and it is pure, unfigurative REPULSION, when I push any body from me. The same words are applied to the mechanical phenomena, merely because they resemble the results of real attraction or repulsion. We must be much on our guard to avoid metaphor in our conceptions, and never allow those words to suggest to our mind any opinion about the *manner* in which the mechanical forces produce their effects. It is plain, that if the opinion of those who maintain the existence and action of the above-mentioned invisible fluid be just, there is nothing like attraction or repulsion in the universe. We must always recur to the simple phenomenon, the motion to or from the attracting or repelling body; for this is all we see, and ge-
17 nerally all that we know.

Forces are conceived as measurable quantities.

We conceive one man to have twice the strength of another man, when we see that he can withstand the united effort of two others. Thus animal force is conceived as a quantity, made up of, and measured by, its own parts. But we doubt exceedingly, whether this be an accurate conception. We have not a distinct notion of one strain added to another; though we have of their being joined or combined. We want words to express the difference of these two notions in our own minds; but we imagine that others perceive the same difference. We conceive clearly the addition of two lines or of two minutes: we can conceive them apart, and perceive their boundaries common to both, where one ends and the other begins. We cannot conceive thus of two forces combined; yet we cannot say, that two equal forces are *not* double of one of them. We measure them by the effects which they are known to produce. Yet there are not wanting many cases where the action of two men, equally strong, does not produce a double motion.

How measured.

In like manner, we conceive all mechanical forces as measurable by their effects; and thus they are made the subjects of mathematical discussion. We talk of the proportions of gravity, magnetism, electricity, &c.; nay, we talk of the proportion of gravity to magnetism: Yet these considered in themselves, are disparate, and do not admit of any proportion; but they produce effects, some of which are measurable, and whose assumed measures are susceptible of comparison, being quantities of the same kind. Thus, one of the effects of gravity is the acceleration of motion in a falling body: magnetism will also accelerate the motion of a piece of iron; these two accelerations are comparable. But we cannot compare magnetism with heat; because we do not know any measurable effects of magnetism that are of the same kind with any effects of heat.

By their effects.

When we say, that the gravitation of the moon is the 3600th part of the gravitation at the sea shore, we mean that the fall of a stone in a second is 3600 times greater than the fall of the moon in the same time. But we also mean (and this expresses the proportion of the *tendency* of gravitation more purely), that if a stone, when hung on a spring steelyard, draw out the rod of the steelyard to the mark 3600, the same stone, taken up to the distance of the moon, will draw it out no further than the mark 1. We also mean, that if the stone at the sea shore draw out the rod to any mark, it will require 3600 such stones to draw it out to that mark, when the trial is made at the distance of the moon. It is not, therefore, in consequence of any immediate perception of the proportion of the gravitation at the moon to that at the surface of the earth that we make such an assertion; but these motions, which we consider as its effects in these situations being magnitudes of the same kind, are susceptible of comparison, and have a proportion which can be ascertained by observation. It is these proportions that we contemplate; although we speak of the proportions of the unseen causes, the forces or endeavours to descend. It will be of material service to the reader to peruse the judicious and acute dissertation on *quantity* in the 45th volume of the Philosophical Transactions; or he may study the article QUANTITY in the *Encyclopædia*, where, we trust, he will see clearly how force, velocity, density, and many other magnitudes of very frequent occurrence in mechanical philosophy, may be made the subjects of mathematical discussion, by means of some of those proper quantities, measurable by their own parts, which are to be assumed as their measures. Pressures are measurable only by pressures. When we consider them as moving powers, we should be able to measure them by *any* moving powers, otherwise we cannot compare them; therefore it is not as pressures that we then measure them. This observation is momentous.

One circumstance must be carefully attended to. That

That thofe affumed meafures may be accurate, they muft be invariably connected with the magnitudes which they are employed to meafure, and fo connected, that the degrees of the one muft change in the fame manner with the degrees of the other. This is evident, and is granted by all. But we muft alfo *know* this of the meafure we employ; we muft fee this conftant and precife relation. How can we know this? We do not perceive force as a feparate exiftence, fo as to fee its proportions, and to fee that thefe are the fame with the proportions of the meafures, in the fame manner that Euclid fees the proportions of triangles and thofe of their bafes, and that thefe proportions are the fame, when the triangles are of equal altitudes. How do we difcover that to every magnitude which we call *force* is invariably attached a correfponding magnitude of acceleration or deflection?—Clearly. In fact, the very exiftence of the force is an inference that we make from the obferved acceleration; and the degree of the force is, in like manner, an inference from the obferved magnitude of the acceleration. Our meafures are therefore neceffarily connected with the magnitudes which they meafure, and their proportions are the fame; becaufe the one is always an inference from the other,
18 both in fpecies and degree.

Dynamics is a demonftrative fcience.

It is now evident, that thefe difquifions are fufceptible of mathematical accuracy. Having felected our meafures, and obferved certain mathematical relations of thofe meafures, every inference that we can draw from the mathematical relations of the proportions of thofe reprefentations is true of the proportions of the motions, and therefore of the proportions of the forces. And thus dynamics becomes a demonftrative fcience, one of the *difciplinæ accuratæ*.

19 But moving forces are confidered as differing alfo in kind; that is in direction. We affign to the force the direction of the obferved change of motion; which is not only the indication, but alfo the characteriftic, of the changing force. We call it an *accelerating*, *retarding*, *deflecting*, *force*, according as we obferve the motion to be accelerated, retarded or deflected.

Thefe denominations fhew us inconteftibly that we have no knowledge of the forces different from our knowledge of the effects. The denominations are all either defcriptive of the effects, as when we call them accelerating, penetrating, protrufive, attractive, or repulfive forces; or they are names of reference to the fubftances in which the accelerating, protrufive, &c. forces, are fuppofed to be inherent, as when we call them
20 *magnetifm*, *electricity*, *corpufcular*, &c.

Forces are difcovered by their oppofition to other forces.

When I ftruggle with another, and feel, that in order to prevent being thrown, I muft exert force, I learn that my antagonift is exerting force. This notion is transferred to matter; and when a moving power which is *known* to operate produces no motion, we conceive it to be oppofed by another equal force; the exiftence, agency, and intenfity of which is detected and meafured by thefe means. The quiefcent ftate of the body is confidered as a change on the ftate of things that would have been exhibited in confequence of the known action of one power, had this other power not acted; and this change is confidered as the indication, characteriftic, and meafure, of another power, detected in this way. Thus forces are recognifed not only by the changes of motion which they produce, but alfo by the changes of motion which they prevent. The cohefion of matter in a ftring is inferred not only by its giving motion to a ball which I pull toward me by its intervention, but alfo by its fufpending that ball, and hindering it from falling. I know that gravity is acting on the ball, which, however, does not fall. The folidity of a board is equally inferred from its ftopping the ball which ftrikes it, and from the motion of the ball which it drives before it. In this way we learn that the particles of tangible matter cohere by means of moving forces, and that they refift compreffion with force; and in making this inference we find that this corpufcular force exerted between the particles is mutual, oppofite and equal: for we muft apply force equally to *a* or to *b*, in order to produce a feparation or a compreffion. We learn their equality, by obferving that no motion enfues while thefe mutual forces are known to act on the particles; that is, each is oppofed by another force, which is neither inferior nor fuperior to it.

Of the Laws of Motion.

Such, then, being our notions of mechanical forces, the caufes of the fenfible changes of motion, there will refult certain confequences from them, which may be called axioms or laws of motion. Some of thefe may be intuitive, offering themfelves to the mind as foon as the notions which they involve are prefented to it. Others may be as neceffary refults from the relations of thefe notions, but may not readily offer themfelves without the mediation of axioms of the firft clafs. We fhall felect thofe which are intuitive, and may be taken for the firft principles of all difcuffions in mechanical philofophy.

First Law of Motion.

Every body continues in a ftate of reft, or of uniform rectilineal motion, unlefs affected by fome mechanical force.

This is a propofition, on the truth of which the whole 21
fcience of mechanical philofophy ultimately depends. It is therefore to be eftablifhed on the firmeft foundation; and a folicitude on this head is the more juftifiable, becaufe the opinions of philofophers have been, and ftill are, extremely different, both with refpect to the truth of this law, and with refpect to the foundation on which it is built. Thefe opinions are, in general, very obfcure and unfatisfactory; and, as is natural, they influence the difcuffions of thofe by whom they are held through the whole fcience. Although of contradictory opinions one only can be juft, and it may appear fufficient that this one be eftablifhed and uniformly applied; yet a fhort expofition, at leaft, of the reft is neceffary, that the greateft part of the writings of the philofophers may be intelligible, and that we may avail ourfelves of much valuable information contained in them, by being able to perceive the truth in the midft of their imperfect or erroneous conceptions of it. 22

Does continued motion indicate continued action?

It is not only the popular opinion that reft is the natural ftate of body, and that motion is fomething foreign to it, but it has been ferioufly maintained by the greateft part of thofe who are efteemed philofophers. They readily grant, that matter will continue at reft, unlefs fome moving force act upon it. Nothing feems neceffary for matter's remaining where it is, but its

First Law of Motion.

continuing to exiſt. But it is far otherwiſe, ſay they, with reſpect to matter in motion. Here the body is continually changing its relations to other things; therefore the continual agency of a changing cauſe is neceſſary (by the fundamental principle of all philoſophical diſcuſſion), for there is here the continual production of an effect. They ſay that this metaphyſical argument receives complete confirmation (if confirmation of an intuitive truth be neceſſary) from the moſt familiar obſervation. We ſee that all motions, however violent, terminte in reſt, and that the continual exertion of ſome force is neceſſary for their continuance.

23 Whimſical notion of elemental minds.

Theſe philoſophers therefore aſſert, that the continual action of the moving cauſe is *eſſentially* neceſſary for the continuance of the motion: but they differ among themſelves in their notions and opinions about this cauſe. Some maintain, that all the motions in the univerſe are produced and continued by the immediate agency of Deity; others affirm, that in every particle of matter there is inherent a ſort of mind, the φυσις and ὁσπερ-ψυχη of Ariſtotle, which they call an Elemental Mind, which is the cauſe of *all* its motions and changes. An overweaning reverence for Greek learning has had a great influence in reviving this doctrine of Ariſtotle. The Greek and Roman languages are affirmed to be more accurate expreſſions of human thought than the modern languages are. In thoſe ancient languages, the verbs which expreſs motion are employed both in the active and paſſive voice; whereas we have only the active verb *to move*, for expreſſing both the ſtate of motion and the act of putting in motion. "The ſtone *moves* down the ſlope, and *moves* all the pebbles which lie in its way;" but in the ancient languages, the mere ſtate of motion is always expreſſed by the paſſive or middle voice. The accurate conception of the ſpeakers is therefore extolled. The ſtate of motion is expreſſed as it ought to be, as the reſult of a continual action." κινειται, *movetur*, is equivalent to "it is moved." According to theſe philoſophers, every thing which *moves* is mind, and every thing that *is moved* is body.

The argument is futile, and it is falſe; for the modern languages are, in general, equally accurate in this inſtance: "*ſe mouvoir*," in French; "*ſich bewegen*," in German; "*dvigatſu*," in Slavonic; are all paſſive or reflected. And the ancients ſaid, that "rain falls, water runs, ſmoke riſes," juſt as we do. The ingenious author of *Ancient Metaphyſics* has taken much pains to give us, at length, the procedures of thoſe elementary minds in producing the oſtenſible phenomena of local motion; but it ſeems to be merely an abuſe of language, and a very frivolous abuſe. This elemental mind is known and characteriſed only by the effect which we aſcribe to its action; that is, by the motions or changes of motions. Uniform and unexcepted experience ſhews us that theſe are regulated by laws as preciſe as thoſe of mathematical truth. We conſider nothing as more fixed and determined than the common laws of mechaniſm. There is nothing here that indicates any thing like ſpontaneity, intention, purpoſe; none of thoſe marks by which mind was firſt brought into view; but they are very like the effects which we produce by the exertions of our corporeal forces, and we have accordingly given the name of *force* to the cauſes of motion. It is ſurely much more appoſite than the name mind, and conveys with much more readineſs and perſpicuity the very notions that we wiſh to convey.

24 Action not neceſſary for the continuance of motion.

We now wiſh to know what reaſon we have to think that the continual action of ſome cauſe is neceſſary for continuing matter in motion, or for thinking that reſt is its natural ſtate; if we pretend to draw any argument from the nature of matter, that matter muſt be known, as far as is neceſſary, for being the foundation of argument. Its very exiſtence is known only from obſervation; all our knowledge of it muſt therefore be derived from the ſame ſource.

If we take this way to come at the origin of this opinion, we ſhall find that experience gives us no authority for ſaying that reſt is the natural condition of matter. We cannot ſay that we have ever ſeen a body at reſt; this is evident to every perſon who allows the validity of the Newtonian philoſophy, and the truth of the Copernican ſyſtem of the ſun and planets; all the parts of this ſyſtem are in motion. Nay, it appears from many obſervations, that the ſun, with his attending planets, is carried in a certain direction, with a velocity which is very great. We have no unqueſtionable authority for ſaying that any one of the ſtars is abſolutely fixed. But we are *certain* that many of them are in motion. Reſt is therefore ſo rare a condition of body, that we cannot ſay, from any experience, that it is its natural ſtate.

It is eaſy, however, to ſee, that it is from obſervation that this opinion has been derived; but the obſervation has been limited and careleſs. Our experiments in this ſublunary world do indeed always require continued action of ſome moving force to continue the motion; and if this be not employed, we ſee the motions ſlacken every minute, and terminate in reſt after no long period. Our firſt notions of ſublunary bodies are indicated by their operation in caſes where we have ſome intereſt. Perpetually ſeeing our own exertions neceſſary, we are led to conſider matter as ſomething not only naturally quieſcent and inert, but ſluggiſh, averſe from motion, and prone to reſt (we muſt be pardoned this metaphorical language, becauſe we can find no other term). What is expreſſed by it, on this occaſion, is preciſely one of the erroneous or inadequate conceptions that are ſuggeſted to our thoughts by reaſon of the poverty of language. We animate matter in order to give it motion, and then we endow it with a ſort of moral character in order to explain the appearance of thoſe motions. 25

But more extended obſervation has made men gradually deſert their firſt opinions, and at laſt allow that matter has no peculiar aptitude to reſt. All the retardations that we *obſerve* have been diſcovered, one after another, to have a diſtinct reference to ſome external circumſtances. The diminution of motion is always obſerved to be accompanied by the removal of obſtacles, as when a ball moves through ſand, or water, or air; or it is owing to oppoſite motions which are deſtroyed; or it is owing to roughneſs of the path, or to friction, &c. We find that the more we can keep thoſe things out of the way, the leſs are the motions diminiſhed. A pendulum will vibrate but a ſhort while in water; much longer in air; and in the exhauſted receiver it will vibrate a whole day. We know that we cannot remove *all* obſtacles; but we are led by ſuch obſervations 26 ſervations to conclude that, if they *could be completely removed*, our motions would continue forever. And this concluſion is almoſt demonſtrated by the motions of the heavenly bodies, to which we know of no obſtacles, and which we really obſerve to retain their motions for many thouſand years without the ſmalleſt ſenſible diminution.

27 Inactivity of matter denied by Leibnitz.

Another ſet of philoſophers maintain an opinion directly oppoſite to that of the inactivity of matter, and aſſert, that it is eſſentially active, and continually changing its ſtate. Faint traces of this are to be found in the writings of Plato, Ariſtotle, and their commentators. Mr Leibnitz is the perſon who has treated this queſtion moſt ſyſtematically and fully. He ſuppoſes every particle of matter to have a principle of individuality, which he therefore calls a Monad. This monad has a ſort of *perception* of its ſituation in the univerſe, and of its relation to every other part of this univerſe. Laſtly, he ſays that the monad acts on the material particle, much in the ſame way that the ſoul of man acts on his body. It modifies the motion of the material atom (in conformity, however, to unalterable laws), producing all thoſe modifications of motion that we obſerve. Matter, therefore, or, at leaſt, particles of matter, are continually active, and continually changing their ſituation.

Monads, what.

This opinion ill-founded.

It is quite unneceſſary to enter on a formal confutation of Mr Leibnitz's ſyſtem of monads, which differs very little from the ſyſtem of elemental minds, and is equally whimſical and frivolous; becauſe it only makes the unlearned reader ſtare, without giving him any information. Should it even be granted, it would not, any more than the action of animals, invalidate the general propoſition which we are endeavouring to eſtabliſh as the fundamental law of motion. Thoſe powers of the monads or of the elemental minds, are the cauſes of all the changes of motion; but the mere material particle is ſubject to the law, and requires the exertion of the monad in order to exhibit a change of motion.

28 Some philoſophers deduce this law of motion from the want of a *determining* cauſe.

A third ſect of philoſophers, at the head of which we may place Sir Iſaac Newton, maintain the doctrine enounced in the propoſition. But they differ much in reſpect of the foundation on which it is built.

Some aſſert that its truth flows from the nature of the thing. If a body be at reſt, and you aſſert that it will not remain at reſt, it muſt move in ſome one direction. If it be in motion in any direction, and with any velocity, and do not continue its equable rectilineal, motion, it muſt either be accelerated or retarded; it muſt turn either to one ſide or to ſome other ſide. The event, whatever it be, is individual and determinate; but no cauſe which can determine it is ſuppoſed: therefore the determination cannot take place, and no change will happen in the condition of the body with reſpect to motion. It will continue at reſt, or perſevere in its rectilineal and equable motion.

But conſiderable objections may be made to this argument of *ſufficient reaſon*, as it is called. In the immenſity and perfect uniformity of ſpace and time, there is no determining cauſe why the viſible univerſe ſhould exiſt in the place in which we ſee it rather than in another, or at this time rather than at another. Nay, the argument ſeems to beg the queſtion. A cauſe of determination is required as eſſentially neceſſary—a determination may be without a cauſe, as well as a motion without a cauſe.

29 Others deduce it from experience.

Other philoſophers, who maintain this doctrine, conſider it merely as an experimental truth; and proofs of its univerſality are innumerable.

When a ſtone is thrown from the hand, we preſs it forward while in the hand, and let it go when the hand has acquired the greateſt rapidity of motion that we can give it. The ſtone continues in that ſtate of motion which it acquired gradually along with the hand. We can throw a ſtone much farther by means of a ſling; becauſe, by a very moderate motion of the hand, we can whirl the ſtone round till it acquire a very great velocity, and then we let go one of the ſtrings, and the ſtone eſcapes, *by continuing* its rapid motion. We ſee it ſtill more diſtinctly in ſhooting an arrow from a bow. The ſtring preſſes hard on the notch of the arrow, and it yields to this preſſure and goes forward. The ſtring alone would go faſter forward. It therefore *continues* to preſs the arrow forward, and accelerates its motion. This goes on till the bow is as much unbent as the ſtring will allow. But the ſtring is now a ſtraight line. It came into this poſition with an accelerated motion, and it therefore goes a little beyond this poſition, but with a retarded motion, being checked by the bow. But there is nothing to check the arrow; therefore the arrow quits the ſtring, and flies away.

Theſe are ſimple caſes of perſeverance in a ſtate of motion, where the procedure of nature is ſo eaſily traced that we perceive it almoſt intuitively. It is no leſs clear in other phenomena which are more complicated; but it requires a little reflection to trace the proceſs. We have often ſeen an equeſtrian ſhowman ride a horſe at a gallop, ſtanding on the ſaddle, and ſtepping from it to the back of another horſe that gallops alongſide at the ſame rate; and he does this ſeemingly with as much eaſe as if the horſes were ſtanding ſtill. The man has the ſame velocity with the horſe that gallops under him, and keeps this velocity while he ſteps to the back of the other. If that other were ſtanding ſtill, the man would fly over his head. And if a man ſhould ſtep from the back of a horſe that is ſtanding ſtill to the back of another that gallops paſt him, he would be left behind. In the ſame manner, a ſlack wire dancer toſſes oranges from hand to hand while the wire is in full ſwing. The orange, ſwinging along with the hand, retains the velocity; and when in the air follows the hand, and falls into it when it is in the oppoſite extremity of its ſwing. A ball, dropped from the maſt-head of a ſhip that is ſailing briſkly forward, falls at the foot of the maſt. It retains the motion which it had while in the hand of the perſon who dropped it, and follows the maſt during the whole of its fall.

We alſo have familiar inſtances of the perſeverance of a body in a ſtate of reſt. When a veſſel filled with water is drawn ſuddenly along the floor, the water daſhes over the poſterior ſide of the veſſel. It is left behind. In the ſame manner, when a coach or boat is dragged forward, the perſons in it find themſelves ſtrike againſt the hinder part of the carriage or boat. Properly ſpeaking, it is the carriage that ſtrikes on them. In like manner, if we lay a card on the tip of the finger, and a piece of money on the card, we may nick away the card by hitting it neatly on its edge; but the piece of money will be left behind, lying on the tip of the finger. A ball will go through a wall and fly onward; but the wall is left behind. Buildings are thrown down by earthquakes; ſometimes by being toſſed from their foundations, but more generally by the ground on which they ſtand being haſtily drawn ſidewiſe from under them, &c.

30 Common experience inſufficient.

But common experience ſeems inſufficient for eſtabliſhing this fundamental propoſition of mechanical philoſophy. We muſt, on the faith of the Copernican ſyſtem, grant that we never ſaw a body at reſt, or in uniform rectilineal motion; yet this ſeems abſolutely neceſſary before we can ſay that we have eſtabliſhed this propoſition experimentally.

What we imagine, in our experiments, to be putting a body, formerly at reſt, into motion, is, in fact, only changing a moſt rapid motion, not leſs, and probably much greater, than 90,000 feet per ſecond. Suppoſe a cannon pointed eaſt, and the bullet diſcharged at noon day with 60 times greater velocity than we have ever been able to give it. It would appear to ſet out with this unmeaſurable velocity to the eaſtward; to be gradually retarded by the reſiſtance of the air, and at laſt brought to reſt by hitting the ground. But, by reaſon of the earth's motion round the ſun, the fact is quite the reverſe. Immediately before the diſcharge, the ball was moving to the weſtward with the velocity of 90,000 feet per ſecond nearly. By the exploſion of the powder, and its preſſure on the ball, ſome of this motion is deſtroyed, and at the muzzle of the gun, the ball is moving ſlower, and the cannon is hurried away from it to the weſtward. The air, which is alſo moving to the weſtward 90,000 feet in a ſecond, gradually communicates motion to the ball, in the ſame manner as a hurricane would do. At laſt (the ball dropping all the while) ſome part of the ground hits the ball, and carries it along with it.

Other obſervations muſt therefore be reſorted to, in order to obtain an experimental proof of this propoſition. And ſuch are to be found. Although we cannot meaſure the abſolute motions of bodies, we can obſerve and meaſure accurately their relative motions, which are the differences of their abſolute motions. Now, if we can ſhew experimentally, that bodies ſhew equal tendencies to reſiſt the augmentation and the diminution of their relative motions, they, *ipſo facto*, ſhew equal tendencies to reſiſt the augmentation or diminution of their abſolute motions. Therefore let two bodies, A and B, be put into ſuch a ſituation, that they cannot (by reaſon of their impenetrability, or the actions of their mutual powers) perſevere in their relative motions. The change produced on A is the effect and the meaſure of B's tendency to perſevere in its former ſtate; and therefore the proportion of theſe changes will ſhew the proportion of their tendencies to maintain their former ſtates. Therefore let the following experiment be made at noon.

Experiments proper for the purpoſe.

Let A, apparently moving weſtward three feet per ſecond, hit the equal body B apparently at reſt. Suppoſe, 1*ſt*, That A impels B forward, without any diminution of its own velocity. This reſult would ſhew that B manifeſts no tendency to maintain its motion unchanged, but that A retains its motion undiminiſhed.

2*dly*, Suppoſe that A ſtops, and that B remains at reſt. This would ſhew that A does not reſiſt a diminution of motion, but that B retains its motion unaugmented.

3*dly*, Suppoſe that both move weſtward with the velocity of one foot per ſecond. The change on A is a diminution of velocity, amounting to two feet per ſecond. This is the effect and the meaſure of B's tendency to maintain its velocity unaugmented. The change on B is an augmentation of one foot per ſecond made on its velocity; and this is the meaſure of A's tendency to maintain its velocity undiminiſhed. This tendency is but half of the former; and this reſult would ſhew, that the reſiſtance to a diminution of velocity is but half of the reſiſtance to augmentation. It is perhaps but one quarter; for the change on B has produced a double change on A.

4*thly*, Suppoſe that both move weſtward at the rate of $1\frac{1}{2}$ feet per ſecond. It is evident that their tendencies to maintain their ſtates unchanged are now equal.

5*thly*, Suppoſe A = 2 B, and that both move, after the colliſion, two feet per ſecond, B has received an addition of two feet per ſecond to its former velocity. This is the effect and the meaſure of A's whole tendency to retain its motion undiminiſhed. Half of this change on B meaſures the perſevering tendency of the half of A; but A, which formerly moved with the apparent or relative velocity three, now moves (by the ſuppoſition) with the velocity two, having loſt a velocity of one foot per ſecond. Each half of A therefore has loſt this velocity, and the whole loſs of motion is two. Now this is the meaſure of B's tendency to maintain its former ſtate unaugmented; and this is the ſame with the meaſure of A's tendency to maintain its own former ſtate undiminiſhed. The concluſion from ſuch a reſult would therefore be, that bodies have equal tendencies to maintain their former ſtates of motion without augmentation and without diminution.

What is ſuppoſed in the 4*th* and 5*th* caſes is really the reſult of all the experiments which have been tried; and this law regulates all the changes of motion which are produced by the mutual actions of bodies in impulſions. This aſſertion is true without exception or qualification. Therefore it appears that bodies have no preferable tendency to reſt, and that no fact can be adduced which ſhould make us ſuppoſe that a motion once begun ſhould ſuffer any diminution without the action of a changing cauſe.

But experience is not the proper foundation of an axiom.

But we muſt now obſerve, that this way of eſtabliſhing the firſt law of motion is very imperfect, and altogether unfit for rendering it the fundamental principle of a whole and extenſive ſcience. It is ſubject to all the inaccuracy that is to be found in our beſt experiments; and it cannat be applied to caſes where ſcrupulous accuracy is wanted, and where no experiment can be made.

Let us therefore examine the propoſition by means of the general principles adopted in the article PHILOSOPHY, *Encycl.* which contain the foundation of all our knowledge of active nature. Theſe principles will, we imagine, give a deciſion of this queſtion that is ſpeedy and accurate; ſhewing the propoſition to be an axiom or intuitive conſequence of the relations of thoſe ideas which we have of motion, and of the cauſes of its production and changes.

31 Logical proof.

'It has been fully demonſtrated that the powers or forces, of which we ſpeak ſo much, are never the immediate

diate objects of our perception. Their very existence, their kind, and their degree, are instinctive inferences from the motions which we observe and class. It evidently follows from this experimental and universal truth, *1st*, That where no change of motion is observed, no such inference is made; that is, no power is *supposed* to act. But whenever any change of motion is observed, the inference is made; that is, a power or force is supposed to have acted.

In the same form of logical conclusion, we must say that, *2dly*, When no change of motion is *supposed* or thought of, no force is *supposed;* and that whenever we *suppose* a change of motion, we, in fact, though not in terms, suppose a changing force. And, on the other hand, whenever we suppose the action of a changing force, we suppose the change of motion; for the action of this force, and the change of motion, is one and the same thing. We cannot think of the action without thinking of the indication of that action; that is, the change of motion.—In the same manner, when we do not think of a changing force, or suppose that there is no action of a changing force, we, in fact, though not in terms, suppose that there is no indication of this changing force; that is, that there is no change.

It is a law of human thought,

Whenever, therefore, we suppose that no mechanical force is acting on a body, we, in fact, suppose that the body continues in its former condition with respect to motion. If we suppose that nothing accelerates, or retards, or deflects the motion, we suppose that it is not accelerated, nor retarded, nor deflected. Hence follows the proposition in express terms—*We suppose that the body continues in its former state of rest or motion, unless we suppose that it is changed by some mechanical force.*

Thus it appears, that this proposition is not a matter of experience or contingency, depending on the properties which it has pleased the Author of Nature to bestow on body: it is, to us, a necessary truth. The proposition does not so much express any thing with regard to body, as it does the operations of our mind when contemplating body. It may perhaps be essential to body to move in some particular direction. It may be essential to body to stop as soon as the moving cause has ceased to act; or it may be essential to body to diminish its motion gradually, and finally come to rest. But this will not invalidate the truth of this proposition. These circumstances in the nature of body, which render those modifications of motion essentially necessary, are the causes of those modifications; and, in our study of nature, they will be considered by us as changing forces, and will be known and called by that name. And if we should ever see a particle of matter in such a situation that it is affected by those essential properties alone, we shall, from observation of its motion, discover what those essential properties are.

And almost an identical proposition.

This law turns out at last to be little more than a tautological proposition: But mechanical philosophy, as we have defined it, requires no other sense of it; for, even if we should suppose that body, of its own nature, is capable of changing its state, this change must be performed according to some law which characterises the nature of body; and the knowledge of the law can be had in no other way than by observing the deviations from uniform rectilineal motion. It is therefore indifferent whether those changes are derived from the nature of the thing, or from external causes: for in order to consider the various motions of bodies, we must first consider this nature of matter as a mechanical affection of matter, operating in every instance; and thus we are brought back to the law enounced in this proposition. This becomes more certain when we reflect that the external causes (such as gravity or magnetism,) which are acknowledged to operate changes of motion, are equally unknown to us with this essential original property of matter, and are, like it, nothing but inferences from the phenomena.

The above very diffuse discussions may appear superfluous to many readers, and even cumbersome; but we trust that the philosophical reader will excuse our anxiety on this head, when he reflects on the complicated, indistinct, and inaccurate notions commonly had of the subject; and more especially when he observes, that of those who maintain the truth of this fundamental proposition, as we have enounced it, many (and they too of the first eminence), reject it in fact, by combining it with other opinions which are inconsistent with it, nay, which contradict it in express terms. We may even include Sir Isaac Newton in the number of those who have at least introduced modes of expression which mislead the minds of incautious persons, and suggest inadequate notions, incompatible with the pure doctrine of the proposition. Although, in words, they disclaim the doctrine that rest is the natural state of body, and that force is necessary for the continuation of its motion, yet in words they (and most of them in thought) likewise abet that doctrine: for they say, that there resides in a moving body a *power* or *force*, by which it perseveres in its motion. They call it the VIS INSITA, the INHERENT FORCE OF A MOVING BODY. This is surely giving up the question: for if the motion is supposed to be continued in consequence of a force, that force is *supposed* to be exerted; and it is supposed, that if it were not exerted, the motion would cease; and therefore the proposition must be false. Indeed it is sometimes expressed so as seemingly to ward off this objection. It is said, that the body continues in uniform rectilineal motion, unless affected by some *external cause*. But this way of speaking obliges us, at first setting out in natural philosophy, to assert that gravity, magnetism, electricity, and a thousand other mechanical powers, are external to the matter which they put in motion. This is quite improper: It is the business of philosophy to discover whether they be external or not; and if we assert that they are, we have no principles of argumentation with those who deny it. It is this one thing that has filled the study of nature with all the jargon of æthers and other invisible intangible fluids, which has disgraced philosophy, and greatly retarded its progress.

38 *Vis insita*, inherent force, are improper terms in their usual acceptation.

We must observe, that the terms *vis insita*, inherent *force*, are very improper. There is no dispute among philosophers in calling every thing a force that produces a change of motion, and in inferring the action of such a force whenever we observe a change of motion. It is surely incongruous to give the same name to what has not this quality of producing a change, or to infer (or rather to suppose) the energy of a force when no change of motion is observed. This is one among many instances of the danger of mistake when we indulge in analogical discussions. All our lan-

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guage, at leaſt, on this ſubject is analogous. I feel, that in order to oppoſe animal force, I muſt exert force. But I muſt exert force in order to oppoſe a body in motion: Therefore I imagine that the moving body poſſeſſes force. A bent ſpring will drive a body forward by unbending: Therefore I ſay that the ſpring exerts force. A moving body impels the body which it hits: Therefore I ſay, that the impelling body poſſeſſes and exerts force. I imagine farther, that it poſſeſſes force only by being in motion, or becauſe it is in motion; becauſe I do not find that a quieſcent body will put another into motion by touching it. But we ſhall ſoon find this to be falſe in many, if not in all caſes, and that the communication of motion depends on the mere vicinity, and not on the motion, of the impelling body; yet we aſcribe the exertion of the *vis inſita* to the circumſtance of the continued motion. We therefore conceive the force as ariſing from, or as conſiſting in, the impelling body's being in motion; and, with a very obſcure and indiſtinct conception of the whole matter, we call it *the force by which the body preſerves itſelf in motion.* Thus, taking it for granted that a force reſides in the body, and being obliged to give it ſome office, this is the only one that we can think of.

But philoſophers imagine that they perceive the neceſſity of the exertion of a force in order to the continuation of a motion. Motion (ſay they) is a continued action; the body is every inſtant in a new ſituation; there is the continual production of an effect, therefore the continual action of a cauſe.

33 Motion is not the continual production of an effect.

But this is a very inaccurate way of thinking. We have a diſtinct conception of motion; and we conceive that there is ſuch a thing as a moving cauſe, which we diſtinguiſh from all other cauſes by the name *force*. It produces motion. If it does this, it produces the character of motion, which is a continual change of place. Motion is not action, but the effect of an action; and this action is as complete in the inſtant immediately ſucceeding the beginning of the motion as it is a minute after. The ſubſequent change of place is the continuation of an effect already produced. The *immediate* effect of the moving force is a DETERMINATION, by which, if not hindered, the body would go on forever from place to place. It is in this determination only that the ſtate or condition of the body can differ from a ſtate of reſt; for in any inſtant, the body does not deſcribe any ſpace, but has a determination, by which it will deſcribe a certain ſpace uniformly in a certain time. Motion is a condition, a ſtate, or mode, of exiſtence, and no more requires the continued agency of the moving cauſe than yellowneſs or roundneſs does. It requires ſome chemical agency to change the yellowneſs to greenneſs; and it requires a mechanical cauſe or a force to change this motion into reſt. When we ſee a moving body ſtop ſhort in an inſtant, or be gradually, but quickly, brought to reſt, we never fail to ſpeculate about a cauſe of this ceſſation or retardation. The caſe is no way different in itſelf although the retardation ſhould be extremely ſlow. We ſhould always attribute it to a cauſe. It requires a cauſe to put a body out of motion as much as to put it into motion. This cauſe, if not external, muſt be found in the body itſelf; and it muſt have a ſelf-determining power, and may as well be able to put itſelf into motion as out of it.

If this reaſoning be not admitted, we do not ſee how any effect can be produced by any cauſe. Every effect ſuppoſes ſomething *done*; and any thing done implies that the thing done may remain till it be *undone* by ſome other cauſe. Without this, it would have no exiſtence. If a moving cauſe did not produce continued motion by its inſtantaneous action, it could not produce it by any continuance of that action; becauſe in no inſtant of that action does it produce continued motion.

We muſt therefore give up the opinion, that there reſides in a moving body a force by *which it is kept in motion*; and we muſt find ſome other way of explaining that remarkable difference between a moving body and a body at reſt, by which the firſt cauſes other bodies to move by hitting them, while the other does not do this by merely touching them. We ſhall ſee, with the cleareſt evidence, that motion is neceſſary in the impelling body, in order that it may permit the forces inherent in one or both bodies to continue this preſſure long enough for producing a ſenſible or conſiderable motion. But theſe moving forces are inherent in bodies, whether they are in motion or at reſt. 34

Communication of motion is an improper phraſe,

The foregoing obſervations ſhew us the impropriety of the phraſe *communication of motion*. By thus reflecting on the notions that are involved in the general conception of one body being made to move by the impulſe of another, we perceive that there is nothing individual transferred from the one body to the other. The determination to motion, indeed, exiſted only in the impelling body before colliſion; whereas, afterwards, both bodies are ſo conditioned or determined. But we can form no notion of the thing transferred. With the ſame metaphyſical impropriety, we ſpeak of the communication of joy, of fever. 35

So is *vis inertiæ*.

Kepler introduced a term INERTIA VIS INERTIÆ, into mechanical philoſophy; and it is now in conſtant uſe. But writers are very careleſs and vague in the notions which they affix to theſe terms. Kepler and Newton ſeem generally to employ it for expreſſing the fact, the perſeverance of the body in its preſent ſtate of motion or reſt: but they alſo frequently expreſs by it ſomething like an indifference to motion or reſt, *manifeſted by its requiring the ſame quantity of force to make an augmentation of its motion as to make an equal diminution of it.* The popular notion is like that which we have of actual reſiſtance; and it always implies the notion of force *exerted* by the reſiſting body. We ſuppoſe this to be the exertion of the *vis inſita*, or the *inherent force* of a body in motion. But we have the ſame notion of reſiſtance from a body at reſt which we ſet in motion. Now ſurely it is in direct contradiction to the common uſe of the word *force*, when we ſuppoſe reſiſtance from a body at reſt; yet *vis inertiæ*, is a very common expreſſion. Nor is it more abſurd (and it is very abſurd) to ſay, that a body maintains its ſtate of reſt by the exertion of a *vis inertiæ*, than to ſay, that it maintains its ſtate of motion by the exertion of an *inherent force*. We ſhould avoid all ſuch metaphorical expreſſions as *reſiſtance*, *indifference*, *ſluggiſhneſs*, or *proneneſs to reſt* (which ſome expreſs by *inertia*), becauſe they ſeldom fail to make us indulge in metaphorical notions, and thus lead us to miſconceive the *modus operandi*, or procedure of nature.

There is *no reſiſtance whatever obſerved* in theſe phenomena;

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nomena; for the force employed always produces its *complete* effect. When I throw down a man, and find that I have employed no more force than was sufficient to throw down a similar and equal mass of dead matter, I know by this that he *has not* resisted; but I conclude that he *has* resisted, if I have been obliged to employ much more force. There is therefore no resistance, properly so called, when the exerted force is observed to produce its full effect. To say that there *is* resistance, is therefore a real misconception of the way in which mechanical forces have operated in the collision of bodies. There is no more resistance in these cases than in any other natural changes of condition. We are guilty, however, of the same impropriety of language in other cases, where the cause of it is more evident. We say that colours in grain *resist* the action of soap and of the sun, but that Prussian blue does not. We all perceive, that in this expression the word resistance is entirely figurative: and we should say that Prussian blue *resists* soap, if we are right in saying that a body resists any force employed to change its state of motion; for soap must be employed to discharge or change the colour; and *it does change it*. Force must be employed to change a motion; *and it does change it*. The impropriety, both of thought and language, is *plain* in the one case, and it is no less *real* in the other. Both of the terms, *inherent force* and *inertia*, may be used with safety for abbreviating language, if we be careful to employ them only for expressing, *either the simple fact of persevering in the former state*, or *the necessity of employing a certain determinate force, in order to change that state, and if we avoid all thought of resistance.*

36 Deviations from uniform rectilineal motion are the only indications of force.

From the whole of this discussion, we learn, that the deviatians from uniform motions are the indications of the existence and agency of mechanical forces, and that they are the only indications. The indication is very simple, mere change of place; it can therefore indicate nothing but what is very simple, the something competent to the production of the very motion that we observe. And when two changes of motion are precisely similar, they indicate the same thing. Suppose a mariner's compass on the table, and that by a small tap with my finger I cause the needle to turn off from its quiescent position 10 degrees. I can do the same thing by bringing a magnet near it; or by bringing an electrified body near it; or by the unbending of a fine spring pressing it aside; or by a puff of wind; or by several other methods. In all these cases, the indication is the same; therefore the thing indicated is the same, namely, a certain intensity and direction of a moving power. How it operates, or in what manner it exists and exerts itself in these instances, outwardly so different, is not under consideration at present. Impulsiveness, intensity, and direction, are all the circumstances of resemblance by which the affections of matter are to be characterised; and it is to the discovery and determination of these alone that our attention is now to be directed. We are directed in this research by the

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Every change of motion is proportional to the force impressed, and is made in the direction of that force.

37 This law also may almost be considered as an identical proposition; for it is equivalent to saying, that the changing force is to be measured by the change which it produces, and that the direction of this force is the direction of the change. Of this there can be no doubt, when we consider the force in no other sense than that of the cause of motion, paying no attention to the form or manner of its exertion. Thus, when a pellet of tow is shot from a pop-gun by the expansion of the air compressed by the rammer, or where it is shot from a toy pistol by the unbending of the coiled wire, or when it is nicked away by the thumb like a marble—if, in all these cases, it moves off in the same direction, and with the same velocity, we cannot consider or think of the force, or at least of its exertion, as any how different. Nay, when it is driven forward by the instantaneous percussion of a smart stroke, although the manner of producing this effect (if possible) is essentially different from what is conceived in the other cases, we must still think that the propelling force, considered as a propelling force, is one and the same. In short, this law of motion, as thus expressed by Sir Isaac Newton, is equivalent to saying, "That we take the changes of motion as the measures of the changing forces, and the direction of the change for the indication of the direction of the forces:" For no reflecting person can pretend to say, that it is a deduction from the acknowledged principle, that effects are proportional to their causes. We do not affirm this law, from having observed the proportion of the forces and the proportion of the changes, and that these proportions are the same; and from having observed that this has obtained through the whole extent of our study of nature. This would indeed establish it as a physical law, an universal fact; and it is, in fact, so established. But this does not establish it as a law of motion, according to our definition of that term; as a law of human thought, the result of the relations of our ideas, as an intuitive truth. The injudicious attemps of philosophers to prove it as a matter of observation, have occasioned the only dispute that has arisen in mechanical philosophy. It is well known, that a bullet, moving with double velocity, penetrates four times as far. Many other similar facts corroborate this: and the philosophers observe, that four times the force has been expended to generate this double velocity in the bullet; it requires four times as much powder. In all the examples of this kind, it would seem that the ratio of the forces employed has been very accurately ascertained; yet this is the invariable result. Philosophers, therefore, have concluded, that moving forces are not proportional to the velocities which they produce, but to the squares of those velocities. It is a strong confirmation, to see that the bodies in motion seem to possess forces in this very proportion, and produce effects in this proportion; penetrating four times as deep when the velocity is only twice as great, &c.

But if this be a just estimation, we cannot reconcile it to the concession of the same philosophers, who grant that the velocity is proportional to the force impressed, in the cases where we have no previous observation of the ratio of the forces, and of its equality to the ratio of the velocities. This is the case with gravity, which these philosophers always measure by its accelerating power, or the velocity which it generates in a given time. And this cannot be refused by them; for cases occur, where the force can be measured, in the most natural manner, by the actual pressure which it exerts.

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Gravity

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Gravity is thus meafured by the preffure which a ftone exerts on its fupports. A weight which at Quito will pull out the rod of a fpring fteelyard to the mark 312, will pull it to 313 at Spitzbergen. And it is a fact, that a body will fall 313 inches at Spitzbergen in the fame time that it falls 312 at Quito. Gravitation is the caufe both of the preffure and the fall; and it is a matter of unexcepted obfervation, that they have always the fame ratio. The philofophers who have fo ftrenuoufly maintained the other meafure of forces, are among the moft eminent of thofe who have examined the motions produced by gravity, magnetifm, electricity, &c.; and they never think of meafuring thofe forces any other way than by the velocity. It is in this way that the whole of the celeftial phenomena are explained in perfect uniformity with obfervation, and that the Newtonian philofophy is confidered as a demonftrative fcience.

There muft, therefore, be fome defect in the principle on which the other meafurement of forces is built, or in the method of applying it. Preffure is undoubtedly the immediate and natural meafure of force; yet we know that four fprings, or a bow four times as ftrong, give only a double velocity to an arrow.

The truth of our law refts on this only, that we affume the changes of motion as the meafure of the changing forces; or, at leaft, as the meafures of their exertions in producing motion. In fact, they are the meafures only of a certain circumftance, in which the actions of very different natural powers may refemble each other; namely, the competency to produce motion. They do not, perhaps, meafure their competency to produce heat, or even to bend fprings. We can furely confider this apart from all other circumftances; and it is worthy of feparate confideration. Let us fee what can be, and what ought to be, deduced from this way of treating the fubject.

38 Change of motion is, itfelf, a motion.

The motion of a body may certainly remain unchanged. If the direction and velocity remain the fame, we perceive no circumftance in which its condition, with refpect to motion, differs. Its change of place or fituation can make no difference; for this is implied in the very circumftance of the bodies being in motion.

But if either the velocity or direction change, then furely is its mechanical condition no longer the fame; a force has acted on it, either intrinfic or from without, either accelerating, or retarding, or deflecting it. Suppofing the direction to remain the fame, its difference of condition can confift in nothing but its difference of velocity. This is the only circumftance in which its condition can differ, as it paffes through two different points of its rectilineal path. It is this determination by which the body will defcribe a certain determinate fpace uniformly in a given time, which defines its condition as a moving body: the changes of this determination are the meafures of their own caufes;—and to thofe caufes we have given the name *force*. Thofe caufes may refide in other bodies, which may have other properties, characterifed and meafured by other effects. Preffure may be one of thofe properties, and may have its own meafures; thefe may, or may not, have the fame proportion with that property which is the caufe of a change of velocity: and therefore changes of velocity may not be a meafure of preffure. This is a queftion of fact, and requires obfervation and experience; but, in the mean time, velocity, and the change of velocity, is the meafure of moving force and of changing force. When therefore the change of velocity is the fame, whatever the previous velocity may be, the changing force muft be confidered as the fame: therefore, finally, if the previous velocity is nothing, and confequently the change on that body is the very velocity or motion that it acquires, we muft fay, that the force which produces a certain change in the velocity of a moving body, is the fame with the force which would impart to a body at reft a velocity equal to this change or difference of velocity produced on the body already in motion.

39 This manner of eftimating force is in perfect conformity to our moft familiar notions on thefe fubjects. We conceive the weight or downward preffure of a body as the caufe of its motion downwards; and we conceive it as belonging to the body at all times, and in all places, whether falling, or rifing upwards, or defcribing a parabola, or lying on a table; and, accordingly, we obferve, that in every ftate of motion it receives equal changes of velocity in the fame, or an equal time, and all in the direction of its preffure.

40 All that we have now faid of a change of velocity might be repeated of a change of direction. It is furely poffible that the fame change of direction may be made on any two motions. Let one of the motions be confidered as growing continually flower, and terminating in reft. In every inftant of this motion it is poffible to make one and the fame change on it. The fame change may therefore be made at the very inftant that the motion is at an end. In this cafe, the change is the very motion which the body acquires from the changing force. Therefore, in this cafe alfo, we muft fay, that a change of motion is itfelf a motion, and that it is the motion which the force would produce in a body that was previoufly at reft.

41 How afcertained and meafured.

The refult of thefe obfervations is evidently this, that we muft afcertain, in every inftance, what is the change of motion, and mark it by characters that are confpicuous and diftinguifhing; and this mark and meafure of change muft be a motion: Then we muft fay, that the changing force is that which would produce this motion in a body previoufly at reft. We muft fee how this is manifeft, as a motion, in the difference between the former motion and the new motion; and, on the other hand, we muft fee how the motion produceable in a quiefcent body may be fo combined with a motion already exifting, as to exhibit a new motion, in which the agency of the changing force may appear.

Suppofe a fhip at anchor in a ftream; while one man walks forward on the quarter deck at the rate of two miles per hour, another walks from ftem to ftem at the fame rate, a third walks athwart fhip, and a fourth ftands ftill. Let the fhip be fuppofed to cut or part her cable, and float down the ftream at the rate of three miles per hour. We cannot conceive any difference in the change made on each man's motion in abfolute fpace; but their motions are now exceedingly different from what they were: the firft man, whom we may fuppofe to have been walking weftward, is now moving eaftward one mile per hour; the fecond is moving eaftward four miles per hour; and the third is moving in an oblique direction, about three points north or fouth of due eaft. All have fuffered the fame change of condition

SecondLaw of Motion. dition with the man who had been ftanding ftill. He has now got a motion eaftward three miles per hour. In this inftance, we fee very well the circumftance of famenefs that obtains in the change of thefe four conditions. It is the motion of the fhip, which is blended with the other motions. But this circumftance is equally prefent whenever the fame previous motions are changed into the fame new motions. We muft learn to expifcate this; which we fhall do, by confidering the manner in which the motion of the fhip is blended with each of the mens motions.

42 Compofition of motion. This kind of combination has been called the COMPOSITION OF MOTION; becaufe, in every point of the motion really purfued, the two motions are to be found.

The fundamental theorem on this fubject is this:— Two uniform motions in the fides of a parallelogram compofe an uniform motion in the diagonal.

Plate XXI. Suppofe that a point A (fig. 1.) defcribes AB uniformly in fome given time, while the line AB is carried uniformly along AC in the fame time, keeping always parallel to its firft pofition AB. The point A, by the combination of thefe motions, will defcribe AD, the diagonal of the parallelogram ABDC, uniformly in the fame time.

For it is plain, that the velocities in AB and AC are proportional to AB and AC, becaufe they are uniformly defcribed in the fame time. When the point has got to E, the middle of AB, the line AB has got into the fituation GH, half way between AB and CD, and the point E is in the place *e*, the middle of GH. Draw E *e* L parallel to AC. It is plain, that the parallelograms ABDC and AE *e* G are fimilar; becaufe AE and AG are the halves of AB and AC, and the angle at A is common to both. Therefore, by a propofition in the elements, they are about the fame diagonal, and the point *e* is in the diagonal of AD. In like manner, it may be fhewn, that when A has defcribed AF, $\frac{3}{4}$ths of AB, the line AB will be in the fituation IK, fo that AI is $\frac{3}{4}$ths of AC, and the point *f*, in which A is now found, is in the diagonal AD. It will be the fame in whatever point of AB the defcribing point A be fuppofed to be found. The line AB will be on a fimilar point of AC, and the defcribing point will be in the diagonal AD.

Moreover, the motion in AD is uniform; for A *e* is defcribed in the time of defcribing AE; that is, in half the time of defcribing AB, or in half the time of defcribing AD. In like manner, A *f* is defcribed in $\frac{3}{4}$ths of the time of defcribing AD, &c. &c.

Laftly, the velocity in the diagonal AD is to the velocity in either of the fides as AD is to that fide. This is evident, becaufe they are uniformly defcribed in the fame time.

This is juftly called *a compofition of the motions* AB *and* AC, as will appear by confidering it in the following manner: Let the lines AB AC be conceived as two material lines like wires. Let AB move uniformly from the fituation AB into the fituation CD, while AC moves uniformly into the fituation BD. It is plain, that their interfection will always be found on AD. The point *e*, for example, is a point common to both lines. Confidered as a point of EL, it is then moving in the direction *e* H or AB; and, confidered as a point of GH, it is moving in the direction *e* L. Both of thefe motions are therefore blended in the motion of the interfection along AD. We can conceive a fmall ring at *e*, embracing loofely both of the wires. This material ring will move in the diagonal, and *will really partake* of both motions.

Thus we fee how the motion of the fhip is actually blended with the motions of the three men; and the circumftance of famenefs which is to be found in the four changes of motion is this motion of the fhip, or of the man who was ftanding ftill. By compofition with each of the three former motions, it produces each of the three new motions. Now, when each of two primitive motions is the fame, and each of the new motions is the fame, the change is furely the fame. If one of the changes has been brought about by the actual compofition of motions, we know precifely what that change is; and this informs us what the other is, in whatever way it was produced. Hence we infer, that,

43 Its mark and meafure. *When a motion is any how changed, the change is that motion which, when compounded with the former motion, will produce the new motion.* Now, becaufe we affume the change as the meafure and characteriftic of the changing force, we muft do fo in the prefent inftance; and we muft fay,

44 Changing force. That *the changing force is that which will produce in a quiefcent body the motion which, by compofition with the former motion of a body, will produce the new motion.*

And, on the other hand,

Its effect. *When the motion of a body is changed by the action of any force, the new motion is that which is compounded of the former motion, and of the motion which the force would produce in a quiefcent body.*

Deflecting force. When a force changes the direction of a motion, we fee that its direction is tranfverfe in fome angle BAC; becaufe a diagonal AD always fuppofes two fides. As we have diftinguifhed any change of direction by the term DEFLECTION, we may call the tranfverfe force a DEFLECTING FORCE.

In this way of eftimating a change of motion, all the characters of both motions are preferved, and it expreffes every circumftance of the change; the mere change of direction, or the angle BAD, is not enough, becaufe the fame force will make different angles of deflection, according to the velocity of the former motion, or according to its direction: but in this eftimation, the full effect of the deflecting force is feen; it is feen *as a motion*; for when half of the time is elapfed, the dody is at *e* inftead of E; when three-fourths are elapfed, it is at *f* inftead of F; and at the end of the time it is at D inftead of B. In fhort, the body has moved uniformly away from the points at which it would have arrived independent of the change; and this motion has been in the fame direction, and at the fame rate, as if it had moved from A to C by the changing force alone. Each force has produced its full effect; for when the body is at D, it is as far from AC as if the force AC had not acted on it; and it is as far from AB as it would have been by the action of AC alone.

For all thefe reafons, therefore, it is evident, that if we are to abide by our meafure and character of force as a mere producer of motion, we have felected the proper characteriftic and meafure of a changing force: and our defcriptions, in conformity to this felection, muft be agreeable to the phenomena of nature, and retain

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tain the accuracy of geometrical procedure; becaufe, on the other hand, the refults which we deduce from the fuppofed influence of thofe forces are formed in the fame mould. It is not even requifite that the real exertions of the natural forces, fuch as preffure of various kinds, &c. fhall follow thefe rules; for their deviations will be confidered as new forces, although they are only indications of the differences of the real forces from our hypothefis. We have obtained the precious advantage of mathematical inveftigation, by which we can examine the law of exertion which characterifes every force in nature.

On thefe principles we eftablifh the following fundamental elementary propofition, of continual and indifpenfable ufe in all mechanical enquiries.

45 Fundamental theorem

If a body or material particle be fubjected at the fame time to the action of two moving forces, each of which would feparately caufe it to defcribe the fide of a parallelogram uniformly in a given time, the body will, defcribe the diagonal uniformly in the fame time.

For the body, whofe motion AB was changed into AD, had gotten its motion by the action of fome force. It was moving along NAB; and, when it reached the point A, the force AC acted on it. The primitive motion is the fame, or the body is in the fame condition in every inftant of the primitive motion. It may have acquired this motion when it was in N, or when at O, or any other point of NA. In all thefe cafes, if AC act on it when it is in A, it will always defcribe AD; therefore it will defcribe AD when it acquires the primitive motion alfo in A; that is, if the two forces act on it at one and the fame inftant. The demonftration may be neatly expreffed thus: The change induced by each force on the motion produced by the other, is the motion which it would produce in the body if previoufly at reft. Therefore the motion refulting from joint action is the motion which is compounded of thefe two motions; or it is a motion in the diagonal of the parallelogram, of which thefe motions are the fides.

Compofition of forces.

This is called the Composition of Forces. The forces which produce the motions along the fides of the parallelogram are called the Simple Forces, or the Constituent Forces; and the force which would alone produce the motion along the diagonal is called the Compound Force, the Resulting Force, the Equivalent Force.

46 On the other hand, the force which produces a motion along any line whatever, may be conceived as refulting from the combined action of two or more forces. We may *know* or *obferve* it to be fo; as when we fee a lighter dragged along a canal by two horfes, one on each fide. Each pulls the boat directly toward himfelf in the direction of the track-rope; the boat cannot go both ways, and its real motion, whatever it is, refults from this combined action. This might be produced by a fingle force; for example, if the lighter be dragged along the canal by a rope from another lighter which precedes it, being dragged by one horfe, aided by the helm of the foremoft lighter. Here the real force is not the refulting, or the compound, but the equivalent force.

Refolution of forces.

This view of a motion, mechanically produced, is called the Resolution of Forces. The force in the diagonal is faid to be *refolved* into the two forces, having the directions and velocities reprefented by the fides. This practice is of the moft extenfive and multifareous ufe in all mechanical difquifitions. It may frequently be exceedingly difficult to manage the complication of the many real forces which concur in producing a phenomenon; and by fubftituting others, whofe combined effects are equivalent, our inveftigation may be much expedited. But more of this afterwards.

We muft carefully remember, that when the motion AD is once begun, all compofition is at an end, and the motion is a fimple motion. The two determinations, by one of which the body would defcribe AB, and by the other of which it would defcribe AC, no longer *co-exift* in the body. This was the cafe only *in the inftant*, in the very act of changing the motion AB into the motion BD; yet is the motion AD equivalent to a motion which is produced by the *actual compofition* of two motions AB and AC; in which cafe the two motions co-exift in every point of AD.

47 Ufual demonftration inconclufive.

Accordingly this is the way in which the compofition of forces is ufually illuftrated, and thought to be demonftrated. A man is fuppofed (for inftance) to walk uniformly from A to C on a fheet of ice, while the ice is carried uniformly along AB by the ftream. The man's real motion is undoubtedly along AD; but this is by no means a demonftration that the inftantaneous or fhort lived action of two forces would produce that motion; the man muft continue to exert force in order to walk, and the ice is dragged along by the ftream. Some indeed exprefs this proof in another way, faying, let a body defcribe AB, while the fpace in which this motion is performed is carried along AC. The ice may be carried along, and may, by friction, or otherwife, drag the man along with it; but a fpace cannot be removed from one place to another, nor, if it could, would it take the man with it. Should a fhip ftart fuddenly forward while a man is walking acrofs the deck, he would be left behind, and fall toward the ftern. We muft *fuppofe* a tranfverfe force, and we muft *fuppofe* the compofition of this force without proof. This is no demonftration.

We apprehend, that the demonftration given above of this fundamental propofition is unexceptionable, when the terms force and deflection are ufed in the abftract fenfe which we have affixed to them; and we hope, by thefe means, to maintain the rigour of mathematical difcuffion in all our future difquifitions on thefe fubjects. The only circumftance in it which can be the fubject of difcuffion is, whether we have felected the proper meafure and characteriftic of a change of motion—We never met with any objection to it.

48 Objections to the demonftration of nº 45. It will not apply to preffures.

But fome have ftill maintained, that it does not evidently appear, from thefe principles, that the motion which refults from the joint action of two natural powers, whofe known and meafurable intenfities have the fame proportions with AB and BC, and which alfo exert themfelves in thofe directions, will produce a motion, having the direction and proportion of AD. They will not, if the velocities produced by thefe forces are not in the proportion of thofe intenfities, but in the fubduplicate ratio of them. Nay, they fay, that it is not fo. If a body be impelled along AC by one fpring, and along AB by two fprings equally ftrong, it will not defcribe the diagonal of a parallelogram, of which the fide AB is double the fide AC. Nay, they add,

Second Law of Motion.

add, that an indefinite number of examples can be given where a body *does not* deſcribe the diagonal of the parallelogram by the joint action of two forces, which, ſeparately, would cauſe it to deſcribe the ſides. And, laſtly, they ſay, that, at any rate, it does not appear evident to the mind, that two *incitements* to motion, having the directions and the ſame proportion of intenſity with that of the ſides of a parallelogram, actually generate a third, which is the immediate cauſe of the motion in the diagonal. An equivalent force is not the ſame with a reſulting force.

49 Yet we ſee numberleſs caſes of the compoſition of incitements to motion, and they ſeem as determinate, and as ſuſceptible of being combined by compoſition, as the things called moving forces, which are meaſured by the velocities: we ſee them actually ſo combined in a thouſand inſtances, as in the example already given of a lighter dragged by two horſes pulling in different directions. Nay, experiment ſhews, that this compoſition follows preciſely the ſame rule as the compoſition of the forces which are meaſured by the velocities; for if the point A (fig. 1.) be pulled by a thread, or preſſed by a ſpring, in the direction AB, and by another in the direction AC, and if the preſſures are proportional to AB and AC, then it will be withheld from moving, if it be pulled or preſſed by a third force, acting in the direction A*d*, oppoſite to AD, the preſſure being alſo proportional to AD. This force, acting in the direction A*d*, would certainly withſtand an equal force acting in the direction AD; therefore we muſt conclude, that the two preſſures AB and AC really generate a force AD. This uniform agreement ſhews that the compoſition is deducible from fixed principles; but it does not appear that it can be held as demonſtrated by the arguments employed in the caſe of motions. A demonſtration of the compoſition of preſſures is ſtill wanted, in order to render mechanics a demonſtrative ſcience.

This compoſition is of more difficult inveſtigation.

Accordingly, philoſophers of the firſt eminence have turned their attention to this problem. It is by no means eaſy; being ſo nearly allied to firſt principles, that it muſt be difficult to find axioms of greater ſimplicity by which it may be proved.

Mechanicians generally contented themſelves with the ſolution given by Ariſtotle; but this is merely a compoſition of motions: indeed he does not give it for any thing elſe, and calls it "συνθεσις των φυ αν." The firſt writer who appears to have conſidered it as different from the mere compoſition of motions, was the celebrated Dutch engineer Stevinus in his work *on Sluices;* but his ſolution is obſcure. It was ſufficient, however, to convince Daniel Bernoulli of the neceſſity and the difficulty of the problem. He has given the firſt complete demonſtration of it in the firſt volume of the Commentaries of the Imperial Academy of Sciences at St Peterſburgh. It is extremely ingenious; but it is tedious and intricate, requiring a ſeries of 15 propoſitions to demonſtrate that two preſſures, having the directions and magnitudes of the ſides of any parallelogram, compoſe a third, which has the direction and magnitude of its diagonal. His firſt propoſition is, that *two equal preſſures, acting at right angles, compoſe a third, in the direction of the diagonal of a ſquare, and having to either of the other two the proportion of the diagonal of a ſquare to its ſides.*

Mr D'Alembert has greatly ſimplified and improved this demonſtration, by beginning with a caſe that is ſelf-evident; namely, *If three equal forces are inclined to each other in equal angles of* 120 *degrees, any one of them will balance the combined action of the other two.* Surely; for neither of them can prevail. Therefore *two* equal forces, inclined in an angle of 120 degrees, produce a third, which has the direction and proportion of the diagonal of the rhombus; for this is equal and oppoſite to one of the three above mentioned. He then demonſtrates the ſame thing of two equal forces inclined in *any* angle; and by a ſeries of eight propoſitions more, demonſtrates the general theorem. This diſſertation is in the Memoirs of the Academy at Paris for 1769. He improves it ſtill farther in a ſubſequent memoir.

Mr Riccati and Mr Fonſenex, in the Commentaries of the Academy of Turin, have given analytical demonſtrations, which are alſo very ingenious and conciſe, but require acquaintance with the higher methematics.—There is another very ingenious demonſtration in the *Journal des Sçavans* for June 1764, but too obſcure for an elementary propoſition. It is ſomewhat ſimplified by Belidor in his *Ingénieur François*. Friſius, in his *Coſmographia*, has given one, which is perhaps the beſt of all thoſe that are eaſily comprehended without acquaintance with the higher mathematics: but we imagine that, although no one can doubt of the concluſion, it has not that intuitive evidence for every ſtep of the proceſs that ſeems neceſſary.

50 Compoſition of preſſures.

We here offer another, compoſed by blending together the methods of Bernoulli and D'Alembert; and we imagine that no objection can be made to any ſtep of it. We limit it entirely to preſſures, and do not at all conſider nor employ the motions which they may be ſuppoſed to produce.

(A) If two equal and oppoſite preſſures or incitements to motion act at once on a material particle, it ſuffers no change of motion; for if it yields in either direction by their joint action, one of the preſſures prevails, and they are not equal.

Equal and oppoſite preſſures are ſaid TO BALANCE each other; and ſuch as balance muſt be eſteemed equal and oppoſite.

(B) If a and b are two magnitudes of the ſame kind, proportional to the intenſities of two preſſures which act in the ſame direction, then the magnitude $a+b$ will meaſure the intenſity of the preſſure, which is equivalent, and may be called equal, to the combined effort of the other two; for when we try to form a notion of preſſure as a meaſurable magnitude, diſtinct from motion or any other effect of it, we find nothing that we can meaſure it by but another preſſure. Nor have we any notion of a double or triple preſſure different from a preſſure that is equivalent to the joint effort of two or three equal preſſures. A preſſure a is accounted triple of a preſſure b, if it balances three preſſures, each equal to b, acting together. Therefore, in all proportions which can be expreſſed by numbers, we muſt acknowledge the legitimacy of this meaſurement; and it would ſurely be affectation to omit thoſe which the mathematicians call *incommenſurable*.

In like manner, the magnitude $a-b$ muſt be acknowledged to meaſure that preſſure which ariſes from the joint action of two preſſures a and b acting in oppoſite directions, of which a is the greateſt.

(C) Let ABCD and $AbCd$ (fig. A) be two rhombuſes, which have the common diagonal AC. Let the angles BAb, DAd, be biſected by the ſtraight lines AE and AF.

If there be drawn from the points E and F the lines EG, EH, Fg, Fh, making equal angles on each ſide of EA and FA, and if Gg, Hh be drawn, cutting the diagonal AC in I and L: then AI + AL will be greater or leſs than AQ, the half of AC, according as the angles GEH, gFh, are greater or leſs than GAH, gAh.

Draw GH, gh, cutting AE, AF, in O and o, and draw Oo, cutting AC in K.

Becauſe the angles AEG and EAG are reſpectively equal to AEH and EAH, and AE is common to both triangles, the ſides AG, GE are reſpectively equal to AH, HE, and GH is perpendicular to AE, and is biſected in O; for the ſame reaſons, gh is biſected in o. Therefore the lines Gg, Oo, Hh, are parallel, and IL is biſected in K. Therefore AI + AL is equal to twice AK. Moreover, if the angle GEH be greater than GAH, AO is greater than EO, and AK is greater than KQ. Therefore AI + AL is greater than AQ; and if the angle GEH be leſs than GAH, AI + AL is leſs than AQ.

(D) Two equal preſſures, acting in the directions AB and AC (fig. 2.), at right angles to each other, compoſe a preſſure in the direction AD, which biſects the right angle; and its intenſity is to the intenſity of each of the conſtituent preſſures as the diagonal of a ſquare to one of the ſides. It is evident, that the direction of the preſſure, generated by their joint action, will biſect the angle formed by their directions; becauſe no reaſon can be aſſigned for the direction inclining more to one ſide than to the other.

In the next place, ſince a force in the direction AD does, in fact, ariſe from the joint action of the equal preſſures AB and AC, the preſſure AB may be conceived as ariſing from the joint action of two equal forces ſimilarly inclined and proportioned to it. Draw EAF perpendicular to AD. One of theſe forces muſt be directed along AD, and the other along AE. In like manner, the preſſure AC may ariſe from the joint action of a preſſure in the direction AD, and an equal preſſure in the direction AF. It is alſo plain, that the preſſures in the directions AE and AF, and the two preſſures in the direction AD, muſt be all equal. And alſo, any one of them muſt have the ſame proportion to AB or to AC, that AB or AC, has to the force in the direction AD, ariſing from their joint action.

Therefore, if it be ſaid that AD does not meaſure the preſſure ariſing from the joint action of AB and AC, let A d, greater than AD, be its juſt meaſure, and make A d: AB = AB : Ag = AB : A e. Then A g and A e have the ſame inclination and proportion to AB that AB and AC have to A d. We determine, in like manner, two forces A f and A g as conſtituents of AC.

Now A d is equivalent to AB and AC, and AB is equivalent to A e and Ag; and AC is equivalent to A f and A g. Therefore A d is equivalent to A e, A f, A g, and A g. But (A) A e and A f balance each other, or annihilate each other's effect; and there remain only the two forces or preſſures A g, A g. Therefore (B) their meaſure is a magnitude equal to twice A g. But if A d be greater than the diagonal AD of the ſquare, whoſe ſides are AB and AC; then A g muſt be leſs than AI, the ſide of the ſquare whoſe diagonal is AB. But twice A g is leſs than AD, and much leſs than A d. Therefore the meaſure of the eqivalent of AB and AC cannot be a line A d greater than AD. In like manner, it cannot be a line A δ that is leſs than AD. Therefore it muſt be equal to AD, and the propoſition is demonſtrated.

(E) *Cor.* Two equal forces AB, AC, acting at right angles, will be balanced by a force AO, equal and oppoſite to AD, the diagonal of the ſquare whoſe ſides are AB and AC; for AO would balance AD, which is the equivalent of AB and AC.

(F) Let AECF (fig. 3.) be a rhombus, the acute angle of which EAF is half of a right angle. Two equal preſſures, which have the directions and meaſures AE, AF, compoſe a preſſure, having the direction and meaſure AC, which is the diagonal of the rhombus.

It is evident, in the firſt place, that the compound force has the direction AC, which biſects the angle EAF. If AC be not its juſt meaſure, let it be AP leſs than AC. Let ABCD be a ſquare diſcribed on the ſame diagonal, and make AP : AQ = AE : AO, = AF : Ao. Draw KOG, K o g perpendicular to AE, AF; draw G I g, OH o, EG, EK, F g, FK, PF, and PE.

The angles CAB and FAE are equal, each being half of a right angle. Alſo the figures AEPF and AGEK are ſimilar, becauſe AP : AQ = AE : AO. Therefore FA : AP = KA : AE, and EA : AP = GA : AE. Therefore, in the ſame manner that the forces AE, AF are affirmed to compoſe AP, the forces AG and AK may compoſe the force AE, and the forces A g and AK may compoſe the force AF. Therefore (B) the force AP is equivalent to the four forces AG, AK, A g, AK. But (D) AG and Ag are the ſides of a ſquare, whoſe diagonal is equal to twice AI: and the two forces AK, AK are equal to, or are meaſured by, twice AK. Therefore the four forces AG, AK, A g, AK, are equivalent to 2 AI + 2 AK, = 4 AH.

But becauſe AP was ſuppoſed leſs than AC, the angle FPE is greater than FAE, and GEK is greater than GAK, AO is greater than OE, and AH is greater than HQ, and 2 AH is greater than AQ; and therefore 4 AH is greater than AC, and much greater than AP. Therefore AP is not the juſt meaſure of the force compoſed of AE and AF.

In like manner, it is ſhewn, that AE and AF do not compoſe a force whoſe meaſure is greater than AC. It is therefore equal to AC; and the propoſition is demonſtrated.

(G) By the ſame proceſs it may be demonſtrated, that if BAD be half a right angle, and EAF be the fourth of a right angle, two forces AE, AF will compoſe a force meaſured by A C. And the proceſs may be repeated for a rhombus whoſe acute angle is $\frac{1}{8}$th, $\frac{1}{16}$th, &c. of a right angle; that is, any portion of a right angle that is produced by continual biſection. Two forces, forming the ſides of ſuch a rhombus, compoſe a force meaſured by the diagonal.

(H) Let ABCD, A b c d (fig. 4.) be two rhombuſes formed by two conſecutive biſections of a right angle. Let AECF be another rhombus, whoſe ſides AE and AF biſect the angles BA b and DA d.

The

DENDROMETER. PLATE XXI.

Fig. 1.

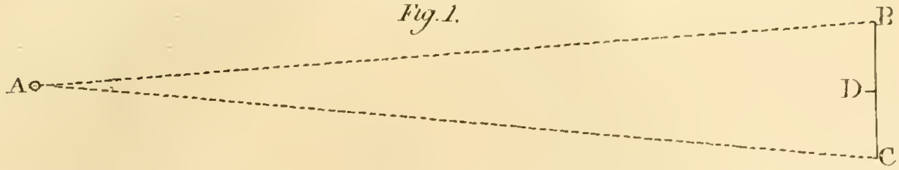


Fig. 2.

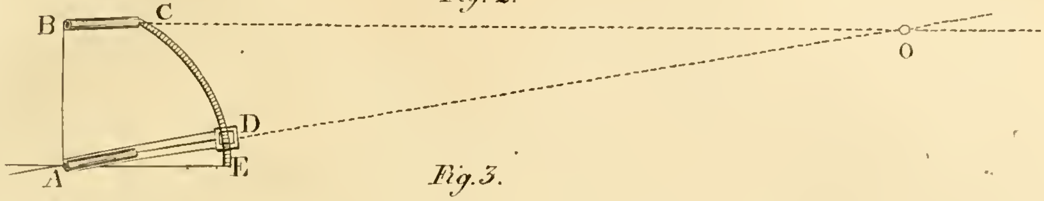
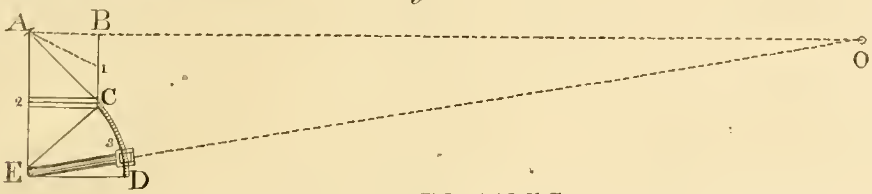


Fig. 3.



DYNAMICS.

Fig. 3.

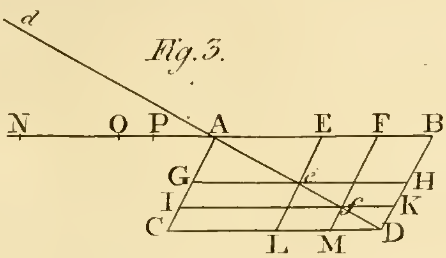


Fig. A.

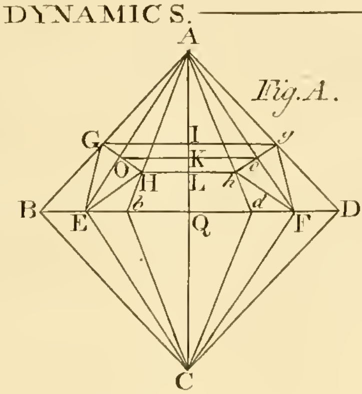
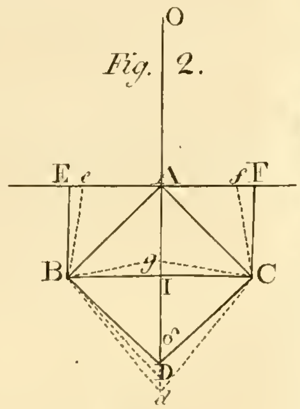


Fig. 2.



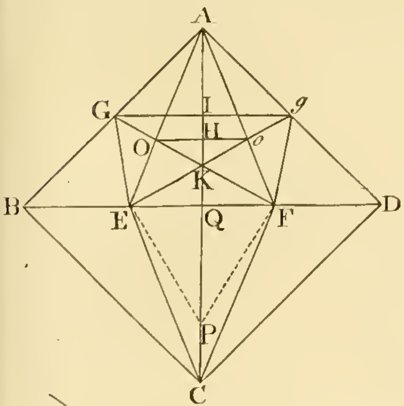


Fig. 5.

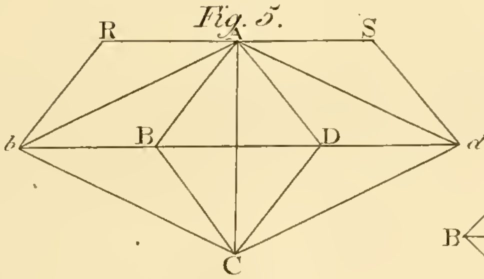


Fig. 4.

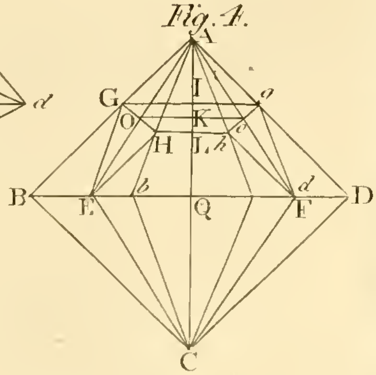


Fig. 7. N.º 2.

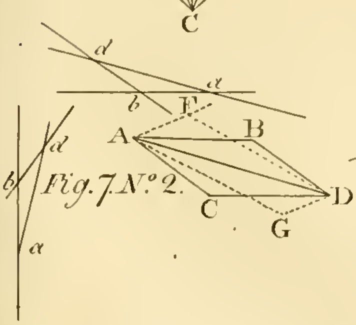


Fig. 6.

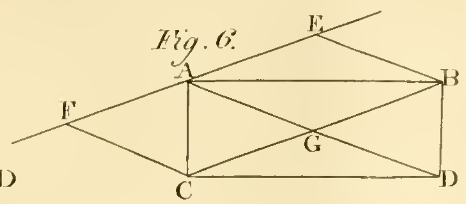
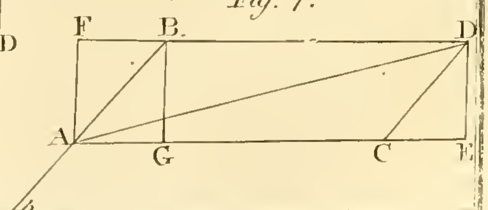


Fig. 7.



The two forces AE, AF, compose a force AC.

Bisect AE and AF in O and *o*. Draw the perpendiculars GOH, *g o h*, and the lines GI*g*, OK*o*, HL*h*, and the lines EG, EH, F*g*, F*h*.

It is evident, that AGEH and A*g*F*h* are rhombuses; because AO = OE, and A*o* = *o*F. It is also plain, that since *b*A*d* is half of BAD, the angle GAH. is half of *b*A*d*. It is therefore formed by a continual bisection of a right angle. Therefore (G) the forces AG, AH, compose a force AE; and A*g*, A*h*, compose the force AF. Therefore the forces AG, AH, A*g*, A*h*, acting together, are equivalent to the forces AE, AF acting together. But AG, A*g* compose a force = 2 AI; and the forces AH, A*h* compose a force = 2 AL. Therefore the four forces acting together are equivalent to 2 AI + 2 AL, or to 4 AK. But because AO is $\frac{1}{2}$ AE, and the lines G*g*, O*o*, H*h*, are evidently parallel, 4 AK is equal to 2 AQ, or to AC; and the proposition is demonstrated.

(I) *Cor.* Let us now suppose, that by continual bisection of a right angle we have obtained a very small angle *a* of a rhombus; and let us name the rhombus by the multiple of *a* which forms its acute angle.

The proposition (G) is true of *a*, 2 *a*, 4 *a*, &c. The proposition (H) is true of 3 *a*. In like manner, because (G) is true of 4 *a* and 8 *a*, proposition (H) is true of 6 *a*; and because it is true of 4 *a*, 6 *a*, and 8 *a*, it is true of 5 *a* and 7 *a*. And so on continually till we have demonstrated it of every multiple of *a* that is less than a right angle.

(K) Let RAS (fig. 5.) be perpendicular to AC, and let ABCD be a rhombus, whose acute angle BAD is some multiple of 2 *a* that is less than a right angle. Let A*bcd* be another rhombus, whose sides A*b*, A*d* bisect the angles RAB, SAD. Then the forces A*b*, A*d* compose a force AC.

Draw *b*R, *d*S parallel to BA, DA. It is evident, that AR*b*B and AS*d*D are rhombuses, whose acute angles are multiples of *a*, that are each less than a right angle. Therefore (I) the forces AR and AB compose the force A*b*, and AS, AD compose A*d*; but AR and AS annihilate each other's effect, and their remains only the forces AB, AD. Therefore A*b* and A*d* are equivalent to AB and AD, which compose the force AC; and the proposition is demonstrated.

(L.) *Cor.* Thus is the corrollary of last proposition extended to every rhombus, whose angle at A is some multiple of *a* less than two right angles. And since *a* may be taken less than any angle that can be named, the proposition may be considered as demonstrated of every rhombus: and we may say,

(M) *Two equal forces, inclined to each other in any angle, compose a force which is measured by the diagonal of the rhombus, whose sides are the measures of the constituent forces.*

(N) Two forces AB, AC (fig. 6.), having the direction and proportion of the sides of a rectangle, compose a force AD, having the direction and proportion of the diagonal.

Draw the other diagonal CB, and draw EAF parallel to it; draw BE, CF parallel to DA.

AEBG is a rhombus; and therefore the forces AE and AG compose the force AB. AFCG is also a rhombus, and the force AC is equivalent to AF and AG. Therefore the forces AB and AC, acting together, are equivalent to the forces AE, AF, AG, and AG acting together, or to AE, AF, and AD acting together: But AE and AF annihilate each other's action, being oposite and equal (for each is equal to the half of BC). Therefore AB and AC acting together, are equivalent to AD, or compose the force AD.

(O) Two forces, which have the direction and proportions of AB, AC (fig. 7.) the sides of any parallelogram, compose a force, having the direction and proportion of the diagonal AD.

Draw AF perpendicular to BD, and BG and DE perpendicular to AC.

Then AFBG is a rectangle, as is also AFDE; and AG is equal to CE. Therefore (N) AB is equivalent to AF and AG. Therefore AB and AC acting together, are equivalent to AF, AG, and AC acting together; that is, to AF and AE acting together; that is (N) to AD; or the forces AB and AC compose the force AD.

Hence arises the most general proposition, 51 Composition of all incitements to motion.

If a material particle be urged at once by two pressures or incitements to motion, whose intensities are proportional to the sides of any parallelogram, and which act in the directions of those sides, it is affected in the same manner as if it were acted on by a single force, whose intensity is measured by the diagonal of the parallelogram, and which acts in its direction: Or, two pressures, having the direction and proportion of the sides of a parallelogram, generate a pressure, having the direction and proportion of the diagonal.

52 Seeming difference of the compositions of motion and of pressure disappear when carefully examined.

Thus have we endeavoured to demonstrate from abstract principles the perfect similarity of the composition of pressures, and the composition of forces measured by the motions which they produce. We cannot help being of the opinion, that a separate demonstration is indispensably necessary. What may be fairly deduced from the one case, cannot always be applied to the other. No composition of pressures can explain the chang produced by a deflecting force on a motion already existing; for the changing pressure is the only one that exists, and there is none to be compounded with it. And, on the other hand, our notions and observations of the composition of motions will not explain the composition of pressures, unless we take it for granted that the pressures are proportional to the velocities; but this is perhaps a gratuitous assumption. At any rate, it is not an intuitive proposition; and we have mentioned some facts where it seems that they do not follow the same proportion. The pressure of four equal springs produces only a double velocity. It would appear, therefore, that there are circumstances which oblige us to say, that the *exertion* of pressure, as a cause of motion, is not (always at least) proportional to the real measurable pressure. We are therefore anxious to discover in what the difference consists; and in the mean time must allow, that the pressure exerted on a body at rest is different from its exertion in producing motion. We cannot indeed state any immediate comparison between pressure and motion, nor have we any clear conception of the connection between them. It is only by our sensations of touch that we have any notion of pressure, and it is experience that teaches us that it always accompanies every cause of motion. We can, however, observe the proportions of pressures, and compare them with the proportions of motion. We very often observe them different; and therefore it was indispensably

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neceſſary to inveſtigate the laws of combined preſſure as we did the laws of combined motion in conſequence of preſſure. Yet we ſhould err, if we haſtily aſſerted that preſſures are not proportional to the motions which they produce; all that we are intitled to call in doubt is, whether the preſſures in their exertion, while they actually produce motion, or changes of motion, continue to be the ſame as when they do not produce motion, being withſtood or balanced by oppoſite preſſures. Conſidered as cauſes of motion, we ought to think that they do not vary while they produce motion, and that the actual preſſure, while it produces a double motion, is really double, although it may be quadruple when the body exerting it is made to act on a body that it cannot move. We are confirmed in this opinion by obſerving, that other facts ſhew us, that even while producing motion, the preſſure which we call quadruple, becauſe we have meaſured it by four equal preſſures balancing it, is really quadruple, conſidered as the cauſe of motion, and produces a quadruple motion. A bow which requires four times the force to draw it to any given extent, will communicate the ſame velocity to a bundle of four arrows that a bow four times eaſier drawn communicates to one arrow, and will therefore produce a quadruple motion. Yet it will only produce a double velocity in the arrow that acquired a ſimple velocity from a bow having one fourth of the ſtrength.

Theſe diſcrepancies ſhould excite the endeavours of mechanicians to inveſtigate the laws obſerved in the action of preſſures in producing motion. Had this been done with care and with candour, we ſhould not have had the great difference of opinion, which ſtill divides philoſophers, about the meaſures of moving forces. But a ſpirit of party, which had ariſen from other cauſes, gave importance to what was at firſt only a difference of expreſſion, and made the partiſans of Mr Leibnitz avail themſelves of the figurative language which has done ſo much harm in all the departments of philoſophy. Notwithſtanding all our caution, it is hardly poſſible to avoid metaphorical conceptions when we employ the language of metaphor. The abettors of the Leibnitzian meaſure of moving forces, or perhaps, to ſpeak more properly, the abettors of the Leibnitzian meaſure of that force which is ſuppoſed to preſerve bodies in their condition of motion—inſiſt, that the force which is exerted in producing any change of motion is greater in proportion as the motion changed is greater: and they give a very ſpecious argument for their aſſertion. They appeal to the exertions which we ourſelves make. Here we are conſcious of the fact. Then they give ſimilar examples of the action of bodies. A clay ball, moving ſix feet per ſecond, will make the addition of one foot to the velocity of an equal clay ball that is already moving four feet per ſecond in the ſame direction. But if this laſt ball be already moving ten feet per ſecond, we muſt follow it with a velocity of twelve feet in order to increaſe its velocity one foot. But, without inſiſting on the numberleſs paralogiſms and inconſiſtencies which this way of conceiving the matter would lead us into, it ſuffices to obſerve, that the phenomena give us abundant aſſurance that there has been the ſame exertion in both theſe caſes. This acceleration is always accompanied by a compreſſion of the balls, and the compreſſion is the ſame in both. This compreſſion is a very good meaſure of the force employed to produce it; and in the preſent caſe, we need not even trouble ourſelves with any rule for its meaſurement: for ſurely when the compreſſion is not different, but the ſame, the force exerted is the ſame. This is farther confirmed by obſerving, that it requires the ſame force to make the ſame pit, or to give the ſame motion, to a piece of clay, lying on the table of a ſhip's cabin, whether the ſhip be ſailing two miles or ten miles per hour.

Thus we ſee that there are ſtrong reaſons for believing, that the exertions of preſſure in producing motion, or that the preſſures *actually exerted*, are proportional to the changes of motion obſerved, and that they coincide in this reſpect with our abſtract conceptions of moving forces.

But we have ſtill better arguments. None of the Leibnitzians think of denying the equal exertions of gravity, or of any of thoſe powers which they call *ſolicitations* or *accelerating forces*. They all admit, that gravity, or any conſtant accelerating force, produces equal increments of velocity in equal times, and that a double gravity will produce a double increment in an equal time, and an equal increment in half of the time; and that a quadruple gravity will produce a double velocity in half the time. All theſe things are granted by them, and their writings are full of reaſonings from this principle. Now from the fact, acknowledged by the Leibnitzians, that the quadruple force of a bow gives a double velocity to the arrow, in every inſtant of its action, it indiſputably follows, that it has acted on it only for half the time of the action of the four times weaker bow, which gives the arrow only half the velocity; and thus has the diſcrepancy between the effects of preſſures and of our abſtract moving forces entirely diſappeared. For this circumſtance of the difference in the time of acting will be found, on ſtrict examination, in all the caſes of the change of motion by preſſures which we meaſure by their effects on a body at reſt. When this, and the appreciable changes of actual preſſure, during the time of producing the motion, are taken into conſideration, all difference vaniſhes, and the compoſition of preſſures is in perfect harmony with the compoſition of motions, or of abſtract moving forces. Dynaimcs is thus made a demonſtrative ſcience, and affords the opportunity of inveſtigating, by obſervation and experiment, the nature of thoſe mechanical powers which reſide in bodies, and which appear to us under the form of preſſure, inducing us to conſider preſſure as a cauſe of motion.

In this, however, we are rather inaccurate. Preſſure is one of the ſenſible effects of that property which is alſo the cauſe of motion. It is not the preſſure of a piece of lead, but its heavineſs, that is the reaſon that it gives motion to a kitchen jack. Preſſure is merely a generic name, borrowed from a familiar inſtance, and given to moving forces, which have the ſame nature, but different names that ſerve to mark their connection with certain ſubſtances, in which they may be ſuppoſed to reſide. Natural philoſophy is almoſt entirely employed in examining the nature of theſe various preſſures or accelerative forces; and the general doctrines of dynamics, by aſcertaining what is common to them all, enable us to mark with preciſion what is characteriſtic of each.

53 General corollaries.

We have now advanced very far in this inveſtigation: f r

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for we have obtained the criterion by which we learn the direction and the magnitude of every changing force: and, on the other hand, we see how to state what will be the effect of the exertion of any force that is known or suspected to act. All this we learn by the composition of forces; and the greatest part of mechanical disquisition consists in the application of this doctrine. For such reasons it merits minute consideration; and therefore we must point out some general conclusions from the properties of figure, which will greatly facilitate the use of the parallelogram of forces.

54 1. The constituent and the resulting forces, or the simple and compound forces, act in the same plane; for the sides and diagonal of a parallelogram are in one plane.

55 2. The simple and the compound forces are proportional to the sides of any triangle which are parallel to their directions. For if any three lines, *ab*, *bd*, *ad*, be drawn parallel to AB, AC, and AD (fig. 7, n° 2.), they will form a triangle similar to the triangle ABD. For the same reasons they are proportional to the sides of a triangle *a'b'd*, which are respectively perpendicular to their directions.

56 3. Therefore each is proportional to the sine of the opposite angle of this triangle; for the sides of any triangle are proportional to the sines of the opposite angles.

57 4. Each is proportional to the sine of the angle contained by the directions of the other two; for AD is to AB as the sine of the angle ABD to the sine of the angle ADB. Now the sine of ABD is the same with the sine of BAC contained between the directions AB and AC, and the sine of ADB is the same with the sine of CAD; also AB is to AC, or BD, as the sine of ADB (or CAD) to the sine of BAD.

58 Some special uses of the parallelogram of forces.

We now proceed to the application of this fundamental proposition. And we observe, in the first place, that since AD may be the diagonal of an indefinite number of parallelograms, the motion or the pressure AD may result from the joint action of many pairs of forces. It may be produced by forces which would separately produce the motions AF and AG. This generally gives us the means of discovering the forces which concur in its production. If one of them, AB, is known in direction and intensity, the direction AC, parallel to BD, and the intensity, are discovered. Sometimes we know the directions of both. Then, by drawing the parallelogram or triangle, we learn their proportions. The force which deflects any motion AB into a motion AD, is had by simply drawing a line from the point B (to which the body would have moved from A, in the time of really moving from A to D) to the point D. The deflecting force is such as would have caused the body move from B to D in the same time. And, in the same manner, we get the compound motion AD, which arises from any two simple motions AB and AC, by supposing both of the motions to be accomplished in succession. The final place of the body is the same, whether it moves along AD or along AB and BD in succession.

59 Equivalent of many forces.

This theorem is not limited to the composition of two motions or two forces only; for since the combined action of two forces puts the body into the same state as if their equivalent alone had acted on it, we may suppose this to have been the case, and then the action of a third force will produce a change on this equivalent motion. The resulting motion will be the same as if only this third force and the equivalent of the other two had acted on the body. Thus, in fig. 8. the three forces AB, AC, AE, may act at once on a particle of matter. Complete the parallelogram ABDC; the diagonal AD is the force which is generated by AB and AC. Complete the parallelogram AEFD; the diagonal AF is the force resulting from the combined action of the forces AB, AC, and AE. In like manner, completing the parallelogram AGHF, the diagonal AH is the force resulting from the combined action of AB, AC, AE, and AG, and so on of any number of forces. Plate XXII.

This resulting force and the resulting motion may be much more expeditiously determined, in any degree of composition, by drawing lines in the proportion and direction of the forces in succession, each from the end of the preceding. Thus, draw AB, BD, DF, FH, and join AH; AH is the resulting force. The demonstration is evident.

It is to be noticed here, that in the composition of more than two forces, we are not limited to one plane. 60 The force AD is in the same plane with AB and AC; but AE may be elevated above this plane, and AG may lead below it. AF is in the plane of AD and AE, and AH is in the plane of AF and AG.

Complete the parallelograms ABLE, ACKE, ELFK. It is evident that ABLFKCD is a parallelopiped, and that AF is one of its diagonals. Hence we derive a more general theorem of great use.

Three forces having the proportion and direction of the three sides of a parallelopiped, compose a force having the proportion and direction of the diagonal.

61 One force may balance many acting together.

Any number of forces acting together on one particle of matter are balanced by a force that is equal and opposite to their resulting force; for this force would balance their resulting force which is equivalent to them in action. When this is duly considered, we perceive that each force is then in equilibrio with the equivalent of all the others; for a force can balance only what is equal and opposite to it. It appears very readily by the geometrical construction. If, instead of the circuit A, B, D, F, H, we take B, D, F, H, A, we have BA for the equivalent of the forces AC, AE, AG; but AB is equal and opposite to BA. Therefore the force AB is in equilibrio with the equivalent of all the others.

When any number of forces act on one particle of matter, and are in equilibrio, if they be considered as acting in parcels, the equivalents of these parcels are in equilibrio: for let the forces AB, AC, AE, AG, A*h*, be in equilibrio, and let them be considered in the two parcels AB, AC, and AE, AG, A*h*: then AD is the equivalent of AB, BD (or AC), and DA is the equivalent of DF, FH, HA (or A *h*): now AD and DA balance each other. This corollary enables us to simplify many intricate complications of force; it also enables us to draw accurate conclusions from very imperfect observations. In most of our practical discussions we know, or at least we attend to, a part only of the forces which are acting on a material particle; and in such cases we reason as if we saw the whole: yet is our mathematical reasoning good with respect to the equivalent of all the parcels which we are contemplating, and the equivalents of the smaller parcels of which it consists; 62

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conſiſts; and the neglected force, or parcel of forces, induces no error on our concluſions.

63

Expeditious methods for obtaining the reſulting motion in complicated caſes.

In the ſpontaneous phenomena of nature, the inveſtigation and diſcovery of our ultimate object of ſearch is frequently very difficult, on account of the multiplicity of directions and intenſities of the operating forces or motions. We may generally facilitate the proceſs, by ſubſtituting equivalent forces or motions acting in convenient directions. It is in this way that the navigator computes the ſhip's place with very little trouble, by ſubſtituting equivalent motions in the meridional and equatorial directions for the real oblique courſes of the ſhip. Inſtead of ſetting down ten miles on a courſe, S. 36. 52. W. he ſuppoſes that the ſhip has ſailed eight miles due ſouth, and ſix miles due weſt, which brings her near to the ſame place. Then, inſtead of fourteen miles ſouth-weſt, he ſets down ten miles ſouth and ten miles weſt; and he proceeds in the ſame way for every other courſe and diſtance. He does this expeditiouſly by means of a traverſe table, in which are ready calculated the meridional and equatoreal ſides of right angled triangles, correſponding to every courſe and diſtance. Having done this for the courſe of a whole day, he adds all the ſouthings into one ſum, and all the weſtings into another: he conſiders theſe as forming the ſides of a right angled triangle; he looks for them, paired together, in his traverſe table, and then notices what angle and what diſtance correſponds to this pair. This gives him the poſition and magnitude of the ſtraight line joining the beginning and end of his day's work.

The miner proceeds in the ſame way when he takes the plan of ſubterraneous workings, meaſuring, as he goes along, and noticing the bearing of each line by the compaſs, and ſetting down, from his traverſe table, the northing or ſouthing, and the eaſting or weſting, for each oblique line: but there is another circumſtance which he muſt attend to, namely, the ſlope of the various drifts, galleries, and other workings. This he does by noting the riſe or the dip of each ſloping line. He adds all theſe into two ſums, and taking the riſings from the dips, he obtains the whole dip. Thus he learns how far the workings proceed to the noth, how far to the eaſt, and how far to the dip.

The reflecting reader will perceive that the line joining the two extremities of this progreſſion will form the diagonal of a rectangular parallelopiped; one of whoſe ſides lies north and ſouth, the other lies eaſt and weſt, and the third is right up and down.

The mechanician proceeds in the very ſame way in the inveſtigation of the very complicated phenomena which frequently engage his attention. He conſiders every motion as compounded of three motions in ſome convenient directions, at right angles to each other. He alſo conſiders every force as reſulting from the joint action of three forces, at right angles to each other, and takes the ſum or difference of theſe in the ſame or oppoſite directions. From this proceſs he obtains the three ſides of a parallelopiped, and from theſe computes the poſition and magnitude of the diagonal. This is the motion or force reſulting from the compoſition of all the partial ones.

Forces may be eſtimated by, or reduced to,

This procedure is called the Estimation or Reduction of motions and forces.

A motion or force AB (fig. 9.) is ſaid to be *eſtimated* in the direction EF, or to be *reduced* to this direction when it is conceived as compounded of the motions or forces AC, AD, one of which AC is parallel to EF, and the other AD is perpendicular to it. This expreſſion is abundantly ſignificant; for it is plain that the motion AD neither promotes nor hinders the progreſs along EF, and that AC expreſſes the whole progreſs in this direction.

64

A given direction,

65

Or a given plane.

In like mannar, a force AB (fig. 10.) is ſaid to be *eſtimated in* or *reduced to*, a given plane EFGH, when it is conceived as reſulting from the joint action of two forces AC, AD, one of which is parallel to a line *a b* drawn in that plane, and the other AD is perpendicular to it. The poſition of the line *a b* is determined by letting fall B *b* perpendicular to the plane, and drawing *b* P to the point P, in which BA meets the plane; then A *a* being drawn parallel to B *b*, will cut off *b a*, which is the reduction of the motion AB to the plane. Drawing AC parallel to *a b*, and completing the parallelogram ACBD, it is evident that the motion AB is equivalent to AD and AC, which is parallel to *a b*, and the three forces AB, AC, AD, are, as they ſhould be, in one plane perpendicular to the plane EG.

66

Equilibrium of forces ſo eſtimated or reduced.

If three forces AB, AC, AD (fig. 11.), are in equilibrio, and are reduced to any one direction *d* A *l*, or to one plane EFGH, the reduced forces are alſo in equilibrio.

Firſt, Let them be reduced to one direction *d l* by drawing the perpendiculars B *b*, C *c*, D *d*; make AL equal to AD, and join BL, CL, and draw the perpendiculars L *l*, C *c*; then, becauſe the forces AB, AC, AD, are in equilibrio, ABLC muſt be a parallelogram, and AL is the force equivalent to AB and AC combined; then, becauſe the lines D *d*, B *b*, C *c*, L *l*, are parallel, *d* A is equal to A *l*, and A *b* to C *o*, or to *c l*; therefore A *l* is equal to the ſum of A *b* and A *c*, which are the reductions of AB and AC; therefore *d* A is equal to the ſame ſum, and in equilibrio with them.

Secondly, Let them be reduced to one plane EFGH, and let $\alpha\beta$, $\alpha\kappa$, $\alpha\delta$, be the reduced forces. The lines Dδ, A α, B β, C κ, L λ, are all parallel, being perpendicular to the plane; therefore the planes AB $\beta\alpha$ and C L $\lambda\kappa$ are parallel, and $\alpha\beta$, $\kappa\lambda$, are parallel. For ſimilar reaſons $\beta\lambda$, $\alpha\kappa$, are parallel; therefore $\alpha\beta\lambda\kappa$ is a parallelogram. Alſo, becauſe the lines D δ, A α, L λ, are parallel, and DA is equal to AL; therefore $\delta\alpha$ is equal to $\alpha\lambda$. But becauſe $\alpha\beta\lambda\kappa$ is a parallelogram, the forces $\alpha\beta$, $\alpha\kappa$, are equivalent to $\alpha\lambda$; and $\alpha\delta$ is equal and oppoſite to $\alpha\lambda$, and will balance it; and therefore will balance $\alpha\beta$ and $\alpha\kappa$, which are the reductions of AB and AC to the plane EFGH, while $\alpha\delta$ is the reduction of AD; therefore the propoſition is demonſtrated.

The moſt uſeful mode of reduction to their co-ordinates.

The moſt uſual and the moſt uſeful mode of reduction, is to eſtimate all forces in the directions of three lines drawn from one point, at right angles to each other, like the three plane angles of a rectangular cheſt, forming the length, the breadth, and the depth of the cheſt. Theſe are commonly called the three co-ordinates. The reſulting force will be the diagonal of this parallelopiped. This proceſs occurs in all diſquiſitions in which the mutual action of ſolids and fluids is conſidered, and when the oſcillation or rotation of detached free bodies is the ſubject of diſcuſſion.

The only other general theorem that remains to be deduced

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67 Relative motions of bodies not affected by any extraneous equal and parallel force.

deduced from this law of motion is, that if a number of bodies are moving in any manner whatever, and an equal force act on every particle of matter in the same or parallel directions, their relative motions will suffer no change; for the motion of any body A (fig. 12.), relative to another body B, which is also in motion, is compounded of the real motion of A, and the opposite to the real motion of B; for let A move uniformly from A to C, while B describes BD uniformly, draw AB, also draw AE equal and parallel to BD, join EC, DC, ED. The motion of A, relative to B, consists in its change of position and distance. Had A described AE, while B described BD, there would have been no change of relative place or distance; but A is now at C, and DC is its new direction and distance. The relative or apparent motion of A therefore is EC. Complete the parallelogram ACFE; it is plain that the motion EC is compounded of EF, which is equal and parallel to AC, the real motion of A, and of EA, the equal and opposite to BD, the real motion of B.

Now let the motions of A and B sustain the same change; let the equal and parallel motions AG, BH, be compounded with the motions AC and BD; or let forces act at once on A and B, in the parallel directions AG, BH, and with equal intensities; in either supposition, the resulting motions will be A *c*, B *d*, the diagonals of the parallelograms A G *c* C, and B H *d* D. Construct the figure as before, and we see that the relative motion is now *e c*, and that it is the same with EC both in respect of magnitude and position.

Here we still see the constant analogy between the composition of motions and the composition of forces. In the first case, the relative motions of things are not changed, whatever common motion be compounded with them all; or, as it is usually, but inaccurately, expressed, although the space in which they move be carried along with any motion whatever. In the second case, the relative motions and actions are not changed by any external force, however great, when equally exerted on every particle in parallel directions.

Thus it is that the evolutions of a fleet in a uniform current are the same, and produced by the same means, as in still water. Thus it is that we walk about on the surface of this globe in the same manner as if it neither revolved round the sun, nor turned round its axis. Thus it is that the same strength of a bow will communicate a certain velocity to an arrow, whether it is shot east, or west, or north, or south. Thus it is that the mutual actions of sublunary bodies are the same, in whatever directions they are exerted, and notwithstanding the very great changes in their velocities by reason of the earth's rotation and orbital revolution. The real velocity of a body on the earth's equator is about 3000 feet per second greater at midnight than at midday. For at midnight the motion of rotation nearly conspires with the orbital motion, and at midday it nearly opposes it. The difference between the velocities at the beginning of January and the beginning of July is vastly greater. And at other times of the day, and other seasons of the year, both motions of the earth are transversely compounded with the easterly or westerly motion of an arrow or cannon bullet. Yet we can observe no change in the effects of the mutual actions of bodies.

This is an important observation; because it proves that forces are to be measured by no other scale than by the motions which they produce. We have had repeated occasions to mention the very different estimation of moving forces by Mr Leibnitz; and have shewn how, by a very partial consideration of the action of those natural powers called *pressures*, he has attempted to prove, that moving forces are proportional to the squares of the velocities; and we shewed briefly, in what manner a right consideration of what passes when motion is produced by measurable pressures, proves that the forces really exerted are as the velocities produced. But the most copious proof is had from the present observation, that, in fact, the mutual actions of bodies depend on their relative motions alone.

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68 This affords a demonstration of the proportionality of moving forces to the motions produced by them,

69 And is incompatible with their proportionality to the squares of those motions.

The Leibnitzian measure of moving force is altogether incompatible with the universal fact now mentioned, *viz.* that the relative motions of bodies, resulting from their mutual actions, are not affected by any common motion, or the action of any equal and parallel force on both bodies: for this universal fact imports, that when two bodies are moving with equal velocities in the same direction, a force applied to one of them, so as to increase its velocity, gives it the same motion relative to the other, as if both bodies had been at rest. Here it is plain, that the space described by the body in consequence of the primitive force, and of the force now added, is the sum of the spaces which each of them would generate in a body at rest. Therefore the forces are proportional to the velocities or changes of motion which they produce, and not to the squares of those velocities. This measure of forces, or the position that a force makes the same change on any velocity whatever, and the independence of the relative motions on any motion that is the same on all the bodies of a system, are counterparts of each other. Since this independence is a matter of observation in all terrestrial bodies, we are intitled to say, that the powers which the Author of Nature has imparted to natural bodies are no way different from what are competent to matter once called into existence. And it also follows from this, that we must always remain ignorant of the absolute motions of bodies. The fact, that it has required the unremitted study of ages to discover even the relative motions of our solar system, is an argument to prove that the influence of this mechanical principle extends far beyond the limits of this sublunary world; nor has any phenomenon yet been exhibited which should lead us to imagine that it is not universal.

So Bernoulli's defence of this last opinion is without force.

When we have made use of these arguments with some zealous partizans of Mr Leibnitz's doctrine, they have answered, that if indeed this independence of the relative motions of terrestrial bodies were observed to obtain exactly, it would be a conclusive argument. But the motion with which all is carried along is so great in comparison with the motions which we can produce in our experiments, that the small additions or diminutions that we can make to the velocity of this common motion must observe very nearly the proportions of the additions or diminutions of their squares. The differences of the squares of 2, 3, and 4, are very unequal; but the differences of the squares of 9, 10, 11, are much nearer to the ratio of equality; and the differences of the squares of 1000001, 1000002, 1000003, do not sensibly deviate from this ratio. But it is not fact that we cannot produce motions which have a very

very ſenſible proportion to the common motion. The motion of a cannon ball, diſcharged with one-third of its weight of powder, is nearly equal to that of the rotation of the earth's equator. When, therefore, we diſcharge the ball eaſtward, we double its motion; when to the weſtward, we deſtroy it. Therefore, according to Leibnitz, the action in the firſt caſe is three times the action in the ſecond. In the firſt caſe it changes the ſquare of the velocity (which we may call 1) from 1 to 4; and, in the ſecond, it changes it from 1 to 0. But ſay the Leibnitzians, the velocity of rotation is but $\frac{1}{31}$ of the orbital velocity of the earth, and our obſervations of the velocities of cannon bullets are not ſufficiently exact to enſure us againſt an error of $\frac{1}{31\frac{1}{2}}$. But the later obſervations on the peculiar motions of the fixed ſtars concur in ſhewing, that the ſun, with his attending planets, are carried along with a very great motion, which, in all probability, has a ſenſible ratio to the orbital motion of the earth. This muſt make a prodigious change on the earth's abſolute motion, according as her orbital motion conſpires with, oppoſes, or croſſes, this other motion: the earth may even be at abſolute reſt in ſome points of its orbit. Thus will the compoſition with the motions produced in our experiments be ſo varied, that caſes muſt occur when the difference of the reſults of the two meaſures of force will be very ſenſible.

But, farther, they have not attended to the agreement of our experiments, when the diſcharges of cannon are made in a direction tranſverſe to that of the common motion. Here the immenſity of the common motion, and the minuteneſs of our experimental velocities, can have no effect in diminiſhing the difference of the reſults of the two doctrines. This will appear diſtinctly to every reader who is much converſant in diſquiſitions of this kind: and it is in theſe more moderate motions that the complete independence of the relative motions on the common motions moſt accurately appears. Pendulum clocks and watches have been often executed which do not deviate from perfect equability of motion one part in 86400. This could not be obtained in all directions of the oſcillations, if the forces deviated from the ratio of the velocities one part in 86400.

Perfect agreement of the abſtract notion of force with all our accurate obſervations of the exertions of natural powers,

On the whole, we may conſider it as eſtabliſhed on the ſureſt foundation, that the action of thoſe powers of natural bodies which we call *preſſures*, ſuch as the force of ſprings, the exertions of animals, the coheſion of bodies, as well as the action of thoſe other incitements to motion which we call *attractions* and *repulſions*, ſuch as gravitation, magnetiſm and electricity—is proportional to the change of velocity produced by it. And we muſt obſerve here, that this is not a mere mode of conception, the reſult of the laws of human thought, which cannot conceive a natural power as the cauſe of motion otherwiſe than by its producing motion, and which cannot conceive any degree of *moving* power different from the degree of the motion. This is the abſtract doctrine, and is true whether the preſſures are proportional to the velocities, or to the ſquares of the velocities. But we ſee farther, that whatever is the preſſure of a ſpring (for example) on a quieſcent body, yet the preſſure actually exerted in producing a double velocity is only double and not quadruple as our firſt imperfect obſervations make us imagine.

Sir Iſaac Newton has added another propoſition to the number of laws of motion, namely, that *every action is accompanied by an equal and contrary reaction.* 70
But in affirming this to be a law of nature, he only means that it is an univerſal fact; and he makes this affirmation on the authority of what he conceives to be a law of human thought; namely, that thoſe qualities which we find in all bodies on which we can make experiments and obſervations are to be conſidered as univerſal qualities of body. But we have limited the term *law of motion* to thoſe conſequences that neceſſarily flow from our notions of motion, of the cauſes of its production and changes. Now this third Newtonian propoſition is not ſuch a reſult. A magnet is ſaid to act on a piece of iron when, and only when, the vicinity of the magnet is obſerved to be accompanied by certain motions of the iron. But it by no means follows from this obſervation, that the preſence of the iron ſhall be accompanied by any motion, or any change of ſtate whatever of the magnet, or any appearance that can ſuggeſt the notion that the iron acts on the magnet. When this was obſerved, it was accounted a diſcovery. Newton *diſcovered*, that the ſun acts on the planets, and that the earth acts on the moon; and Kepler *diſcovered*, that the moon reacts on the earth. Newton had obſerved, that the iron reacts on the magnet; that the actions of electrified bodies were mutual; and that every action of ſublunary bodies was, in fact, accompanied by an equal and contrary reaction. On the authority of his rule of philoſophizing he affirmed, that the planets react on the ſun, and that the ſun is not at reſt, but is continually agitated by a ſmall motion round the general centre of gravitation. He pointed out ſeveral conſequences of this reaction. Aſtronomers examined the celeſtial motions more narrowly, and found that thoſe conſequences do really obtain, and diſturb all the planetary motions. It is now found that this reciprocity of action obtains throughout the ſolar ſyſtem with the utmoſt preciſion, and that the third Newtonian propoſition is really a law of nature, although it is not a law of human thought. It is a diſcovery. The contrary involves no abſurdity or contradiction. It would indeed be contrary to experience; but things might have been otherwiſe. It is conceivable, and poſſible, that a ball A ſhall ſtrike another equal ball B, and carry it along with it, without any diminution of its velocity. The fact, that the velocity of A is reduced to one-half, is the indication of a force reſiding in B, which force changes the motion of A; and the intenſity of this force is learned from the change which it produces. This *is found* to be equal to the change produced by A on B. And thus the reaction of B is *diſcovered* to be equal to the action of A.

Newton's third law of motion is founded on experience alone, and is not a neceſſary truth.

It is highly probable, that this univerſality and equality of reaction to action is the conſequence of ſome general principle, which we may in time diſcover; meanwhile we are intitled to ſuppoſe it univerſal, and to reaſon from this topic in our diſquiſitions about the actions of bodies on each other.

Maupertuis, Leibnitz, and other philoſophers, have entertained very inadequate opinions concerning the foundation of the laws of motion.

Although the celebrated philoſophers of Europe have at laſt agreed in the reception of the two propoſitions ſo largely diſcuſſed by us as the laws of motion, they have differed exceedingly in their opinion about their origin and validity: Some aſſerted that they are entirely matters of experience; while others affirmed them to be neceſſary truths. The royal academy of Berlin

Second Law of Motion.

Berlin made this queſtion the ſubject of their prize diſſertation in the year 1744. Mr Maupertuis, preſident of the academy, publiſhed a diſſertation; in which he endeavoured to prove that they are neceſſary truths, only becauſe *they are ſuch as make the quantity of action the leaſt poſſible*, an economy which is worthy of infinite wiſdom; and therefore certainly directs the choice of the Author of Nature. On this account alone are they neceſſary truths.

But this is not the way to conſider a queſtion of this kind. We know too little about infinite wiſdom to be able to ſay with Meſſrs Leibnitz and Maupertuis, that the Deity ſhould or ſhould not impreſs on bodies laws different from thoſe which are eſſential to matter; and we are not to inquire whether God could or could not do this. We know from our own experience, that matter, when ſubjected to the action of intelligence, may be moved in a way extremely different from what it would follow if left to itſelf, and that its motions may either be regulated by fixed, but contingent, laws, or may be without any conſtancy whatever, and vary in every inſtance. When we ſuppoſe the exiſtence of matter and motion, a variety of truths are involved in the ſuppoſition, in the ſame manner as all the theorems in the third book of Euclid's Elements are involved in the conception of a circle and a ſtraight line. Our firſt employment ſhould be to evolve thoſe truths. We can do this in no way but by firſt noticing the relations of the ideas that we have of the different objects of contemplation, and then following the laws of human thought in our judgments concerning thoſe relations. This proceſs of the mind is expreſſed in the train of a geometrical demonſtration. The different parts or argumentations of this train are not the cauſes of our concluſions, but the means by which we form our judgment; not the reaſons of the truth of our ultimate concluſion, but the ſteps by which we arrive at the knowledge of it. The young geometer generally thinks otherwiſe: But that this is the matter of fact is plain from this, that more than one demonſtration, and often very different, can be given of the ſame theorem. We muſt proceed in the ſame manner in the preſent queſtion; and the firſt general truths which we find involved in the notions of matter, motion and force, muſt be received as *neceſſary* truths. The ſteps by which we arrive at the diſcovery are the laws of human thought; and the expreſſion of the diſcovery, involving both the truth itſelf, and the manner of conceiving it, is a neceſſary law of motion. There may be other facts, perhaps as general as any of thoſe neceſſary laws, but which do not neceſſarily reſult from the relations of our notions of motion and of force. Theſe are diſcovered by obſervation only; and they ſerve to characteriſe the forces which nature preſents to our view. Theſe facts are *contingent* laws of motion.

We apprehend that this method has been followed in treating this article. The firſt propoſition, termed *a law of motion*, is only a more convenient way of expreſſing our contemplation of motion in body as an effect of the general cauſe which we term *force*. The ſecond propoſition does nothing but expreſs more diſtinctly the relation between this cauſe and its effect; it expreſſes what we mean by the magnitude and the kind of the cauſe. The propoſition, ſtating the compoſition of forces, is but another form of the ſame law, better ſuited to the ordinary procedure in geometrical diſquiſitions.

These propoſitions might have completed the doctrines of dynamics; but it appears that, in order to the production of a material univerſe which ſhould accompliſh the purpoſes of the Creator, it was neceſſary that there be certain characteriſtic differences between the forces inherent in the various collections of matter which compoſe this univerſe. The facts or phyſical laws (for the above-mentioned laws are metaphyſical) of motion may be different from thoſe which would have been obſerved had matter been left entirely to itſelf. This difference may have introduced other laws of motion as neceſſarily reſulting from the nature of the forces. We have occaſionally mentioned ſome inſtances where this appears to obtain, but gave good reaſons for affirming, that a due examination of all circumſtances which may be obſerved in the production or variation of motion by thoſe forces, has demonſtrated, that there are no ſuch deviations from the two laws of motion already determined, but that all the mechanical powers of bodies, when conſidered merely as cauſes of motion, act agreeably to the ſame laws. Careful examination was, however, ſaid to be neceſſary.

This examination muſt conſiſt in diſtinctly noticing the circumſtances that occur in the production of motion by any force whatever. It is by no means enough to ſtate ſimply the intenſity of the force and the direction of its exertion. If a force continue to act, it continues to vary the motion already produced. Should the force change its intenſity or direction while it is acting, theſe circumſtances muſt induce ſtill farther changes in the motion; and it is not till all action has ceaſed, that the motion is brought to its oſtenſible ſtate in which it is the object of our attention and our future diſcuſſions. Inſtances of the effects of ſuch continued, and ſuch varied actions are to be ſeen in moſt of the phenomena of nature or art. The communication of motion by impulſe is perhaps the only inſtance (very frequent indeed) that can be produced where this is not neceſſary: Nay, we ſhall perhaps find reaſon to conclude, that this inſtance is not an exception, and that even the communication of motion from one billiard ball to another, is brought about by an action continued for ſome time, and greatly varied during that time. Much preparation is therefore neceſſary before we can apply the general laws of motion to the ſolution of moſt of the queſtions which come before us in the courſe even of our elementary diſquiſions. We muſt lay down ſome general propoſitions which determine the reſults of the continued, and perhaps varied, actions of moving forces; and we muſt mark the different effects of the ſimple continuation of action, and alſo thoſe of the variations in this continued action, both in reſpect of intenſity and direction. The effect of a mere continuance of action muſt be an acceleration of the motion; or a retardation of it, if the force continue to act in the oppoſite direction. The effect of the continued action of a tranſverſe force muſt be a continual deflection, that is, a curvelineal motion. Theſe muſt therefore now occupy our attention in their order.

Of Accelerated and Retarded Motions.

All men can perceive, that a ſtone dropped from the

Of Accelerated and Retarded Motions.

the hand, or fliding down an uniform flope, has its motion continually accelerated, and that the motion of an arrow rifing perpendicularly through the air is continually retarded; and they feel no difficulty in conceiving thefe changes of motion as the effects of the continual operation of their weight or heavinefs. The falling ftone is in a different condition in refpect of motion in the beginning and the end of its fall. In what refpect do thefe ftates of the body differ? Only in refpect to what we call its *velocity*. This is an affection of motion; it is an expreffion of the relation between the two notions or ideas which concur to form the idea of motion, namely, the fpace and the time. Thefe are all the circumftances that we obferve in a motion. Time elapfes, and during its currency a fpace is defcribed. The term *velocity* expreffes the magnitude of the fpace which correfponds to fome unit of time. Thus, the rate of a fhip's motion is determined, when we fay that it is nine miles in an hour, or nine miles per hour. We fometimes fay (but aukwardly) "The motion is at the rate, or with the velocity, of a mile in three days." It is moft conveniently expreffed by a number of fome given units of length, which completely make up the line defcribed during this unit of time. But the mechanicians exprefs it in a way more general by a fraction, of which the numerator is a number of inches, feet, yards, fathoms, or miles, and the denominator is the number of feconds, minutes, or hours, employed in moving along this line. This is a very proper expreffion; for when we fpeak of any velocity, and continue to reafon from it, we conceive ourfelves to fpeak of fomething that remains the fame, in the different occafions of ufing the term. Now if the velocity be conftant, it is indifferent how long the line may be; becaufe the time of its defcription will be lengthened in the fame proportion. Thus if 48 feet be defcribed in 12 feconds, 36 feet will be defcribed in 9 feconds, 16 feet will be defcribed in 4 feconds, &c. Now $\frac{48}{12}$, $\frac{36}{9}$, and $\frac{16}{4}$, are fractions of equal value, being equal to $\frac{4}{1}$, or 4, that is, to the velocity of 4 feet per fecond. The value of this fraction, or the quotient of the number of the units of length, divided by the number of units of time, is the number of thofe units of length defcribed uniformly in one unit of time.

71 Circumftantial expofition of our conception of the condition of a body in refpect to motion.

Magnitude of a velocity of which we have no actual meafure.

But how fhall we determine the velocity in any inftant or in any point of a motion that is continually changing? Suppofe that a body has fallen 144 feet, and that we would afcertain its velocity in that point of its fall, or the velocity which it has in paffing through that point? In the next fecond the body falls 112 feet farther. This cannot be the meafure of the velocity at the beginning of the fourth or the end of the third fecond. It is two great. The fall during the preceding fecond was 80 feet. This is too fmall. The mean of thefe two, or $\frac{80+112}{2}, = \frac{192}{2}, = 96$, is probably more exact. Due attention to the nature of this motion fhews us, that 96 is the proper meafure, or that the motion at that inftant is at the rate of 96 feet per fecond. But it is peculiar to this kind of motion that the half fum of the fpaces defcribed in two fucceeding equal moments is the meafure of the velocity in the middle inftant. Therefore this method will not generally give an accurate meafure. Yet it is indifpenfably neceffary to obtain fome accurate meafure; for it is in this particular alone that the ftate of the body differs from its fimilar ftate in another inftant. The difference of place makes no diftinction; for if a body continue its motion unchanged, its condition in every different inftant of time, or point of fpace, is unchanged or the fame. The change of place is not a change of motion, but is involved in the very conception of the continuation of the motion. The change of condition confifts, therefore, in the change of velocity: Therefore the change of velocity is the only indication, and the only meafure of the action (perhaps accumulated) of the changing force. It is therefore the chief object of our fearch; and accurate meafures of velocity are abfolutely neceffary.

When the velocity changes continually, there can be no *actual* meafure of it. In what then does the magnitude of a velocity confift, when there is no actual meafure of it? It is a certain undefcribable DETERMINATION; by which, if not changed, a certain fpace *would* be uniformly defcribed in a given unit of time. Thus we know, that if, when a ftone has fallen 16 feet, its motion be directed along a horizontal plane, without diminution, it will move on for ever at the rate of 32 feet per fecond. The fpace which would be thus defcribed is not the velocity, but the meafure of the velocity. But the proportions of thofe fpaces, being the proportions of thofe meafures, are the proportions of the velocities themfelves. We may difcover thefe proportions in the following manner:

72 Momentary proportion of velocities that are continually changing.

Let ACG (fig. 13.) be a line defcribed by a body with a motion anyhow continually, but gradually, varied; and let it be required to determine the proportion of the velocity in any point C to the velocity in any other point F.

Fundamental requifite in all mechanical difquifitions.

AXIOM.—If A be to B in a ratio that is greater than any ratio lefs than that of C to D, but lefs than any ratio greater than that of C to D, then A is to B as C to D. Take the ftraight line acg to reprefent the time of the body's motion along ACG, fo that the points a, c, f, g, may reprefent the inftants of time in which the body paffes through the points A, C, F, G; and the portions ac, cf, fg, of the line ag, may reprefent the times employed in defcribing the portions AC, CF, FG; and therefore ac is to af as the time of defcribing AC to the time of defcribing AF.

Moreover, let $hkno$ be a line fo related to the ftraight line $acfg$, by the perpendicular ordinates ah, ck, fn, go, that the areas $ackh$, $afnh$, $agoh$, may be proportional to the portions AC, AF, AG, of the line defcribed by the moving body; and let this relation be true with refpect to every point B, D, E, &c. and the correfponding points b, d, e, &c.

Then it is affirmed, that *the velocity in the point* C *is to the velocity in the point* F *as* ck *is to* fn.

Let the equal lines bc, cd, ef, fg, reprefent equal moments of time, and let B, D, E, G, be the points through which the body is paffing at the inftants b, d, e, g. Then the areas $bikc$, $ckld$, $emnf$, $fnog$, will reprefent, and be proportional to, the fpaces BC, CD, EF, FG, which are defcribed during the moments bc, cd, ef, fg.

Draw tp parallel to ag, fo as to make the rectangle $btpc$ equal to the trapezium $bikc$; and draw the lines qv, ur, sx, in the fame manner, fo that each rectangle may be equal to its correfponding trapezium.

If the motions had been uniform during the moments

ments *b c* and *f g*, that is, if the spaces BC and FG had been uniformly described, then the velocity in the point C would have been to the velocity in the point F as *c p* to *f s*: For since the rectangles *b t p c* and *f s x g* are respectively equal to the trapeziums *b i k c* and *f n o g*; and since *b i k c* is to *f n o g* as BC is to FG, the rectangle *b t p c* is to the rectangle *f s x g* as BC to FG. But because these two rectangles have equal altitudes *b c* and *f g*, they are to each other in the proportion of their bases *c p* and *g x*, or *c p* and *f s*. Therefore BC is to FG as *c p* to *f s*. But if BC and FG are uniformly described in equal times, they are proportional to the velocities of those uniform motions. Therefore *c p* is to *f s* as the velocity with which BC is uniformly described to the velocity with which FG is uniformly described in an equal time.

But the motion expressed by the figure is not uniform, because the line *h l o* recedes from the axis *a g*, and the areas, cut off by the parallel ordinates, increase in a greater proportion than the corresponding parts of the axis; that is, the spaces increase faster than the times, for the moments *b c*, *c d*, *e f*, *f g*, being all equal, it is evident that the corresponding slips of the area continually augment. The motion is swifter at the instant *c* than at the instant *b*, and the velocity at the instant *c* is *greater* than that with which the space BC would be uniformly described in the same time. For the same reason, the velocity at the instant *f* is *less* than that with which the space FG would be uniformly described in the same time. Therefore the velocity at the instant *c* is to the velocity at the instant *f* in a greater ratio than that of *c p* to *f s*. In the very same manner, it will appear, by comparing the motion during the moment *c d* with the motion during the moment *e f*, that the velocity at the instant *c* is to the velocity at the instant *f* in a less ratio than that of *c q* to *f r*.

Therefore the velocity in the point C is to the velocity in the point F in a greater ratio than that of *c p* to *f s*, but in a less ratio than that of *c q* to *f r*.

But by continually diminishing the equal moments *b c*, *c d*, *e f*, *f g*, it is evident that *c p* and *c q* continually approach to equality with *c k*; and *f r* and *f s* continually approach to equality with *f n*, that when *c p* is less than *c k*, *f s* is greater than *f n*, and when *c q* is greater than *c k*, *f r* is less than *f n*.

Therefore the velocity in the point C is to the velocity in the point F in a ratio that is greater than the ratio of *any* line less than *c k* to *any* line greater than *f n*, but which is less than the ratio of any line greater than *c k* to any line less than *f n*. Therefore the ratio of the velocity in C to the velocity in F is greater than any ratio that is less than that of *c k* to *f n*; but it is less than any ratio that is greater than that of *c k* to *f n*. Therefore the velocity in the point C is to the velocity in the point F as *c k* to *f n*.

This important theorem may be expressed in more general terms as follows:

If the abscissa a g *of a line* h k o *represent the time of any motion, and if the areas bounded by parallel ordinates be proportional to the spaces described, the ordinates are proportional to the velocities.*

Remark. The propriety or aptitude of expressing the time by the portions of the axis *a c g*, will, perhaps, appear more clearly in the following manner.

Let *a c g* be any straight line, and let *h k v* be another line, straight or curved. Let the straight line *a h z*, perpendicular to *a g*, be carried uniformly down along this line, keeping always perpendicular to it, and therefore always parallel to its first position *a h z*. In its various situations *c k z*, *e m z*, &c. it will cut off areas *a c k h*, *a e m h*, &c. bounded by the axis by the ordinates *a h* and *c k*, or by the ordinates *a h* and *e m*, &c. and by the line *h k g*. By this motion the moveable ordinate is said, in a language of modern geometry, to *generate* the areas *a c k h*, *a e m h*, &c. At the same time, let a point A move along the line ACG, setting out from A at the instant when the line *a z* sets out from *a*; and let the motion of the point A be so regulated, that the spaces AB, AC, AD, &c. generated by this motion, may increase at the same rate with the areas *a b*, *i h*, *a c k h*, *a d l h*, &c. or such that we shall have AB to AC as *a b i h* to *a c k h*, &c. It is plain, that the motion along AG is the same with that described in the enunciation of the proposition: for because the motion of the ordinate *a z*, along the axis *a g*, is supposed to be uniform, the spaces *a b*, *a c*, *a d*, &c. are proportional to the times in which they are described, and may therefore be taken to measure or to represent those times.

73 Cor. I. *In a motion continually varied, the velocities in the different points of the path are to each other in the limiting or ultimate ratio of the spaces described in equal times*, those times being supposed to diminish continually: for it is evident, that if the equal moments *b c*, *c d*, *e f*, *f g*, are supposed to diminish continually, till the instants *b* and *d* coalesce with *c*, and the instants *e* and *g* coalesce with *f*; then the ratio of *c k* to *f n* is the limit of the continually increasing ratio of *c p* to *f s*, or of the continually diminishing ratio of *c q* to *f r*. Sir Isaac Newton calls this the ultimate ratio of *c p* to *f s*, or of *c q* to *f r*. Now the ratio of *c p* to *f s* is, by construction, the same with the ratio of the rectangle *b t p c* to the rectangle *f s x g*, and the ratio of *c q* to *f r* is the same with the ratio of the rectangle *c q v d* to the rectangle *e u r f*. But the ratio of the rectangle *b t p c* to the rectangle *f s x g* is the same with the ratio of the space *b i k c* to the space *f n o g*; that is (by hypothesis), the same with the ratio of the space BC to the space FG; and the ratio of the rectangles *c q v d* and *e u r f* is the same with that of the spaces CD and EF. Therefore the ratio of the velocity at C to the velocity at F is the same with the ultimate ratio of the small increments BC, FG, or CD, EF of the spaces generated in very small and equal times.

It is also evident, that because the ratio of *c k* to *f n* is the limit both of the ratio of *c p* to *f s* and of the ratio of *c q* to *f r*, these ultimate ratios are the same, and that we may say that the velocity in C is to the velocity in F in the ultimate ratio of BC to EF, or in the ultimate ratio of CD to FG.

We also can easily perceive, that the ratio of the area *b i k c* to the area *e m n f* approaches more near to the ratio of *c k* to *f n* as we take the moments *b c* and *e f* smaller. Therefore, in many cases of practice, where it may be easy to measure the spaces described in the different small moments of the motion, but difficult to ascertain their ultimate ratio, so as to obtain accurate measures of the proportions of the velocities, we may reduce the errors of measurement to something very insignificant, by taking these moments extremely small;

 and

and we ſhall diminiſh the error ſtill more, by taking the proportion of the half ſum of BC and CD to the half ſum of EF and FG for the proportion of the velocities in C and F.

It often happens that we have it not in our power to compare the ſpaces deſcribed in ſmall moments which are preciſely equal. Still we can find the exact proportion of the velocities, if we can aſcertain the ultimate ratio of the increments of the ſpaces, and the ultimate ratio of the moments of time in which theſe increments are deſcribed: for it is plain, by conſidering the gradual approach of the points *p* and *r* to the points *k* and *n*, that the ratio of *c k* to *f n* is ſtill the ultimate ratio of the baſes of rectangles equal to the mixtilineal areas, whether the altitudes (repreſenting the moments) are equal or not. Now the baſes of two rectangles are in the proportion of the rectangles directly, and of their altitudes inverſely. But the ultimate ratio of the altitudes is the ultimate ratio of the moments, and the ultimate ratio of the rectangles is the ultimate ratio of the ſpaces deſcribed in thoſe unequal moments. Therefore, in ſuch caſes, we have,

74 Cor. 2. *The velocities are in the ratio compounded of the direct ultimate ratio of the momentary increments of the ſpaces, and the inverſe ultimate ratio of the increments (or moments) of the times in which theſe increments of the ſpaces are made.*

If s, v, and t, are taken to repreſent the magnitudes of the ſpaces, velocities, and times, and if $\dot{s}$, $\dot{v}$, and $\dot{t}$, are taken always in the limiting or ultimate ratio of their momentary increments, we ſhall have v always in the proportion of $\dot{s}$ directly, and of $\dot{t}$ inverſely. We expreſs this by the proportional equation $v \doteq \frac{\dot{s}}{\dot{t}}$, which is equivalent to the analogy $V : v = \frac{\dot{S}}{\dot{T}} : \frac{\dot{s}}{\dot{t}}$, or $V : v = \dot{S}\dot{t} : \dot{s}\dot{T}$.

75 *N. B.* Here obſerve, that this is not the only way of ſtating the relation of ſpace and time—the abſciſſa may be made the time and the ordinate the ſpace; then the velocity $= \frac{\dot{y}}{\dot{x}}$.

The converſe of this propoſition may be thus expreſſed.

76 Converſe theorem.

If the axis a g *of the line* h k o *repreſent the time of a varied motion along the line* AG, *and if the ordinates* a h, b i, c k, *&c. be as the velocities in the inſtants* a, b, c, *or in the points* A, B, C; *then the areas* a b i h, a c k h, a d l h, *&c. are proportional to the ſpaces* AB, AC, AD, *&c.*

This may be demonſtrated in the ſame way with the former; but the indirect demonſtration is more brief, and equally ſtrict.

If the ſpaces AC, AF, &c. are not proportional to the areas *a c k h*, *a f n h*, &c. they are proportional to ſome other areas *a c k h'*, *a f n' h'*, &c. which are bounded by the ſame ordinates, and by another line *h' k n'*. But becauſe the areas *a c k h'*, *a f n' h'*, &c. are always proportional to the ſpaces AC, AF, &c. deſcribed on the line AG, the velocity in the point C is to the velocity in the point F as the ordinate *c k* is to the ordinate *f n'*. But, by hypotheſis, the velocity in C is to the velocity in F as *c k* to *f n* and *f n'* is equal to *f n*; which is abſurd. Therefore the ſpaces AC, AF, are not proportional to any other areas, &c.

Cor. *The ultimate ratio of the momentary increments of the ſpaces is compounded of the ratio of the velocities, and the ultimate ratio of the increments of the times:* 77 for when the moments *b c*, *e f*, are equal, it is evident, that the ultimate ratio of the rectangles *b c p t*, *e f r u* is the ſame with the ultimate ratio of the increments of the ſpaces. But the ultimate ratio of theſe rectangles is the ſame with that of their baſes *c p* and *f r*; that is, the ratio of *c k* to *f n*, that is, the ratio of the velocities, and when the moments are unequal, the ratio of the rectangles is compounded of the ratio of their baſes, and the ratio of their altitudes: that is, compounded of the ratio of the velocities and the ultimate ratio of the moments of time.

We have, therefore, $\dot{S} : \dot{s} = V\dot{T} : v\dot{t}$, and $\dot{s} \doteq v\dot{t}$.

It moſt commonly happens, that we can only obſerve the accumulated reſults of varied motions; and in them we only obſerve a ſpace paſſed over, and a certain portion of time that has elapſed during the motion. But being able to diſtinguiſh the portions of the whole ſpace which are deſcribed in known portions of the whole time, and having made ſuch obſervations in ſeveral parts of the motion, we diſcover the general law that the motion affects, and we affirm this law to hold univerſally, even though we have not obſerved it in *every* point. We do this with a degree of probability and confidence proportioned to the frequency of our obſervation. It is not till we have done this, that we can make uſe of the firſt of theſe two propoſitions, which enables us to aſcertain the velocity of the motion in its different moments. Thus if we obſerve, that a ſtone in falling, deſcends one foot in the quarter of a ſecond, 16 feet in a ſecond, 64 feet in two ſeconds, and 144 feet in three ſeconds; the general law immediately obſerved is, "that the ſpaces deſcribed are as the ſquares of the times;" for 1 is to 16 as the ſquare of $\frac{1}{4}$ to the ſquare of 1. Again, 16 is to 64 as 1^2 to 2^2; and 16 is to 144 as 1^2 to 3^2. Hence we infer, with great probability, that the ſtone would fall 36 feet in a ſecond and a half; for 16 is to 36, as 1^2 to $1\frac{1}{2}^2$; and we conclude in the ſame way for all other parts of the motion. 78

A good example of the geometrical method.

This immediate obſervation of the analogy between the ſpaces and the ſquares of the times ſuggeſts an eaſy determination of the velocity in this particular kind of motion; and it merits particular notice, being very often referred to. We can take *a g* to repreſent the time; and then, becauſe the areas, which are to repreſent the ſpaces deſcribed muſt be proportioned to the ſquares of the portions of *a g*, we perceive that the line which comes in place of *h k o* muſt be a ſtraight line drawn from *a*. For example, the ſtraight line *a δ γ*. For this is the only boundary which will give areas *a b β*, *a c κ*, *a d δ*, &c. proportional to $a\,b^2$, $a\,c^2$, $a\,d^2$, &c. And we perceive, that *any* ſtraight line drawn from *a* will have this property.

Having thus got our repreſentations of the times and the ſpaces, we ſay, on the authority of our theorem, that the velocity at the inſtant *b* is to the velocity at the inſtant *d* as *b β* to *d δ*, &c. And now we begin to make inferences purely geometrical, and expreſs our diſcovery of the velocities in a very general and ſimple manner. We remark, that *b β* is to *d δ* as *a b* is to *a d*: and

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and we make the same affirmation concerning the magnitudes represented by these lines. We say that the velocity at the instant b is to the velocity at the instant d as the time $a\ b$ is to the time $a\ d$. We say, in terms still more general, that the velocities are proportional to the times from the beginning of the motion. We moreover perceive, that the spaces are also proportional to the squares of the acquired velocities; or the velocities are as the square roots of the spaces.

We can farther infer, from the properties of the triangle, that the momentary increments of the spaces are proportional to the momentary increments of the squares of the times, or of the squares of the velocities.

We also observe, that not only the whole acquired velocities are proportional to the whole elapsed times, but that the increments of the velocities are proportional to the times in which they are acquired; for $\pi\ \varkappa$ is to $\rho\ \varphi$ as $b\ c$ to $d\ f$, &c. Equal increments of velocity are therefore acquired in equal times. Therefore such a motion may, in great propriety of language, be denominated a UNIFORMLY ACCELERATED MOTION; that is, *a motion in which we observe the spaces proportioned to the squares of the times, is a motion uniformly accelerated;* and spaces in the duplicate ratio of the times form the ostensible characteristic of an uniformly accelerated motion.

79 Lastly, if we draw $\varepsilon\ \lambda$ parallel to the axis $a\ b$, we perceive that the rectangle $a\ e\ \varepsilon\ \lambda$ is double of the triangle $a\ e\ \varepsilon$. Now because $a\ e$ represents the time of the motion, and $e\ \varepsilon$ represents the acquired velocity, the rectangle $a\ e\ \varepsilon\ \lambda$ will represent the space which would be uniformly described with the velocity $e\ \varepsilon$ during the time $a\ e$. But the triangle $a\ e\ \varepsilon$ represents the space really described with the uniformly accelerated motion during the same time. Hence we infer, that the space that is described in any time, with a motion increasing uniformly from nothing, is one half of the space which would be uniformly described during the same time with the final velocity.

These are but a part of the inferences which we may draw from the geometrical properties of those representations which we had selected of the different measureable affections of motion. We may affirm, with respect to the motions themselves, all the inferences which relate to magnitude and proportion, and thus improve our knowledge of the motions.

We took the opportunity of this very simple and perspicuous example, to give our young readers a just conception of the *mathematical method* of prosecuting mechanical knowledge, and to make them sensible of the unquestionable authority for every theorem deduced in this manner.

One of the most important is, to discover the accumulated result of a motion of which we only observe the momentary increments. This is to be done by finding the area, or portions of the area, of the mixtilineal space $a\ g\ o\ h$; and it is evidently analogous to the inverse method of fluxions, or the integral calculus.

In most cases, we must avail ourselves of the corollary $\dot{s} = v\ \dot{t}$, and we obtain the solution of our question only in the cases where our knowledge of the quantities s, t and v (considered as geometrical magnitudes, that is, as lines and surfaces), enables us to discover s and t.

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80 Having thus discovered the proportions of the velocities in motions varying in any manner whatever, we can observe the variations which happen in them. These variations are the effects, and the only marks and measures of the changing forces. They are the characteristics of their kinds (considered merely as moving forces); that is, the indications of the directions in which they act; for this is the only difference *in kind* of which they are susceptible in this general point of view. If they increase the velocity, their direction must be conceived as the same with that of the previous motion; because the result of the action of a force is equivalent to the composition of the motion which that force would produce in a quiescent body with the motion already existing; and an increase of velocity is equivalent to the composition of a motion in the same direction.

Having no other mark of the force but the acceleration, we have no other name for it in the abstract doctrines of dynamics, and we call it an ACCELERATING FORCE. Had it retarded the motion, we should have called it a RETARDING FORCE.

In like manner, we have no measure of the *magnitude* or *intensity* of an accelerating force, but the acceleration which it produces. In order therefore to investigate the powers which produce all the changes of motion, we must endeavour to obtain measures of the acceleration.

A continual increase of velocity is the effect of the continued action of accelerating forces. If equal increments of velocity are produced in every succeeding equal moment of time, we cannot conceive that there is any change in the accelerating force. Therefore a uniformly accelerated motion is the mark of the unvaried action of an accelerating force, that is, of the continued action of a constant force; of a force whose intensity is always the same. When therefore we observe a body describe spaces proportional to the squares of the times, we must infer that it is urged forward by a force whose intensity does not change; and, on the other hand, a constant force must produce a uniformly accelerated motion by its continued action. And if any previous circumstances assure us of this continued action of an invaried force, we may make all the inferences which were mentioned under the article of uniformly accelerated motion.

Measure of an accelerating force.

81 That force must surely be accounted double which produces a double increment of velocity in the same time by its uniform action, we can form no other estimation of its magnitude. And, in general, *accelerating forces must be accounted proportional to the increments of velocity which they produce, by acting uniformly during the same or equal times.*

Supposing them to act on a body at rest. Then the velocity produced is itself the increment; and we must say, that accelerating forces are proportional to the velocities which they generate in a body in equal times. And because we found (n° 79.), that the space described with a uniformly accelerated motion is half the space which would be uniformly described in the same time with the final velocity, which space is the direct measure of this velocity, and because halves have the same proportion with the wholes—we may say, that *accelerating*

accelerating forces are proportional to the spaces through which they impel a body from rest in equal times by their uniform action.

Another measure.

This is an important remark; because it gives us an easy measure of the force, without the trouble of first computing the velocities. It also gives us the only distinct notion that we have of the measurement of forces by the motions which they produce. When speaking of the composition of forces, we distinguished or denominated them by the sides and diagonal of a parallelogram. These lines must be conceived as proportional to the spaces through which the forces urge the body *uniformly* during the small and insensible time of their action, which time is supposed to be the same for both forces; for the sides of the parallelogram are supposed to be separately described in equal times, and therefore to be proportional to the velocities generated by the constituent forces. If indeed the forces do not act uniformly, nor similarly, nor during equal times, we cannot say (without farther investigation) what is the proportion of the intensity of the forces, nor can we infer the composition of their action. We must at least suppose, that in every instant of this very small time of their joint action, their direction remains unchanged, and that their intensities are in the same ratio. We shall see by and bye, that with these conditions the sides of the parallelogram are still proportional to the velocities generated. In the mean time, we may take the spaces through which a body is uniformly impelled from rest (that is, with a uniformly accelerated motion) as the measures of the forces; yet these spaces are but the halves of the measures of the velocities. Then, if a body be moving with the velocity of 32 feet per second, and an accelerating force acts on it during a second, and if this force be such that it would impel the body (from a state of rest) 16 feet, it will add to the body a velocity of 32 feet per second. Accordingly, this is the effect of gravity—the weight of a pound of lead may be considered as a force which does not vary in its intensity. We know that it will cause the lead to fall 16 feet in a second; but if the body has already fallen 16 feet, we know that it is then moving with the velocity of 32 feet per second. And the fact is, that it will fall 48 feet farther in the next second, and will have acquired the velocity of 64 feet per second. It has therefore received an augmentation of 32 feet of velocity by the action of gravity during the second second; and gravity is in fact a constant force, causing equal increments of velocity in equal times, however great the velocities may be. It does not act like a stream of fluid, whose impulse or action diminishes as the solid body withdraws from it by yielding.

But supposing that we have not compared the increments of velocity uniformly acquired during equal times, in what manner shall we measure the accelerating forces? In such a case, that force must be accounted double which generates the same velocity, by acting uniformly during half the time; for when the force is supposed invariable, the changes of velocity which it produces are proportional to the times of its action; therefore if it produces an equal velocity in half the time, it will produce a double velocity in an equal time, and is therefore a double force. The same may be said of every proportion of time in which an equal change of velocity is produced by the uniform action of an accelerating force. The force must be accounted greater in the same proportion that the time required for the production of a given velocity in a body is less. Hence we infer, that *accelerating forces are inversely proportional to the times in which a given change of velocity is produced by their uniform action.*

By combining these two propositions we establish this general theorem; 82

Measure of accelerating force,

Accelerating forces are proportional to the changes of velocity which they produce in a body by their uniform action directly, and to the times in which these changes are produced inversely.

If, therefore, A and a are the forces, V' and v' the changes of velocity, and T' and t' the portions of time in which they are uniformly produced, we have

$$A : a = V't' : v'T', = \frac{V'}{T'} : \frac{v'}{t'}$$

$$\text{And } a \doteq \frac{v'}{t'}.$$

The formula $a \doteq \frac{v'}{t'}$ is not restricted to any particular magnitude of v' and t'. It is true, therefore, when the portion of time is diminished without end; for since the action is supposed uniform, the increment of velocity is lessened in the same proportion, and the value of the fraction $\frac{v'}{t'}$ remains the same. The characters or symbols v' and t' are commonly used to express *finite* portions of v and t. The symbols $\dot{v}$ and $\dot{t}$ are used by Newton to express the same things taken in the ultimate or limiting ratio. They are usually considered as *indefinitely small* portions of v and t. We shall abide by the formula $a \doteq \frac{\dot{v}}{\dot{t}}$.

83

Is an abstract number.

It must always be kept in mind, that v and t are abstract numbers; and that v refers to some unit of space, such as a foot, an inch, a yard; and that t refers to some unit of time, such as an hour, a minute, a second; and especially that a is the number of the same units of space, which will be uniformly described in *one* unit of the time with the velocity generated, by the force acting uniformly during *that* unit. It is twice the space actually described by the body during that unit when impelled from rest by the accelerating force. It is necessary to keep hold of these clear ideas of the quantities expressed by the symbols.

Measure of a change of velocity.

On the other hand, when the measure of the accelerating force is previously known, we employ the theorem $a\,t' = v'$; that is, the addition made to the velocity during the whole, or any part, of the time of the action of the force is obtained by multiplying the acceleration of one unit of time by the number of such units contained in t'.

These measures express the greatest part of our knowledge of mechanical nature.

These are evidently leading theorems in dynamics; because all the mechanical powers of nature come under the predicament of accelerating or retarding forces. It is the collection of these in any subject, and the manner in which they accompany, or are inherent in it, which determine the mechanical character of that subject; and therefore the phenomena by which they are brought into view are the characteristic phenomena. Nay, it may even be questioned, whether the phenomena bring any thing more into view. This force, of which we

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we speak so familiarly, is no object of distinct contemplation; it is merely a something that is proportional to $\dot{\frac{v}{t}}$. And when we observe, that the $\dot{\frac{V}{T}}$, found in the motions that result from the vicinity of a body A, is double of the $\dot{\frac{v}{t}}$, which results from the vicinity of another body B; we say that a force resides in A, and that it is double of the force residing in B. The accelerations are the things immediately and truly expressed by these symbols. And the whole science of dynamics may be completely taught without once employing the word *force*, or the conception which we imagine that we form of it. It is of no use till we come to study the mechanical history of bodies. Then, indeed, we must have some way of expressing the fact, that an acceleration $= \frac{32 \text{ feet}}{1''}$ is observed in every thing on the surface of this globe; and that an acceleration $= \frac{418 \text{ feet}}{1''}$ is observed over all the surface of the sun. These facts are characteristic of this earth and of the sun; and we express them shortly by saying, that such and such forces reside in the earth and in the sun. It will preserve us from many mistakes and puzzling doubts, if we resolutely adhere to this meaning of the term *force;* and this will carry mathematical evidence through the whole of our investigations.

84 Another measure of accelerating force.

As velocity is not an immediate object of contemplation, and all that we observe of motion is a space and a time, it may be proper to give an expression of this measure of accelerating force which involves no other idea. Supposing the body to have been previously at rest, we have $a \doteqdot \frac{v}{t}$. Multiply both parts of the fraction by t, which does not change its value, and we have $a \doteqdot \frac{vt}{t^2}$. But $vt = s$; and therefore $a \doteqdot \frac{s}{t^2}$.

The formula $a = \frac{s}{t^2}$ is equivalent to the proportion $t^2 : 1 = s : a$; and a would then be the space through which the accelerating force would impel the body in one unit of the time t. But this is only half of the measure of the velocity which the accelerating force generates during that unit of time. For this reason we did not express the accelerating force by an ordinary equation, but used the symbol $\doteqdot$. In this case, therefore, of uniform action, we may express the accelerating force by $a = \frac{2s}{t^2}$.

The following theorem is of still more extensive use in all dynamical disquisitions.

85 Most general measure of accelerating force.

Accelerating forces are proportional to the momentary increments of the squares of the velocities directly, and as the spaces along which they are uniformly acquired inversely.

Let A′B, A′C, and AD (fig. 14.), be three lines, described in the same or equal times by the uniform action of accelerating forces; the motions along these lines will be uniformly accelerated, and the lines themselves will be proportional to the forces, and may be employed as their measures. On the greatest of them AD, describe the semicircle ABCD, and apply the other two lines A′B, A′C as chords AB, AC. Draw EB, FC perpendicular to AD. Take any small portions Bb, Cc of AB and AC, and draw be, cf perpendicular to AD, and Eh and Fk parallel to AB and AC.

Then, because the triangles DAB and BAE are similar, we have $AD : AE = AD^2 : AB^2$. And because AD is to AB as the velocity generated at D is to the velocity generated at B (the times being equal), we have AD to AE as the square of the velocity at D to the square of the velocity at B; which we may express thus:

$AD : AE = V^2, D : V^2, B.$

For the same reasons we have also

$AD : AF = V^2, D : V^2, C.$ Therefore

$AE : AF = V^2, B : V^2, C.$

But because in any uniformly accelerated motion, the spaces are as the squares of the acquired velocities, we have also

$AE : Ae = V^2, B : V^2 b$, and

$AF : Af = V^2, C : V^2 c.$

Therefore Ee is to Ff as the increment of the square of the velocity acquired in the motion along Bb to the increment of the square of the velocity acquired along Cc.

But, by similarity of the triangles ABD and Eeh, we have

$AB : AD = Ee : Eh$; and, in like manner,

$AD : AC = Fk : Ff.$ Therefore

$AB : AC = Ee \times Fk : Ff \times Eh.$

Now AB and AC are proportional to the forces which accelerate the body along the lines A′B and A′C; Ee and Ff are proportional to the increments of the squares of the velocities acquired in the motions along the portions Bb and Cc; and Eh and Fk are equal to those portions respectively. The ratio of AB to AC is compounded of the direct ratio of Ee to Ff; and the inverse ratio of Eh to Fk. The proposition is therefore demonstrated.

The proportion may be expressed thus:

$AB : AC = \frac{Ee}{Eh} : \frac{Ff}{Fk}$, and may be expressed by the proportional equation $AB \doteqdot \frac{Ee}{Eh}$, or, symbolically, $a \doteqdot \frac{(\dot{v^2})}{\dot{s}}$.

$v\dot{v}$ is but one half of the increment of v^2.

Remark. Because the motion along any of these three lines is uniformly accelerated, the relation between spaces, times, and velocities, may be represented by means of the triangle ABC (fig. 15.); where AB represents the time, BC the velocity, and ABC the space. If BC be taken equal to AB, the triangle is half of the square ABCF of the velocity BC; and the triangle ADE is half of the square ADEG of the velocity DE. Let Dd and Bb be two moments of time, equal or unequal. Then DdeE and BbcC are half the increments of the squares of the velocities DE and BC, acquired during the moments Dd and Bb. It was demonstrated, that the ratio of the area DdeE to the area BbcC is compounded of the ratio of DE to BC, and the ultimate ratio of Dd to Bb. But Dd and

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and Bb are refpectively equal to ϵe and κc. Therefore DdeE is to BbcC, in the ratio compounded of the ratio of DE to BC, and the ultimate ratio of ϵe to κc. If we reprefent DE and BC by V and v, then ϵe and κc muft be reprefented by $\dot{V}$ and $\dot{v}$, the increments of V and v; and then the compound ratio will be the ratio of $V\dot{V}$ to $v\dot{v}$; and if we take the ultimate ratio of the moments, and confequently the ultimate ratio of the increments of the velocities, we have the ratio of $V\dot{V}$ to $v\dot{v}$. If, therefore, V^2 and v^2 reprefent the fquares of the velocities, $V\dot{V}$ and $v\dot{v}$ will reprefent, not the increments of thofe fquares, but half the increments of them.

We may now reprefent this propofition concerning accelerating forces by the proportional equation $a \doteqdot \frac{v\dot{v}}{\dot{s}}$; and we muft confider this as equivalent with $a = \frac{V^2 - v^2}{2\,(S - s)}$; keeping always in mind, that a, V, and v, relate to the fame units of time and fpace, and that a is that number of units of the fcale on which S and s are meafured, which is run over in *one* unit of time.

Meafure of gravity confidered as an accelerating force.

This will be more clearly conceived by taking an example. Let us afcertain the accelerative power of gravity, fuppofing it to act uniformly on a body. Let the fpaces be meafured in feet and the time in feconds. It is a matter of obfervation, that when a body has fallen 64 feet, it has acquired a velocity of 64 feet per fecond: and that when it has fallen 144 feet, it has acquired the velocity of 96 feet per fecond. We want to determine what velocity gravity communicated to it by acting on it during one fecond. We have $V^2 = 9216$, and $v^2 = 4096$; and therefore $V'^2 - v^2 = 5120$. $S = 144$, and $s = 64$, and $S - s = 80$, and $2\,(S - s) = 160$. Now $a = \frac{5120}{160}, = 32$. Therefore gravity has generated the velocity 32 feet per fecond by acting uniformly during one fecond.

86 *The augmentation of the fquare of the velocity is proportional to the force and to the fpace jointly.* For, becaufe $a = \frac{v\dot{v}}{\dot{s}}$, we have $a\dot{s} = v\dot{v}$.

Thus we learn, that a given force, acting uniformly on a body along a given fpace, produces the fame increment of the fquare of the velocity, whatever the previous velocity may have been. Alfo, in the fame manner as we formerly found that the augmentation of the velocity was proportioned to the time during which the force has acted, fo the augmentation of the fquare of the velocity is proportional to the fpace along which it has acted.

Theorems refpecting retarding forces.

It is pretty plain, that all that we have faid of the uniform action of an *accelerating* force may be affirmed of a *retarding force*, taking a diminution or decrement of velocity in place of an increment. A uniformly retarded motion is that in which the decrements of velocity in equal times are equal, and the whole decrements are proportional to the whole times of action. Such a motion is the indication of a conftant or invariable force acting in a direction oppofite to that of the motion. We conceive this to be the cafe when an arrow is fhot perpendicularly upwards; its weight is conceived as a force continually preffing it perpendicularly downwards. In fuch motions, however great the initial velocity may be, the body will come to reft; becaufe a certain determined velocity will be taken from the body in each equal fucceffive moment, and fome multiple of this will exceed the initial velocity. Therefore the velocity will be extinguifhed before the end of a time that is the fame multiple of the time in which the velocity was diminifhed by the quantity above mentioned. It is no lefs evident, that the time in which any velocity will be extinguifhed by an oppofing or retarding force is equal to the time in which the fame force would generate this velocity in the body previoufly at reft. Therefore,

1. The times in which different initial velocities will 87
be extinguifhed by the fame oppofing force are proportional to the initial velocities.

2. The diftances to which the body will go till the 88
extinction of its velocity are as the fquares of the initial velocities.

3. They are alfo as the fquares of the times elapfed. 89

4. The diftance to which a body, projected with any velocity, will go till its motion be extinguifhed by the uniform action of a retarding force, is one half of the fpace which it would defcribe uniformly during the fame time with the initial velocity.

Forces generally variable in their intenfity.

It very rarely happens, that the force which accelerates the body acts uniformly, or with an unvaried intenfity. The attraction of a magnet, for example, increafes as the iron approaches it. The preffure of a fpring diminifhes as it unbends. The impulfe of a ftream of water or wind diminifhes as the impelled furface retires from it by yielding. Therefore the effects of accelerating forces are very imperfectly explained, till we have fhewn what motions refult from any given variation of force, and how to difcover the variation of force from the obferved motion. This laft queftion is perhaps the moft important in the ftudy of mechanical nature. It is only thus that we learn what is ufually called *the nature of a mechanical force*. This chiefly confifts in the relation fubfifting between the intenfity of the force and the diftance of the fubftance in which it refides. Thus the nature of that power which produces all the planetary motions, is confidered as afcertained when we have demonftrated that its preffure or intenfity is inverfely as the fquare of the diftance from the body in which it is fuppofed to refide.

Acceleration expreffes fome relation of the velocity and time. This relation may be geometrically expreffed in a variety of ways. In figure 13. the uniform acceleration or the unvaried relation between the velocity and the time is very aptly expreffed by the conftant ratio of the ordinates and abfciffes of the triangle agv. The ratio of $d\delta$ to ad is the fame with that of $e\iota$ to ae, or that of $f\varphi$ to af, &c.; or the ratio of the increment of velocity $\varpi\kappa$ to the increment of the time $\beta\varpi$ or bc, or that of $i\varphi$ to ιi, &c. This ratio $\varpi\kappa : \beta\varpi$ is equivalent to the fymbol $\frac{\dot{v}}{\dot{t}}$.

But when the fpaces defcribed in a varied motion are reprefented by the areas bounded by a curve line hko, we no longer have that conftant ratio of the increments of the ordinates and abfciffes.

Therefore,

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Therefore, in order to obtain measures of the accelerating forces, or at least of their proportions, let the abscissa aeg (fig. 13.) of the line hko again represent the time of a motion. But let the areas bounded by parallel ordinates now represent the velocities, that is, let the whole area increase during the time ag at the same rate with the velocities of the motion along the line AG. In this case the ordinates bi, ck, dl, &c. will be as the accelerations at the instants b, c, d, &c. or in the points B, C, D, &c.

90 Their measures in such cases how obtained? Theorems of most extensive use.

This is demonstrated in the same way as the former proposition (n° 72.). If the accelerating force be supposed constant during any two equal moments bc and fg, the rectangles $bcpt$ and $fgxs$ would express the increments of velocity uniformly acquired in equal times, and their bases cp and fs would have the ratio of the accelerations, or of the accelerating forces. But as the velocities expressed by the figure increase faster than the times during every moment, the force at the instant c is to the force at the instant f in a greater ratio than that of cp to fs; but, for similar reasons, it is in a less ratio than that of cq to fr; and therefore (as in the other proposition) the force at the instant c is to the force at the instant f as ck to fn.

91 *Cor.* Because cp is to fs in the ratio compounded of the direct ratio of the rectangle $cptb$ to the rectangle $fsxg$, and the inverse ratio of the altitude bc to the altitude fg; and because these rectangles are proportional to the increments of velocity, and the ultimate ratio of the altitudes is the ultimate ratio of the moments or increments of the time—we must say, that *the accelerating forces (that is, their intensities or pressures producing acceleration) are directly as the increments of velocity, and inversely as the increments of the times:* Which proposition may be expressed, in regard to two accelerations A and a, by this analogy:

$$A : a = \frac{\dot{V}}{\dot{T}} : \frac{\dot{v}}{\dot{t}}.$$

Or by the proportional equation $a \doteq \frac{\dot{v}}{\dot{t}}$. Also $a\dot{t} \doteq \dot{v}$, and $\int a\dot{t} = v'$. And thus do these theorems extend even to the cases where there cannot be observed an immediate measure, either of velocity or of acceleration; because neither the space nor the velocity increases uniformly.

See *Barrow's Lect. Geometr.* passim.

The theorem $a \doteq \frac{\dot{v}}{\dot{t}}$ is employed when we would discover the variation in the intensity of some natural power. We observe the motion, and represent it by a figure analogous to fig. 13. where the abscissa represents the times, and the area is made to increase at the same rate with the spaces described. Then the ordinates will represent the velocities, or have the proportion of the velocities. Then we may draw a second curve on the other side of the same abscissa, such that the areas of this last curve shall be proportional to the ordinates of the first. The ordinates of this last curve are proportional to the accelerating forces.

92 On the other hand, when we know from other circumstances that a force, varying according to some known law, acts on a body, we can determine its motion. The intensity of the force in every instant being known, we can draw a line so related to another line representing the time that the ordinates shall be proportional to the forces: The areas will be proportional to the velocities. We can draw another curve to the same abscis, such that the ordinates of this shall be proportional to the areas of the other, that is, to the velocities of the motion. The areas of this second curve will be proportional to the spaces described.

93 All these theorems relate to *changes* of velocity; by which means they indicate *immediately* the operation of natural powers.

We must now observe, that all that has been said concerning the effects of accelerating forces continually varying, relates to *changes* of motion, independent of what the absolute motions may be. The areas of the line whose ordinates represent the velocities do not necessarily represent the spaces described, but the change made on the spaces described in the same time; not the motions, but the changes of motion. If, indeed, the body be supposed to be at rest when the forces begin to act, these areas represent the very spaces that are passed over, and the ordinates are the very velocities. In every case, however, the accelerations are the real increments of the velocities.

This circumstance gives a great extension to our theorems, and enables us to ascertain the disturbances of any species of regular motion, apart from the motions themselves, and thus avoid a complication which would frequently be inextricable in any other way. And this process, which is merely mathematical, is perfectly conformable to mechanical principles. It is in fact an application of the doctrine of the composition of motion; a doctrine rigidly demonstrated when we measure a mechanical force by the *change* of motion which it produces. Acceleration is the continual composition of a new motion with the motion already produced.

No finite change of velocity can be produced in an instant by any accelerating force.

We may learn from this investigation of the value of an accelerating force, that no finite change of velocity is effected in an instant by the action of an accelerating force. When the fig. 13. is used for the scale of accelerations, and they are represented by the ordinates of the line hko, the increment of velocity is represented by an area, that is, by a slip of the whole area; which slip must have some altitude, or must occupy some portion of the abscissa which represents time. Some portion of time, however small it may be, must elapse before any measurable addition can be made to the velocity. The velocity must change *continually*. As no motion can be conceived as instantaneous, because this would be to conceive, that in one instant the moving particle is in every point of its momentary path; so no velocity can change, by a finite quantity, in one instant; because this would be to conceive, that in that instant the particle had all the intervening velocities. The instant of change is at once the last instant of the preceding velocity, and the first of the succeeding, and therefore must belong to both. This cannot be conceived, or is absurd. As a body, in passing from one part of space to another, must pass in succession through all the intermediate places; so, in passing from one velocity to another, it must in succession have all the intermediate velocities. It must be *continually* accelerated; we must not say *gradually*, however small the steps. 94

94 More convenient manner of considering the action of forces, and more frequently coming into view.

But to return from this digression:

The most frequent cases which come under examination do not shew us the relation between the forces and times, but the relation between the forces and spaces. Thus,

Thus, when a piece of iron is in the neighbourhood of a magnet, or a planet is conſidered in the neighbourhood of the ſun, a force is acting on it in every point of its path, and we have diſcovered that the intenſity of this force varies in a certain proportion. Thus, a ſpring varies in its preſſure as it unbends; gunpowder preſſes leſs violently as it expands, &c. &c.

Our knowledge is generally confined to ſome ſuch effect as this. We know, that while a body is moving along a line ADE (fig. 16.), it is urged forward by a force, of which the intenſity varies in the proportion of the ordinates BF, CG, DH, EI, &c. of the line FGHI.

To inveſtigate the motion or change of motion produced by the action of this force, let CD be ſuppoſed a very ſmall portion of the ſpace s, which we may expreſs by s'. Draw GK perpendicular to DH. Then, if we ſuppoſe that the force acts with the unvaried intenſity CG through the whole ſpace CD, the rectangle CDKG will expreſs half of the increment of the ſquare of the velocity (n° 85.). We may ſuppoſe that the force acts uniformly along the adjoining ſmall ſpace D r with the intenſity DH. The rectangle DH or will in like manner expreſs another half increment of the ſquare of the velocity. And in like manner we may obtain a ſucceſſion of ſuch increments. The aggregate or ſum of them all will be half the difference between the ſquare of the velocity at B and the ſquare of the velocity at E.

If we employ f to expreſs the indetermined or variable intenſity of the accelerating force, and v to expreſs the variable velocity, and v' its increment *uniformly* acquired; then the rectangle CDKG will be expreſſed by fs'. We have ſeen that this is equal to vv'. Therefore, in every caſe where we can tell the aggregate of all the quantities fs, it is plain that we will obtain half the difference between the ſquares of the velocities in B and E, on the ſuppoſition that the intenſity of the force was conſtant along each little ſpace, and varied by ſtarts. Then, by increaſing the number, and diminiſhing the magnitude, of thoſe little portions of the ſpace without end, it is evident that we terminate in the expreſſion of the real ſtate of the caſe, *i. e.* of a force varying continually; and that in this caſe the aggregate of theſe rectangles occupies the whole area AEIF, and is equivalent to the fluent of $f\dot{s}$, or to the ſymbol $\int f\dot{s}$, uſed by the foreign mathematicians to expreſs this fluent, which they indeed conceive as an aggregate of ſmall rectangles fs'. And we ſee that this area expreſſes half of the augmentation of the ſquare of the velocity. Therefore,

95 Moſt important theorem (Newton's Principia, I. 39.)

If the abſciſſa AE (fig. 16.) *of a line* FGI *is the path along which a body is urged by any accelerating force, and if the ordinates* BF, CG, DH, *&c. are proportional to the forces acting in the points* B, C, D, *&c. the intercepted areas* BCGF, BEIF, *&c. are proportional to the augmentations of the ſquare of the velocity.*

Obſerve that the areas BCGF and DEIH are alſo proportional to the augmentations made on the ſquares of the velocities in B and in D.

Obſerve alſo, that it is indifferent what may have been the original velocity. The action of the forces repreſented by the ordinates make always the ſame addition to its ſquare; and this addition is half the ſquare of the velocity which thoſe forces would generate in the body by impelling it from reſt in the point A.

96 Laſtly, on this head, obſerve, that we can ſtate what conſtant or variable force will make the ſame augmentation of the ſquare of the velocity by impelling the body uniformly along the ſame ſpace BE; or along what ſpace a given force muſt impel the body, in order to produce the ſame increaſe of the ſquare of its velocity. In the firſt caſe, we have only to make a rectangle BEN φ, equal to the area BEIF, and then B φ is the intenſity of the conſtant force wanted. In the ſecond caſe, in which the force EO is given, we muſt make the rectangle A α OE equal to the area BEIF, and AE is the ſpace required.

97 Converſe.

The converſe of this propoſition, *viz. If the areas are as the increments of the ſquare of the velocity, the ordinates are, as the forces,* is eaſily demonſtrated in the ſame way; for if the elementary areas CDKG and EIM e repreſent increments of the ſquares of the velocity, the accelerating forces are in the ratio compounded of the direct ratio of theſe rectangles and the inverſe ratio of their altitudes, becauſe theſe altitudes are the increments of the ſpace (n° 85). Now the baſe CG of the rectangle CDKG, is to the baſe EI of the rectangle EIM e in the ſame compounded ratio; therefore the force in C is to the force in E as CG to EI.

98 Scales of force, velocity, acceleration, time, &c.

The line $h\ k\ o$ (fig. 13.) was called by Dr Barrow (who firſt introduced this extenſive employment of motion into geometry), the SCALE *of velocities*; and the line FHL (fig. 16.) was named by him the *ſcale of accelerations*. Hermann, in his *Phoranomia*, calls it the *ſcale of forces*. We ſhall retain this name, and we may call $h\ k\ a$ of fig. 13. the *ſcale of* accelerations, when the areas repreſent the velocities. Sir Iſaac Newton added another ſcale of very great uſe, *viz.* a ſcale of times. It is conſtructed as follows.

Let ABE (fig. 16.) be the line along which a body is accelerated, and let FHI be the ſcale of forces, that is, having its ordinates FB, HD, IE, &c. proportional to the forces acting at B, D, E, F, &c.; let $f\ h\ i$ be another line ſo related to ABE, that Cg is to E i in the inverſe ſubduplicate ratio of the area BFGC to the area BFIE; or, to expreſs it more generally, let the ſquares of the ordinates to the line $f\ g\ i$ be inverſely, as the areas of the line FHI intercepted between theſe ordinates and the firſt ordinate drawn through B; then the times of the bodies moving from a ſtate of reſt in B are as the intercepted areas of the curve $f\ g\ i$. 99

For let CD and E e be two very ſmall portions of the ſpace deſcribed in equal times. They will be ultimately as the velocities in C and E. The area FBCG is to the area FBEI as the ſquare of E i to the ſquare of C g (by conſtruction); but the area FBCG is to FBEI as the ſquare of the velocity at C to the ſquare of the velocity at E (by the propoſition); therefore the ſquare of the velocity at C is to the ſquare of the velocity at E as the ſquare of E i to the ſquare of C g; therefore E i is to C g as the velocity at C to the velocity at E, that is, as CD to E e: but ſince E i : Cg = CD : Ee, we have E i $\times$ E e = Cg $\times$ C D, and the elementary rectangles C g k D and E i m e are equal, and may repreſent the equal moments of time in which CD and E e were deſcribed. Thus the areas of the line $f\ g\ l$ will repre-

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sent or express the times of describing the corresponding portions of the abscissa.

We may express the nature of this scale more briefly thus. Let BE be the space described with any varied motion, and fgl a curve, such that its ordinates are inversely as the velocities in the different points of the abscissa, then the area will be as the times of describing the corresponding portions of the abscissa.

100 Examples of the application of n° 95.

In all the cases where our mathematical knowledge enables us to assign the values of the ordinates of the figure 16, we can obtain the law of action of the forces, or the nature of the force; and where we can assign the value of the areas from our knowledge of the proportions of the ordinates or forces, we can ascertain the velocities of the motion. We shall give an example or two, which will shew the way in which we avail ourselves of the geometrical properties of figure in order to ascertain the effects of mechanical forces.

1. Let the accelerating force which impels the body along the line AB be constant, and let the body be previously at rest in B; the line which bounds the ordinates that represent the forces must be some line ϕHN parallel to AB. The area BDHϕ is to the area BENϕ as the square of the velocity at D to the square of the velocity at E. These areas, having equal bases DH and EN, are as their altitudes BD and BE. That is, the spaces described are as the squares of the acquired velocities. And we see that this characteristic mark of uniformly accelerated motion is included in this general proposition.

101 Example second of peculiar importance.

2. Let us suppose that the body is impelled from A (fig. 17.) towards the point C, by a force proportional to its distance from that point. This force may be represented by the ordinates DA, EB, eb, &c. to the straight line DC. We may take any magnitude of these ordinates; that is, the line DC may make any angle with AC. It will simplify the investigation if we make the first force AD = AC. About C describe the circle AHa, cutting the ordinate E B in F; let eb be another ordinate, cutting the circle in f very near to F; draw CH perpendicular to AC, and make the arch Hh = fF, and draw hc parallel to HC; join FC and DH, and draw Fg perpendicular to fb. Let IML be another ordinate.

The area DABE is to the area DAKL as the square of the velocity at B to the square of the velocity at K. But DABE is the excess of the triangle ADC above the triangle EBC, or it is half of the excess of the square of CA or CF above the square of CB, that is, half the square of BF. In like manner, the area DAKL is equal to half the square of KM; but halves have the same ratio as the integers; therefore the square of BF is to the square of KM as the square of the velocity at B to the square of the velocity at K; therefore the velocity at B is to the velocity at K as BF is to KM. The velocities are proportional to the sines of the arches of the quadrant AFH described on AC.

Cor. 1. The final velocity with which the body arrives at C, is to the velocity in any other point B as radius to the sine of the arch AF.

Cor. 2. The final velocity is to the velocity which the body would acquire by the uniform action of the initial force at A as 1 to $\sqrt{2}$; for the rectangle DACH expresses the square of the velocity acquired by the uniform action of the force DA; and this is double of the triangle DAC; therefore the squares of these velocities are as 1 and 2, and the velocities are as $\sqrt{1}$ and $\sqrt{2}$, or as 1 to $\sqrt{2}$.

Cor. 3. The time of describing AB is to the time of describing AC as the arch AF to the quadrant AFH.

102 For when the arch Ff is diminished continually, it is plain that the triangle fiF is ultimately similar to CFB, by reason of the equal angles Cib (or CFB) and fiF, and the right angles CBF and fFi; therefore the triangles fgF and CBF are also similar. Moreover, Bb is equal to Fg, Ff is equal to hH, which is ultimately equal to cC; therefore since the triangles fgF and CFB are similar, we have Fg : Ff = FB : FC, = FB : HC; therefore Bb is to cC as FB to HC, that is, as the velocity at B to the velocity at C; therefore Bb and cC are described in equal moments when indefinitely small; therefore equal portions Ff, hH of the quadrant correspond to equal moments of the accelerated motion along the radius AC; and the arches AF, FM, MH, &c. are proportional to the times of describing AB, BK, KC, &c.

Cor. 4. The time of describing AC with the unequally accelerated motion, is to the time of describing it uniformly with the final velocity as the quadrantal arch is to the radius of a circle; for if a point move in the quadrantal arch so as to be in F, f, M, H, &c. when the body is in B, b, K, C, it will be moving uniformly, because the arches are proportional to the times of describing those portions of AC; and it will be moving with the velocity with which the body arrives at C, because the arch hH is ultimately = Cc. Now if two bodies move uniformly with this velocity, one in the arch AFH, and the other in the radius AC, the times will be proportional to the spaces uniformly described; but the time of describing AFH is equal to the time of the accelerated motion along AC; therefore the proposition is manifest.

103 *Cor.* 5. If the body proceed in the line Ca, and be retarded in the same manner that it was accelerated along AC, the time of describing AC uniformly with the velocity which it acquires in C is to the time of describing ACa with the varied motion, as the diameter of a circle to the circumference; for because the momentary retardations at K′, B′, &c. are equal to the accelerations at K and B, &c. the time of describing ACa is the same with that of describing AHa uniformly with the greatest velocity. That is, to the time of describing AC uniformly as AHa to AC, or as the circumference of a circle to the diameter. Therefore, &c. *N. B.* In this case of retarding forces it is convenient to represent them by ordinates K′L, B′E, aD′, lying on the other side of the axis ACa; and to consider the areas bounded by these ordinates as subtractive from the others. Thus the square of the velocity at K′ is expressed by the whole area DACK′L′D, the part C′K′L being negative in respect of the point DAC. This observation is general (see also Optics, n° 125. *Encycl.*).

Cor. 6. The time of moving along KC, the half of AC, by the uniform action of the force at A, is to that of describing ACa by the varied action of the force directed to C, and proportional to the distance from it, as the diameter of a circle to the circumference; for

 when

when the body is uniformly impelled along KC by the conſtant force IK, the ſquare of the velocity acquired at C is repreſented by half the rectangle IKCH, and therefore it is equal to the velocity which the variable force generates by impelling it along AC (by the way, an important obſervation). The body will deſcribe AC uniformly with this velocity in the ſame time that it is uniformly accelerated along KC. Therefore by *Cor.* 5. the propoſition is manifeſt.

Cor. 7. If two bodies deſcribe AC and KC by the action of forces which are every where propotional to the diſtances from C, their final velocities will be proportional to the diſtances run over, and the times will be equal.

For the ſquares of the final velocities are proportional to the triangles ADC, LKC, that is, to AC^2 KC^2, and therefore the velocities are as AC, KC. The times of deſcribing AC and KC uniformly, with velocities proportional to AC and KC, muſt be equal; and theſe times are in the ſame ratio (*viz.* that of radius to $\frac{1}{4}$ of the circumference) to the times of deſcribing AC and KC with the accelerated motion. Therefore, &c.

Thus by availing ourſelves of the properties of the circle, we have diſcovered all the properties or characters of a motion produced by a force always directed to a fixed point, and proportional to the diſtance from it. Some of theſe are remarkable, ſuch as the laſt corollary; and they are all important; for there are innumerable caſes where this law of action obtains in Nature. It is nearly the law of action of a bowſtring, and of all elaſtic bodies, when their change of figure during their mutual action is moderate; and it has been by the help of this propoſition, firſt demonſtrated in a particular caſe by Lord Brouncker and Mr Huyghens, that we have been able to obtain preciſe meaſures of time, and conſequently of actual motions, and conſequently of any of the mechanical powers of Nature. It is for this reaſon, as well as for the eaſy and perſpicuous employment of the mathematical method of proceeding that we have ſelected it.

Inſtead of giving any more particular caſes, we may obſerve in general, that if the intenſity of the force be proportional to any power whoſe index is $n-1$ of the diſtance, and if a be the diſtance from the fixed point at which the body begins to be accelerated, and x its diſtance from that point in any part of the motion, the velocity will be $\doteq\sqrt{a^n-x^n}$. This is very plain, becauſe the increment CGHD of the area of fig. 16. which is alſo the increment of the ſquare of the velocity, is $\doteq x^{n-1}\dot{x}$, and the area is $\doteq x^n$; and the whole area, correſponding to the diſtance a, is a^n. Therefore the portion of the area lying beyond the diſtance x is a^n-x^n. This is as the ſquare of the velocity, and therefore the velocity is as the ſquare root $\sqrt{a^n-x^n}$ of this quantity.

This propoſition, $f\dot{s}\doteq v\dot{v}$, or $f\doteq\frac{v\dot{v}}{\dot{s}}$, is the 39th of the firſt book of Newton's *Principia*, and is perhaps the moſt important in the whole doctrine of dynamics, whether employed for the inveſtigation of forces or for the explanation of motions. It furniſhes the moſt immediate data for both purpoſes, but more eſpecially for the laſt. By its help Sir Iſaac Newton was able to point out the numerous diſturbances of the planetary motions, and to ſeparate them from each other; thus unravelling, as it were, that moſt intricate motion in which all are blended together. He has given a moſt wonderful ſpecimen of its application in his Lunar Theory.

We now are able to explain all the puzzling facts which were adduced by Leibnitz and his partiſans in ſupport of their meaſure of the forces of bodies in motion. We ſee why four ſprings, equally bent, communicate but a double velocity, and nine ſprings but a triple velocity; why a bullet moving twice as faſt will penetrate an earthen rampart to a quadruple depth, &c. &c.

Conſervatio virium vivarum.

This theorem alſo gives a moſt perſpicuous explanation of the famous doctrine called *conſervatio virium vivarum.* When perfectly elaſtic bodies act on each other, it is found that the ſum of the maſſes multiplied by the ſquares of the velocities is always the ſame. This has been ſubſtituted, with great encomiums, by the German philoſophers in place of Des Cartes's principle, that the quantity of motion in the univerſe, eſtimated in one direction, remains always the ſame. They are obliged, however, to acknowledge, that in the actions of perfectly hard bodies, there is always a loſs of *vis viva*, and therefore have denied the exiſtence of ſuch bodies. But there is the ſame loſs in the mutual actions of all ſoft or ductile, or even imperfectly elaſtic, bodies; and they are miſerably puzzled how to explain the fact: but both the *conſervatio* and the *amiſſio* are neceſſary conſequences of this theorem.

In the colliſion of elaſtic bodies, the whole change of motion is produced during the ſhort time that the bodies are compreſſed, and while they regain their figure. When this is completed, the bodies are at the ſame diſtance from each other as when the mutual action began. Therefore the preceding body has been accelerated, and the following body has been retarded, along equal ſpaces; and in every point of this ſpace the accelerating and the retarding force has been equal. Conſequently the ſame area of fig. 17. expreſſes the change made on the ſquare of the velocity of both bodies. Therefore, if V and U are the velocities before colliſion, and v and u the velocities after colliſion, of the two bodies A and B, we muſt have $A\times\overline{V^2-v^2}=B\times\overline{u^2-V^2}$, and therefore $A\times V^2+B\times U^2=A\times v^2+B\times u^2$.

But in the other claſs of bodies, which do not completely regain their figure, but remain compreſſed, they are nearer to each other when their mutual action is ended than when it began. The foremoſt body has been accelerated along a ſhorter ſpace than that along which the other has been retarded. The mutual forces have, in every inſtant, been equal and oppoſite. Therefore the area, which expreſſes the diminution of the ſquare of the velocity, muſt exceed the area expreſſing the augmentation by a quantity that is always the ſame when the permanent compreſſion is the ſame; that is, when the relative motion is the ſame. $A\times\overline{V^2-v^2}$ muſt exceed $B\times\overline{u^2-U^2}$, and $A\times V^2+B\times U^2$ muſt exceed $A\times v^2+B\times u^2$.

This ſame theorem is of the moſt extenſive uſe in all practical queſtions in mechanic arts: and without it mechanics can go no further than the mere ſtatement of equilibrium.

Hermann,

History of nº 95. is curious.

Hermann, profeſſor of mathematics at Pavia, one of the ornaments of the mathematical claſs of philoſophers, has given a pretty demonſtration of this valuable propoſition in the *Acta Eruditorum Lipſiæ* for 1709; and ſays, that having ſearched the writings of the mathematicians with great care, he found himſelf warranted to ſay, that Newton was the undoubted author, and boaſts of his own as the firſt ſynthetical demonſtration. The purpoſe of this aſſertion was not very apparent at the time; but long after, in 1746, when Hermann's papers, preſerved in the town-houſe of Pavia, were examined, in order to determine a diſpute between Maupertuis and Koenig about the claim to the diſcovery of *the principle of leaſt action*, letters of Leibnitz's were found, requeſting Hermann to ſearch for any traces of this propoſition in the writings of the mathematicians of Europe. Leibnitz was by this time the envious detractor from Newton's reputation; and could not but perceive, that all his contorted arguments for his doctrine received a clear explanation by means of this propoſition, in perfect conformity to the uſual meaſure of moving forces. Newton had diſcovered this theorem long before the publication of the *Principia*, and even before the diſcovery of the chief propoſition of that book in 1666: for in his optical Lectures, the materials of which were in his poſſeſſion in 1664, he makes frequent uſe of a propoſition founded on this (ſee nº 42.). We may here remark, that Hermann's demonſtration is, in every ſtep, the ſame with Dr Barrow's demonſtration of it as a theorem merely geometrical, without ſpeaking of moving forces (ſee *Lect. Geometr.* xi. p. 85. edit. 16.), but giving it as an inſtance of the transformation of curves, which he calls SCALES of velocity, of time, of acceleration, &c. It is very true that Barrow, in theſe mathematical lectures, approached very near to both of Newton's diſcoveries, the fluctionary geometry, and the principles of dynamics; and the junto on the continent, who were his continual detractors, charge him with impudent plagiariſm from Dr Barrow, and even ſay that he has added nothing to the diſcoveries of his teacher. But ſurely Dr Barrow was the beſt judge of this matter; and ſo far from reſenting the uſe which Newton has made of what he had taught him, he was charmed with the genius of the *juvenis ſpectatiſſimus* his ſcholar, and of his own accord gave him his profeſſorial chair, and ever after lived in the utmoſt harmony and friendſhip with him. Nay, it would even appear, from ſome expreſſions in thoſe very lectures, that Dr Barrow owed to young Newton the firſt thought of making ſuch extenſive uſe of motion in geomery. We recommend this work of Barrow's to the ſerious peruſal of our readers, who wiſh to acquire clear notions of the ſcience of motion, and an elegant taſte in their mechanical diſquiſitions. After all the cultivation of this ſcience by the commentators and followers of Newton, after the *Phoronomia* of Hermann, the *Mechanica* of Euler, the *Dynamique* of D'Alembert, and the *Mechanique Analytique* of De la Grange, which are undoubtedly works of tranſcendent merit and utility, the *Principia* of Newton will ſtill remain the moſt pleaſing, perſpicuous, and elegant ſpecimen of the application of mathematics to the ſcience of *univerſal mechanics*, or what we call DYNAMICS.

The two fundamental theorems $f\dot{t}=\dot{v}$, and $f\dot{s}=v\dot{v}$, enable us to ſolve every queſtion of motion accelerated or retarded by the action of the mechanical powers of nature. But the employment of them may be greatly expedited and ſimplified by noticing two or three general caſes which occur very frequently.

104 Similar inſtants and points, what?

Theſe may be called ſimilar inſtants of time, and *ſimilar points of ſpace which divide given portions of time*, and *of ſpace in the ſame ratio*. Thus the middle is a ſimilar inſtant of an hour or of a day, and is the ſimilarly ſituated point of a foot or of a yard. The beginning of the 21ſt minute, and of the 9th hour, are ſimilar inſtants of an hour and of a day. The beginning of the 5th inch, and of the 2d foot, are ſimilar points of a foot and of a yard.

105 Similar actions, what?

Forces may be ſaid to act ſimilarly when their intenſities in ſimilar inſtants of time, or in ſimilar points of ſpace, are in a conſtant ratio. Thus in fig. 17. when one body is impelled towards C from A, and another from K, each with a force proportional to the diſtance of every point of its motion from C, theſe forces may be ſaid to act ſimilarly along the ſpaces AC and KC, or during the times repreſented by the quadrantal arches AFH, KNO. The following propoſitions on ſimilar actions will be found very uſeful on many occaſions; but we muſt premiſe a geometrical lemma.

If there be two lines EFGH (fig. 18.), *efgh*, ſo related to their abſciſſes AD, *ad*, that the ordinates IK, *ik*, drawn from ſimilar points I and *i* of the abſciſſes, are in the conſtant ratio of AE to *ae*; then the area ADHE is to the area *adhe* as the rectangle of AD × AE to the rectangle *ad* × *ae*. 106

For let each abſciſſa be divided into the ſame number of equal and very ſmall parts, of which let CD and *cd* be one in each. Inſcribe the rectangles CGID, *cgid*. Then becauſe the number of parts in each axis is the ſame, the lengths of the portions CD and *cd* will be proportional to the whole abſciſſes AD and *ad*. And becauſe C and *c* are ſimilar points, CG is to *cg* as AE is to *ae*. Therefore CD×CG : *cd*×*cg* = AD A·E : *ad*×*ae*. This is true of each pair of correſponding rectangles; and therefore it is true of their ſums. But when the number of theſe rectangles is increaſed, and their breadth diminiſhed without end, it is evident that the ultimate ratio of the ſum of all the rectangles, ſuch as CDHG to the ſum of all the rectangles *cdhg* is the ſame with that of the area ADHE to the area *adhe*, and the propoſition is manifeſt.

If two particles of matter are ſimilarly impelled during given times, the changes of velocity are as the times and as the forces jointly. 107

Let the times be repreſented by the ſtraight lines ABC (fig. 19.) and *abc*, and the forces by the ordinates AD, BE, CF, and *ad*, *be*, *cf*. Then if B and *b* are ſimilar inſtants (ſuppoſe the middles) of the whole times, we have BE : *be* = AD : *ad*. Therefore, by the lemma, the area ACFD is to *acfd* as AC × AD to *ac*×*ad*. But theſe, areas are proportional to the velocities (nº 72), and the propoſition is demonſtrated. For the ſame reaſon, the change of velocity during the time AB is to the change during *ab* as AB × AD to *ab* × *ad*.

Cor. 1. If the times and forces are reciprocally proportional, the changes of velocity are equal; and if the forces are inverſely as the times, the changes of velocity are equal.

If two particles be ſimilarly urged along given ſpaces, the changes made on the ſquares of the velocities are as the forces and ſpaces jointly. 108

For if AC (fig. 19.) and *ac* are the ſpaces along which

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which the particles are impelled, and the forces are as the ordinates AD and *a d*, the areas ACFD, and *a c f d* are as the changes on the squares of the velocities. But these areas are as $AC \times AD$, and $ac \times ad$. Therefore, &c.

Cor. 2. If the spaces are inversely as the forces, the changes of the squares of the velocities are equal; and if these are equal, the spaces are inversely as the forces.

Cor. 3. If the spaces, along which the particles have been impelled from a previous state of rest, are directly as the forces, the velocities are also as the forces. For, because the changes of the squares of the velocities are as the spaces and forces jointly, they are in this case as the squares of the forces or of the spaces; but the changes of the squares of the velocities are in this case the whole squares of the velocities; therefore the squares of the velocities are as the squares of the forces, and the velocities are as the forces. *N. B.* This includes the motions represented in fig. 17.

109 *If two particles be similarly impelled along given spaces, from a state of rest, the squares of the times are proportional to the spaces directly, and to the forces inversely.*

Let ABC (fig. 19.) *a b c* be the spaces described, and AD, *a d*, the accelerating forces at A and *a*. Let V, B express the velocity at B, and *v*, *b* the velocity at *b*.

Let GHK and *g h k* be curves whose ordinates are inversely as the velocities at the corresponding points of the abscissa. These curves are therefore exponents of the times (n° 99.) Then, because the forces act similarly, we have, by the last theorem, $AC \times AD : ac \times ad = V^2, B : v^2, b, = hb^2 : HB^2$. Therefore $HB : hb = \sqrt{ac \times ad} : \sqrt{AC \times AD}$ and therefore in a constant ratio. Call this the ratio of *m* to *n*. But, since the ordinates of the lines GHK, *g h k* are inversely as the velocities, the areas are as the times (n° 99); and since these ordinates are in the constant ratio of *m* to *n*, the areas are in the ratio of $AC \times m$ to $ac \times n$. Therefore (calling the times of the motions T and *t*), we have

$$T : t = m\,AC : n\,ac; \text{ and therefore}$$
$$T^2 : t^2 = m^2 \times AC^2 : n^2 \times ac^2. \quad \text{But}$$
$$m^2 : n^2 = ac \times ad : AC \times AD. \quad \text{Therefore}$$
$$T^2 : t^2 = ac \times ad \times AC^2 : AC \times AD \times ac^2,$$
$$\text{Or } T^2 : t^2 = ad \times AC : AD \times ac.$$
$$\text{Or } T^2 : t^2 = \frac{AC}{AD} : \frac{ac}{ad}.$$

The attentive reader will observe that these three propositions give a great extension to the theorems which were formerly deduced from the nature of uniformly accelerated motion, or of uniform action of the forces, and were afterwards demonstrated to obtain in the momentary action of forces any how variable.

The first of the three propositions, $V : v = F \times T : f \times t$, is the extension of the theorem $f \times \dot{t} = \dot{v}$. The second, $V^2 : v^2 = F \times S : f \times s$, is the extension of the theorem $f \times \dot{s} = v\dot{v}$. And the third, $T^2 : t^2 = \frac{S}{F} : \frac{s}{f}$, is the extension of $f = \frac{\dot{s}}{(t^2)^{\cdot}}$, or of $f \times (t^2)^{\cdot} = \dot{s}$. These theorems hold true of all *similar* actions; and only for this reason, are true of uniformly accelerated motions, or uniform actions.

There remains one thing more to be said concerning the action of accelerating forces. Their magnitude is ascertained by their effect. Therefore that is to be considered as a double force which produces a double quantity of motion. Therefore when a body A contains twice the number of equal atoms of matter, and acquires the same velocity from the action of the force F that another body *a*, containing half the number of atoms, acquires from the action of a force *f*, we conceive F to be double of *f*. That this is a legitimate inference appears clearly from this, that we conceive the sensible weight of a body, or that pressure which it exerts on its supports, as the aggregate of the equal pressure, of every atom, accumulated perhaps on one point; as when the body hangs by a thread, and, by its intervention, pulls at some machine. Without inquiring in what manner, or by what intervention, this accumulation of pressure is brought about, we see clearly that it results from the equal accelerating force of gravity acting immediately on each atom. When this weight is thus employed to move another body by the intervention of the thread, which is attached to one point perhaps of that body, it puts the whole into motion, generating a certain velocity *v* in every atom, by acting uniformly during the time *t*. We conceive each atom to have sustained the action of an equal accelerating force, whose measure is $\frac{v}{t}$. Without considering how this force is exerted on each atom, or by what it is immediately exerted, or how it is diffused through the body from the point to which the weight of the other body is applied by means of the thread; we still consider it as the aggregate of the action of gravity on each atom of that other body. Moreover, attending only to the motion produced by it, and perhaps not knowing the weight of the impelling body, we measure it, as a moving force, by considering it as the aggregate of the forces propagated to each atom of the impelled body, and measured by $\frac{v}{t}$. If we know that the impelled body contains the number *m* of atoms, the aggregate of forces is $m\frac{v}{t}$, or $\frac{mv}{t}$.

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Aggregate of many equal accelerating forces.

But since we measure forces by the quantity of motion which they produce, we must conceive, that when the same force is applied to a body, which consists of *n* particles, and produces the velocity *u*, by acting uniformly during the same time *t*, the force $n\frac{u}{t}$ is equal to the force $m\frac{v}{t}$.

110 Moving force, motive force, vis motrix, as distinguished from accelerating force.

Sir Isaac Newton found it absolutely necessary, in the disquisitions of natural philosophy to keep this circumstance of acceleration clear of all notions of quantity of matter, or other considerations, and to contemplate the affections of motion only. He therefore considered $\frac{v}{t}$ as the true original measure of accelerating force, and $m\frac{v}{t}$ as an aggregate. He therefore calls the aggregate a *vis motrix*, a *moving force*, measured by the *quantity of motion* that it generates. And he confines the term *accelerating force* to the quantity $\frac{v}{t}$, measured by

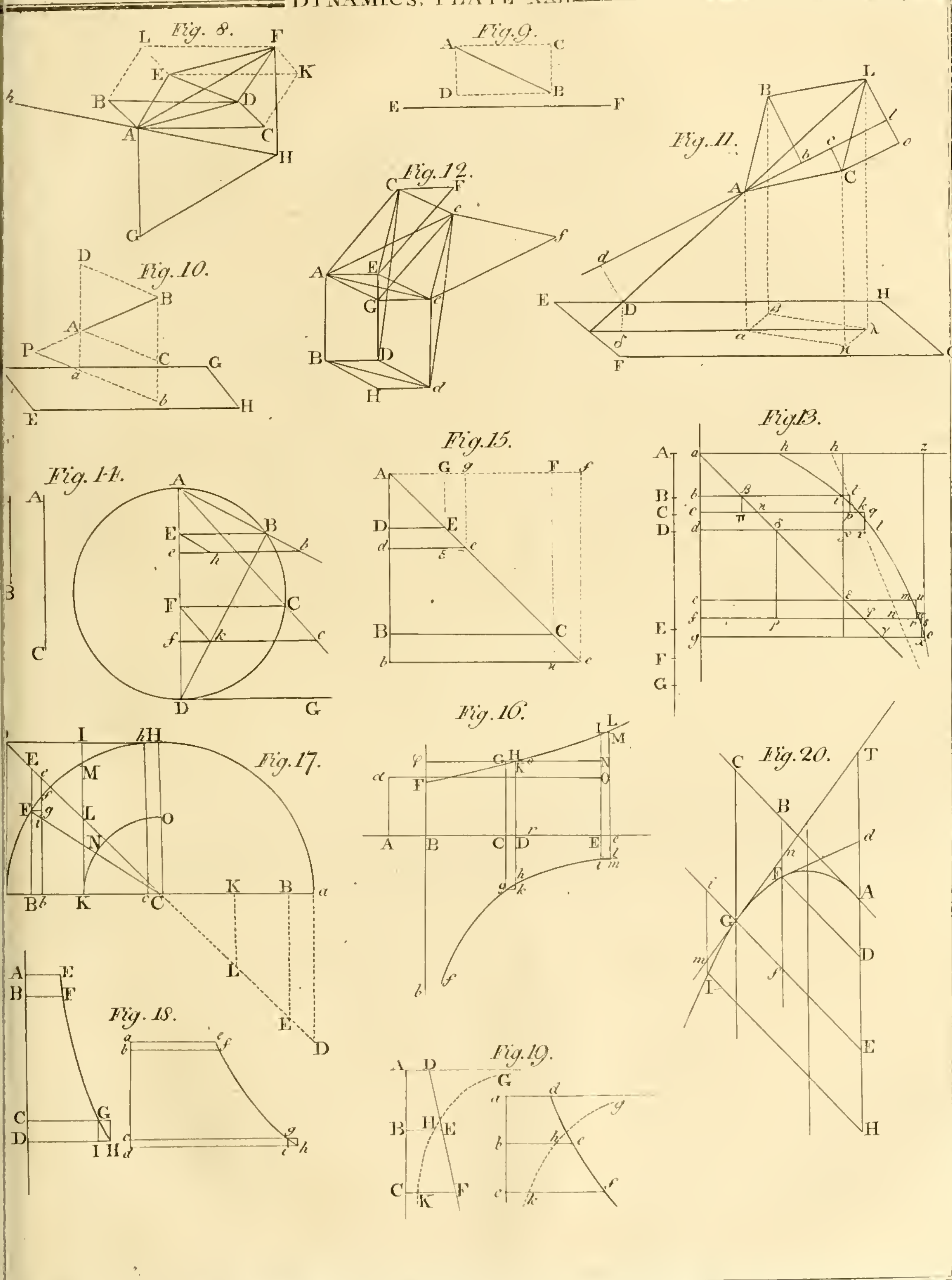
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.

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by the *acceleration* or *velocity* only. It would be convenient, therefore, alſo to confine the ſymbol f to $m\frac{v}{t}$, and to retain the ſymbol a for expreſſing the accelerating force $\frac{v}{t}$.

This appellation of *motive force* is perfectly juſt and ſimple; for we may conceive it as the ſame with the accelerating force which produces the velocity m times v in one particle, by acting on it uniformly during the time t. This motion of one particle having the velocity $m\ v$, is the ſame with that of m particles having each the velocity v.

If therefore a motive force f act on a body conſiſting of m particles, the accelerating force a is $= \frac{f}{m}\frac{v}{t}$.

Therefore the three laſt propoſitions concerning the ſimilar, the uniform, or the momentary actions of *moving* forces, when expreſſed in the moſt general terms, are,

$$v' \doteq \frac{f}{m\,t}.$$

$$v^{2\prime} \doteq \frac{f s'}{m} \text{ or, } v\,\dot{v} = \frac{f\,\dot{s}}{m}.$$

$$t^2 \doteq \frac{m s'}{f}.$$

Of Deflecting Forces.

111 Deflecting forces.

When we obſerve the direction of a body to change, we unavoidably infer the agency of a force which acts in a direction that does not coincide with that of the body's motion; and we may diſtinguiſh this circumſtance by calling it a DEFLECTING FORCE. We have already ſhewn how to eſtimate and meaſure this deflecting force, by conſidering it as competent to the production of that motion which, when compounded with the former motion, will produce the new motion (n° 44.) Now, as all changes of motion are really compoſitions of motions or forces, it is evident that we ſhall explain the action of deflecting forces when we ſhew this compoſition.

Alteration of deflections are continual, and produce curvilineal motions.

We may almoſt venture to ſay *à priori*, that all deflections muſt be continual, or exhibit curvilineal motions: for as no finite velocity, or change of velocity, can be produced in an inſtant by the action of an accelerating force, no polygonal or angular deflection can be produced; becauſe this is the compoſition of a finite velocity produced in an inſtant. Deflective motions are all produced by the compoſition of the former motion, having a finite velocity, with a tranſverſe motion continually accelerated from a ſtate of reſt. Of this we can form a very diſtinct notion, by taking the ſimpleſt caſe of ſuch accelerated motion, namely, an uniformly accelerated motion.

112 Example. Determination of the path,

Let a body be moving in the direction AC (fig. 20.) with any conſtant velocity, and when it comes to A, let it be expoſed to the action of an accelerating force, acting uniformly in any other direction AE. This alone would cauſe the body to deſcribe AE with a uniformly accelerated motion, ſo that the ſpaces AD, AE would be as the ſquares of the times in which they are deſcribed. Therefore, if AB be the ſpace which it would have deſcribed uniformly in the time that it deſcribes AD by the action of the accelerating force, and AC the ſpace which it would have deſcribed uniformly while it deſcribes AE by the action of the accelerating force—nothing more is wanted for aſcertaining the real motion of the body but to compound the uniform motion in the direction AC with the uniformly accelerated motion in the direction AE. AD is to AE as the ſquare of the time of deſcribing AD to the ſquare of the time of deſcribing AE; that is, as the ſquare of the time of deſcribing AB to the ſquare of the time of deſcribing AC; that is, as AB^2 to AC^2 (by reaſon of the uniform motion in AC). This compoſition is performed by taking the ſimultaneous points B, D, and the ſimultaneous points C, E, and completing the parallelograms ABFD, ACGE. The body will be found in the points F and G in the inſtants in which it would have been found at B and C by the uniform motion, or in D and E by the accelerated motion. In the ſame manner may be f und as many points of the real path as we pleaſe. It is plain that theſe points will be in a line AFG, ſo related to AE that AD : AE $=$ $DF^2 : EG^2$; or ſo related to the original motion, AC, that $AB^2 : AC^2 = BF : CG$, &c. This line is therefore a parabola, of which AE is a diameter, DF and EG are ordinates, and which touches AC in A.

And of the motion in this path.

Having thus aſcertained the path of the body, we can alſo aſcertain the motion in that path; that is, the velocity in any point of it. We know, that the velocity in the point G is to the velocity of the uniform motion in the direction AC as the Tangent TG is to the ordinate E G; becauſe this is the ultimate ratio of the momentary increment of the arch AFG to the momentary increment of the ordinate EG. Thus is the velocity in every point of the curve determined. We have taken it for granted, that the line of projection touches the path, and that the direction in every point is that of the tangent. To ſuppoſe that the curve, in any portion of it, coincides with the tangent, is to ſuppoſe that the body is not deflected; that is, is not acted on by a tranſverſe accelerating force: And to ſuppoſe that the tangent makes a finite angle with any part of the path, is to ſuppoſe that the deflection is not continual, but by ſtarts—both of which are contrary to the conditions of the caſe. No ſtraight line can be drawn between the direction of the body and the ſucceeding portion of the path, otherwiſe we muſt again ſuppoſe that the deflection is ſubſultory, and the motion angular.

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But while the inveſtigation is ſo eaſy when the direction and intenſity of the deflecting force in every point of the curve are known, the inveſtigation of the deflecting force from the obſerved motion is by no means eaſy. The obſerved curvilineal motion always ariſes from a compoſition of a uniform motion in the tangent with ſome tranſverſe motion. But the ſame curvilineal motion may be produced by compounding the uniform motion in the tangent with an infinity of tranſverſe motions; and the law of action will be different in theſe tranſverſe motions according as their directions differ. We muſt learn not only the intenſity of the deflecting force and the law of its variation, but alſo its direction in every point of the curve. It is not eaſy to find general rules for diſcovering the direction of the tranſverſe force;

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force; most commonly this is indicated by extrinsic circumstances. The deflecting force is frequently observed to reside in, or to accompany some other body. It may be presumed, therefore, that it acts in the direction of the line drawn to or from that body; yet even this is uncertain. The most general rule for this investigation is to observe the place of the body at several intervals of time before and after its passing through the point of the curve, where we are interested to find its precise direction. We then draw lines, joining those places with the places of the tangent where the body would have been by the uniform motion only. We shall perhaps observe these lines of junction keep in parallel positions: we may be assured, that the direction of the transverse force is the same with that of any of these lines. This is the case in the example just now given of a parabolic motion. But when these lines change position, they will change it gradually; and their position in the point of contact is that to which their positions on both sides of it gradually approximate.

But all this is destitute of the precision requisite in philosophical discussion. We are indebted to Sir Isaac Newton for a theorem which ascertains the direction of the transverse force with all exactness, in the cases in which we most of all wish to attain mathematical accuracy, and which not only opened the access to those discoveries which have immortalised his name, but also pointed out to him the path he was to follow, and even marked his first steps. It therefore merits a very particular treatment.

114 Newton's fundamental theorem for the direction of a deflecting force.

If a body describes a curve line ABC, DEF (fig. 21.) lying in one plane; and if there be a point S so situated in this plane that the line joining it with the body describes areas ASB, ASC, ASD, &c. proportional to the times in which the body describes the arches AB, AC, AD, &c. the force which deflects the body from rectilineal motion is continually directed to the fixed point S.

Let us first suppose that the body describes the polygon ABCDEF, &c. formed of the chords AB, BC, CD, DE, EF, &c. of this curve: and (for greater simplicity of argument) let us consider areas described in equal successive times; that is, let us suppose that the triangles ASB, BSC, CSD, &c. are equal, and described in equal times. Make B c = AB, and draw c S.

Areas ≑ to the times indicate central forces.

Had the motion AB suffered no change in the point B, the body would have described B c in the equal moment succeeding the first: but it describes BC. The body has therefore been deflected by an external force; and BC is the diagonal of a parallelogram (n° 45.46.), of which B c is one side, and c C is another. The deflecting force will be discovered, both in respect of direction and intensity, by completing the parallelogram B c C b. B b is the space which the deflecting force would have caused the body to describe in the time that it describes B c or BC. Because B c is equal to BA, the triangles BS c, BSA are equal. But (by the nature of the motion) BSA is equal to BSC. Therefore the triangles BSC and BS c are equal. They are also on the same base BS; therefore they lie between the same parallels, and C c is parallel to SB. But c C is parallel to B b. Therefore B b coincides with BS, and the deflecting force at B is directed toward S. By the same argument, the deflecting force at the angles D, E, F, &c. is directed to S.

Now, let the sides of the polygon be diminished, and their number increased without end. The demonstration remains the same; and continues, when the polygon finally coalesces with the curve, and the deflection is continual.

When areas are described proportional to the times, equal areas are described in equal times; and therefore the deflection is always directed to S. Q. E. D.

Centre of deflection. Centre of forces. Central forces.

The point S may, with great propriety of language, be called the CENTRE OF DEFLECTION, OR THE CENTRE OF FORCES; and forces which are thus continually directed to one fixed point, may be distinguished from other deflecting forces by the name CENTRAL FORCES.

The line joining the centre of forces with the body, and which may be conceived as a stiff line, carrying the body round, is usually named the RADIUS VECTOR. Radius vector.

115 Central forces produce areas proportional to the times.

The converse of this proposition, *viz.* that if the deflecting forces be always directed to S, the motion is performed in one plane in which S is situated, and areas are described proportional to the times—is easily demonstrated by reversing the steps of this demonstration. The motion will be in the plane of the lines SB and B c; because the diagonal BC of the parallelogram of forces is in the plane of the sides. Areas are described proportional to the times; for C c being parallel to SB, the triangles SCB and S c B are equal; and therefore SCB and SAB are equal, &c. &c.

116 Velocity is inversely as the perpendicular from the centre.

Cor. 1. When a body describes areas round S proportional to the times, or when it is continually deflected toward S. or acted on by a transverse force directed to S, the velocities in the different points A and E of the curve are inversely proportional to the perpendiculars S r and S t, drawn from the centre of forces to the tangents in those points; that is, to the perpendiculars from the centre on the momentary directions of the motion: For since the triangles ASB, ESF are equal, their bases AB, EF are inversely as their altitudes S r, S t. But these bases, being described in equal times, are as the velocities; and they ultimately coincide with the tangents at A and E.

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Cor. 2. If B α and F ε be drawn perpendicular to SA and SE, we have SA $\times$ B α = SE $\times$ F ε, and SA : SE = F ε : B α: For SA $\times$ B α is double of the triangle BSA, and SE $\times$ F ε is double of the equal triangle SFE.

118 Angular velocity is inversely as the square of the distance from the centre of forces.

Cor. 3. The angular velocity round S, that is, the magnitude of the angle described in equal times by the radius vector, is inversely proportional to the square of the distance from S. For when the arches AB, EF are diminished continually, the perpendiculars B α and F ε will ultimately coincide with arches described round S with the radii SB and SF. Now the magnitude of an angle is proportional to the length of the arch which measures it directly, and to the radius of the arch inversely. In any circle, an arch of two inches long measures twice as many degrees as an arch one inch long; and an arch an inch long contains twice as many degrees of a circle whose radius is twice as short. Therefore, ultimately, the angle ASB is to the angle ESF as B α to F ε, and as SF to SB jointly; that is, as B α $\times$ SF to F ε $\times$ SB. But B α : F ε = SE : SA (*Cor.* 2.). Therefore ASB : ESF = SE $\times$ SF : SB $\times$ SA, = ultimately SE^2 : SB_2.

This corollary gives us an ostensible mark, in many very

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very important cafes, of the action of a deflecting force being always directed to a fixed point. We are often able to meafure the angular motion when we cannot meafure the real velocities.

Intimate connection of dynamics and the higher geometry.

Having thus difcovered the chief circumftances which enable us to afcertain the direction of the deflecting force, we proceed to inveftigate the quantity of this deflective determination in the different points of a curvilineal motion. This is a more difficult tafk. The momentary effect of the deflecting force is a fmall deviation from the tangent; and this deviation is made with an accelerated motion. The law of this acceleration regulates the curvature of the path, and is to be determined by it. We may be allowed to obferve by the way, that it appears clearly from the form in which Newton has prefented all his dynamical theorems, that we are indebted to thefe problems for the immenfe improvement which he has made in geometry by his invention of fluxions. The purpofes he had in view fuggefted to his penetrating mind the means for attaining them; and the connection between dynamics and geometry is fo intimate, that the fame theorems are in a manner common to both. This is particularly the cafe in all that relates to curvature. Or fhall we fay that the geometry of Dr Barrow fuggefted the dynamical theorems to Newton? We have feen how the curvature of a parabola is produced by a force acting uniformly. The *momentary* action of all finite forces may be confidered as uniform; and therefore the curvature will be that of fome portion of fome parabola; but it will be difficult to determine the precife degree without fome farther help. We are beft acquainted with the properties of the circle, and will have the cleareft notions of the curvature of other curves by comparing them with circles.

Meafure of curvature.

The curvature of a circular arch of given length is fo much greater as its radius is fhorter; for it will contain fo many more degrees in the fame length; and therefore the change of direction of its extremities is fo much greater. Curvatures may always be meafured by the length of the arch directly and the radius inverfely.

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Evolution and involution of curves.

Suppofe a thread made faft at one end of a material curve ABCD (fig. 22.) and applied to it in its whole length. Taking hold of its extremity D, unfold it gradually from the curve DCBA; the extremity D will defcribe another curve D *c b a*. This geometrical operation is called the Evolution of curves, and D *c b a* is called the Evolute of DCBA, which is called the Involute of D *c b a*. Perhaps this denomination has been given from the genefis of the area or furface contained by the two lines which is folded up and unfolded fomewhat like a fan. When the defcribing point is in *b*, the thread *b* B is, undoubtedly, the momentary radius of a circle *e b f*, whofe centre is B, the point of the involute which it is juft going to quit. The momentary motion of *b* is the fame, whether it is defcribing an arch of the evolute paffing through *b*, or an arch of a circle round the centre B. The fame line *b t*, perpendicular to the thread *b* B, touches the circle *e b f* and the curve D *b a* in the point *b*. This circle *e b f* muft lie within the curve D *b a* on the fide of *b* B toward *a*; becaufe on this fide the momentary radius is continually increafing. For fimilar reafons, the circle *e b f* lies without the curve on the other fide of *b* B. Therefore the circle *e b f* both touches and cuts the curve D *b a* in the point *b*. Moreover, becaufe every portion of the curve between *b* and D is defcribed with radii that are fhorter than *b* B, it muft be more incurvated than any portion of the circle *e b f*. For fimilar reafons, every portion of the curve between *b* and *a* muft be lefs incurvated than this circle; therefore the circle has that precife degree of curvature that belongs to the curve in the point *b*; it is therefore called the Equicurve Circle, or the Circle of Curvature, and B is called the centre, and B *b* the Radius of Curvature. It is eafy to perceive that no circle can be defcribed which fhall touch the curve in *b*, and come between it and the circle *e b f*; for its centre muft be in fome point *i* of the radius *b* B. If *i b* be lefs than B *b*, it muft fall within the curve on both fides of *b*, and if *i b* is greater than B *b*, the circle muft fall without the curve on both fides of B *b*. The circle *e b f* lies clofer to the curve, has clofer contact with it, than any other, and has therefore got the whimfical name of Osculating Circle; and this fort of contact was called Osculation.

Circle of curvature. Equicurve circle.

This view of the genefis of curve lines is of particular ufe in dynamical difcuffions. It exhibits to the eye the perfect famenefs of the momentary motion, and therefore of the momentary deflection, in the curve and in the equicurve circle, and leaves the mind without a doubt but that the forces which produce the one will produce the other. A great variety of curves may be defcribed in this way. If perpendiculars be drawn to the curve D *b a* in every point, they will interfect each other, each its immediate neighbour, in the circumference of the curve DBA; and geometry teaches us how to find the curve DBA which fhall produce the curve D *b a* by evolution (fee Evolution and Involution, *Supplement*).

It is a matter worthy of remark, that the path of a body that is deflected from rectilineal motion by a *finite* force, varying according to any law whatever, may always be defcribed by evolution. This includes almoft every cafe of the action of deflecting forces; none being excepted but when, by the oppofite action of different forces, the body is in equilibrio in one fingle point of its path.

Our tafk is now brought within a very narrow compafs, namely, to meafure the deflection in the arch of a circle.

Had the motion reprefented in fig. 21. been polygonal, it is plain that the deflecting force in the point B is to that in the point E as the diagonal B *b* of the parallelogram ABC *b* to the diagonal E *i* of the parallelogram DEF *i*; therefore let ABCZY be a circle paffing through the points A, B, and C, and let the radius vector BS cut the circumference in Z; draw AZ, CZ, and the diagonal AC, which neceffarily bifects and is bifected by the diagonal B *b*. The triangles *b* BC and CBZ are fimilar; for the angle C *b* B is equal to the alternate angle AB *b* or ABZ, which is equal to the ACZ, ftanding on the fame chord AZ. And the angle CB *b*, or CBZ, is equal to CAZ, ftanding on the fame chord CZ; therefore the remaining angle *b* CB is equal to the remaining angle AZC; therefore ZA is to AC as BC to B *b*, and $Bb = \frac{AC \times BC.}{AZ}$ In like manner $Ei = \frac{DF \times EF.}{Dz}$

Now let the points A and C continually approach, and

Of Deflecting Forces.

and ultimately coalesce with B; it is evident that the circle ABCZY is ultimately the equicurve or coinciding circle at the point B, and that AS ultimately coalesces with, and is equal to, BS, and that $AC \times BC$ is ultimately $2BC^2$; therefore ultimately $Bb : Ei = \frac{2BC^2}{BZ} : \frac{2EF^2}{Ez}$, or $= \frac{BC^2}{\frac{1}{2}BZ} : \frac{EF^2}{\frac{1}{2}Ez}$.

Measure of deflecting forces.

Now BC and EF, being described in equal times, are as the velocities: B *b* and E *i* are the measures of the velocities which the deflective forces at B and E would generate in the time that the body describes BC or EF, and are therefore the measures of those forces. *They are as the squares of the velocities directly, and inversely as these chords of the equicurve circles which have the directions of the deflection.*

Observe, that B *b* or E *i* is the third proportional to half of the chord and the arch described; for $Bb : BC = BC : \frac{BZ}{2}$.

It is evident, that as the arches AB, BC, continually diminish, AC is ultimately parallel to the tangent B *r*, and BO is equal to the actual deflection from the tangent. The triangles BOC and AOZ are similar, and $BO = \frac{OC^2}{OZ}$, or ultimately $= \frac{BC^2}{BZ}$. We may measure the forces by the actual deflections, because they are the halves of the measures of the generated velocities; and we may say that

120 Measure of deflection.

The actual momentary deflection from the tangent is a third proportional to the deflective chord of the equicurve circle and the arch described during the moment.

Caution.

Either of these measures may be taken, but we must take care not to confound them. The first is the most proper, because the change produced on the body (which is the *immediate* effect and measure of the force) is the determination, left inherent in it, to move with a certain velocity. This is the measure also which we obtain by means of the differential or fluxionary calculus; but the other measure must be obtained when our immediate object is to mark the actual path of the body. What is now delivered coincides with what was more briefly stated in ASTRONOMY, *Suppl.* n° 16. and is repeated in this place, because the steps of this demonstration, which is Newton's, so naturally terminate in the equicurve circle, and give at once the immediate measure of the deflecting force: at the same time the reader must perceive that this measure does not depend on the force being always directed to one centre; it is enough that the two sides of the polygon, in immediate succession, are described in equal times. This is necessary in order that AB*Cb* may be a parallelogram, and that the diagonals AC and B *b* may mutually bisect each other.

Thus have we obtained a measure of deflecting force, and, in the most important cases, a method of discovering its direction. It only remains to point out the relation between the intensity of the force, the curvature of the path, and the velocity of the motion. These three circumstances have a necessary connection; for we see that the intensity is expressed by certain values of the other two in the formula $f \doteq \frac{\text{Arch}^2}{\frac{1}{2}\text{Chord}}$, or $f = \frac{2\,BC^2}{BZ}$. The deflective velocity B*b* is acquired in the time that the body describes BC; therefore the deflective velocity is to the velocity in the curve as B *b* to BC. The velocity B *b* is acquired by an accelerated motion along BO; for while, by progressive motion, the body describes BC, it deflects from the tangent through a space equal to the half of B *b*, because the momentary action of the deflecting force may be considered as uniform. The progressive velocity BC may be generated by the same force, uniformly acting through a space greater than BC; call this space *x*. The spaces along which a body must be uniformly impelled in order to acquire different velocities, are as the squares of those velocities; therefore $Bb^2 : BC^2 = Bo : x$; but $Bb : BC = BC : \frac{1}{2}BZ$; therefore $Bb^2 : BC^2 = Bb : \frac{1}{2}BZ$, and $Bb : \frac{1}{2}BZ = Bo : x$, and $Bb : Bo = \frac{1}{2}BZ : x$; but B *o* is $\frac{1}{2}$ of B *b*; therefore *x* is $\frac{1}{4}$ of BZ; that is,

The velocity in any point of a curvilineal path, is that which the deflecting forces in that point would generate in the body by impelling it uniformly along one fourth part of the deflective chord of the equicurve circle. If the velocity increase, the chord of the equicurve circle must increase: that is, the path becomes less incurvated. If the force be increased, the curvature will also increase, for the chord of curvature will be less. 121

There is another general observation to be made on the velocity of a curvilineal motion, which greatly assists us in our investigations. 122

Comparison of orbital motion with direct approach to the centre.

If a body describes a curve by the action of a force always directed to a fixed point, and varying according to any proportion whatever of the distances from that point, and if another body, acted on by the same centripetal force, move toward the centre in a straight line, and if in any one case of equal distances from the centre of force the two bodies have equal velocities, they will have equal velocities in every other case of equal distances from the centre.

Let one body be impelled from A (fig. 23.) toward C along the straight line AVDEC, and let another be deflected along the curve line VIK *k*. About the centre C describe concentric arches ID, KE, very near to each other, and cutting the curve in I and K, and the line AC in D and E; draw IC, cutting KE in N, and draw NT perpendicular to the arch IK of the curve, and complete the parallelogram ITNO. Let the bodies be supposed to have equal velocities at I and at D.

Then, because the centripetal forces are supposed to be the same for both bodies when they are at equal distances, the accelerating forces at D and I may be represented by the equal lines DE and IN; but the force IN is not wholly employed in accelerating the body along the arch IK, but, acting transversely, it is partly employed in incurvating the path. It is equivalent to the two forces IO and IT, of which only IT accelerates the body. Now IKN is a right angled triangle, as is also the triangle INT; and they are similar; therefore IN : IT = IK : IN, or DE : IT = IK : DE; that is, the force which accelerates the body along DE is to the force which accelerates the body along IK as the space IK is to the space DE; therefore (n° 86.) the increment of the square of the velocity acquired along DE is equal to the increment of the square of the velocity acquired along IK. But the velocities at D and I were equal, and consequently their squares were

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were equal; and these having received equal increments, therefore the squares of the velocities at E and K are equal, and the velocities themselves are equal. And since this is the case in all the corresponding points of the line AC and the curve VIK, the velocities at all equal distances from C will be equal.

It is evident that the conclusion will be the same, if the bodies, instead of being accelerated by approaching the centre in the straight line AC, and in the curve VIK, are moving in the opposite directions from E to A, or from I to V, and are therefore retarded by the centripetal force.

123 Retarded curvilineal motion always accompanied by recess from the centre.

Cor. Hence it follows, that if a body be projected from any point, such as V, of the curve, in a line tending straight from the centre, with the velocity which it had in that point of the curve, it would go to a distance VA, such, that if it were impelled along AV by the centripetal force, it would acquire its former velocity in the point V; also in any point between V and A it will have the same velocity in its recess from the centre that it has there in its approach to the centre.

The line BLFG, whose ordinates are as the intensities of the centripetal force in A, V, D, E, or in A, V, I, K, may be called the SCALE or EXPONENT of force; the areas bounded by the ordinates AB, VL, DF, EG, &c. drawn from any two points of the axis, are as the squares of the velocity acquired by acceleration along the intercepted part of the axis, or in any curvilineal path, while the body approaches the centre, or which are lost while the body retires from it. When we can compute these areas we obtain the velocities (see n° 102.).

We are now in a condition to solve the chief problem in the science of dynamics, to which the whole of it is, in a great measure, subservient. The problem is this,

124 Inverse problem of centripetal forces.

Let a body be projected with a known velocity from a given point and in a given direction, and let it be under the influence of a mechanical force, whose direction, intensity, and variation, are all known: it is required to determine its path, and its motion in this path, for any given time?

This problem is susceptible of three distinct classes of conditions, which require different investigation.

1. The force may act in one constant direction; that is, in parallel lines.

2. The force may be always directed to a fixed point.

3. It may be directed to a point which is continually changing its place.

1. When the force acts in parallel lines, the problem is solved by compounding the rectilineal accelerated motion which the force would produce in its own direction with the uniform motion which the projection alone would have produced. The motion must be curvilineal, when the accelerating force is transverse, in any degree whatever, to the projectile motion; and the curvilineal path must be concave on that side to which the deflecting force tends; for the force is supposed to act incessantly. The place of the body will be had for any time, by finding where the body would have been at the end of that time by each force acting alone, and by completing the parallelogram. Thus, suppose a body projected along AB (fig. 20.) while it is continually acted on by a force whose direction is AD. Let D and B be the places where the body would be at the end of a given time. Then the body will, at the end of that time, be in F, the opposite angle of the parallelogram ABFD. But it has not described the diagonal AF, because its motion has been curvilineal, as we shall find by determining its place at other instants of this time.

The velocity in any point F is found by first determining the velocity at D, and making DT to DF as the velocity at D to the velocity at B (that is, the velocity of projection, because the motion along AB is uniform). Then draw TF. Then AB is to TF as the constant velocity of projection to the velocity at F. We have seen already (n° 112—119.) that TF is a tangent to the curve in F. Hence we may determine the velocity at F in another way. Having determined the form of the path in the way already described, by finding its different points, draw the tangent F *d*, cutting the line DA in *d*. Then the velocity at A is to that at F as AB to *d* F. Hence also we see, that the velocities in every point of the curve are proportional to the portion of the tangents at those points which are intercepted between *any* two lines parallel to AD.

Either of these methods for ascertaining the velocity, in this case of parallel deflections, will in general be easier than the general method in n° 121. by the equicurve circle.

It was thus that Galileo discovered the parabolic motion of heavy bodies.

Inverse problem of centripetal forces.

2. We must consider the motions of bodies affected by centripetal or centrifugal forces, always tending to one fixed point. This is the celebrated *inverse problem of centripetal forces*, and is the 42d proposition of the first book of Newton's *Principia*. We shall give the solution after the manner of its illustrious author; because it is elementary, in the purest sense of the word, keeping in view the two leading circumstances, and these only, namely, the motion of approach and recess from the centre, and the motion of revolution. By this judicious process, it becomes a pattern by which more refined, and, in some respects, better solutions should be modelled. At the same time we shall supply some steps of the investigation which his elegant conciseness has made him omit.

Let a body, which tends to C (fig. 24.) with a force 125
proportional to the ordinates of the exponent BLFG, having the axis CA, be projected from V in the direction VQ, with the velocity which the centripetal force would generate in it by accelerating it along AV. It is required to determine the path or orbit VIKI of the body, and its place I in this orbit, at the end of the assigned time T?

Suppose the thing done, and that I is the place of the body. About the centre C, with the distances CV and CI, describe the circles YV and ID. Draw CIX to the circumference, and draw the ordinate DF of the exponent of forces, producing it toward x, and produce the ordinate VL toward a. Let V t be the distance to which the body would go along the tangent VQ in the Time T and join t C. Let this be supposed done for every point of the curve. Let $a\ i\ k$ and $a\ x\ y$ be two curves so related to the curve VIK, that the ordinate DF cuts off an area V $a\ i$ D equal to the orbital sector VCI, and an area V $a\ x$ D equal to the circular sector VCX.

Then,

Then, because the velocity of projection is given, the distance V t is known, and the area of the triangle VC t. But this is equal to the area VCI, by the laws of central forces (n° 115.). Therefore the area V a i D is given. Also, because the area VCI increases in the proportion of the time, the area V a i D increases at the same rate. Therefore, having these subsidiary curves $a\ i\ k$, $a\ x\ y$, the problem is solved as follows:

Draw an ordinate D i, cutting off an area V a i D proportional to the time, and describe a circle DIR. Then draw a line CX, cutting off a sector VCX, equal to the area V a x D cut off by the ordinate D i x. This line will cut the circle DR in the point I, which is the point of the orbit that was demanded.

But the chief difficulty of the problem consists in the description of the two subsidiary curves $a\ i\ k$ and $a\ x\ y$, into which the lines VIK, and VXY are transformed. We attain this construction by resolving the motion in the arch of the orbit into two motions, one of which is in the direction of the transverse force, or of the radius vector, and the other is in the direction of revolution, or perpendicular to the radius.

Let V k and IK be two very small arches described in equal moments, and therefore ultimately in the ratio of the velocities in V and I (n° 73.). Describe the circle KE, cutting IC in N. Draw KC and k C, and $k\ n$ perpendicular to VC.

The element ICK of the orbit is $= \frac{\text{IC} \times \text{KN}}{2}$, or to $\frac{1}{2}$ IC $\times$ KN. This is equal to the element D i k E of the area V a i D, or to D $i \times$ DE, or to D $i \times$ IN. Therefore IN : KN $= \frac{1}{2}$ IC : D i, or 2 IN : KN $=$ IC : D i, and D $i = \frac{\text{IC} \times \text{KN}}{2\ \text{IN}}$.

Now let A $l\ f\ g\ h$ be the exponent of the velocities, that is (n° 86.), let V l^2 be to D f^2 as ABLV to ABFD, or V l : D $f = \sqrt{\text{ABLV}} : \sqrt{\text{ABFD}}$. Make V v and I i in the tangents respectively equal to V l and D f. Draw $v\ u$ and $i\ o$ perpendicular to VC and IC, and $v\ m$ perpendicular to LV produced. Let $m\ r\ z$ be an equilateral hyperbola, having VC, ZC, for its assymptotes, and cutting FD produced in r. Then the ordinates V m, D r, are inversely proportional to CV, CD, or V m : D r = CD : CV, = CI : CV. But because the momentary sectors VC k and ICK are equal, $k\ n$: KN = CI : CV. Therefore,

V m : D r = $k\ n$: KN
but V v : V m = V k : $k\ n$
and I i (or D f) : V v = IK : V k
therefore I i : D r = IK : KN
but I i : $i\ o$ = IK : KN, by sim. triang.

Therefore D r = $i\ o$, and $i\ o$: V m = VC : CI.

Also, by similarity of triangles, I o : $i\ o$ = IN : KN, and 2 I o : $i\ o$ = 2 IN : KN.

Now it was shewn, that in order that the space D i k E may be equal to the space ICK, we must have

2 IN : KN = IC : D i
or 2 I o : $i\ o$ = IC : D i
but $i\ o$: V m = VC : IC
therefore 2 I o : V m = VC : D i

and $$\text{D}\ i = \frac{\text{VC} \times \text{V}\ m}{2\ \text{I}\ o}.$$

Having obtained D i, we easily get D x: for the ultimate ratio of ICK to XCY is that of IC^2 to VC^2. Therefore make

$$\text{IC}^2 : \text{VC}^2 = \text{D}\ i : \text{D}\ x.$$

Thus are the points of the two subsidiary curves $a\ i\ k$, $a\ x\ y$, determined.

The rectangle VC $\times$ V m is a constant magnitude; and is given, because VC is given, and V m is the given velocity V l, diminished in the ratio of radius to the sine of the given angle CVQ.

But the line 2 I o is of variable magnitude, but it is also given, by means of known quantities. I o^2 is $=$ I $i^2 - i\ o^2$, $=$ D f^2 — D r^2, and I $o = \sqrt{\text{D}\ f^2 - \text{D}r^2}$. Moreover, D f^2 = ABFD, and D $r^2 = \frac{\text{VC}^2 \times \text{V}\ m^2}{\text{IC}^2}$. Therefore $2\ \text{I}\ o = 2\sqrt{\text{ABFD} - \frac{\text{VC}^2 \times \text{V}\ m^2}{\text{IC}^2}}$, expressed in known quantities, because ABFD is known from the nature of the centripetal force.

Let the indeterminate distance CI or CD be $= x$, and let the ordinate DF, expressing the force, be y. Let VC be a, and V m be c, and let $a\ b$ be a rectangle equal to the whole area of the exponent of force lying between the ordinate AB and the ordinate CZ, so that $a\ b - \int y\ \dot{x}$ may represent the indeterminate area ABFD.

We have $$\text{D}\ i = \frac{a\ c}{2\sqrt{a\ b - \int y\ \dot{x} - \frac{a^2 c}{x^2}}}$$

and $$\text{D}\ x = \frac{a^3 c}{2\ x^2\sqrt{a\ b - \int y\ \dot{x} - \frac{a\ c^2}{x^2}}}.$$

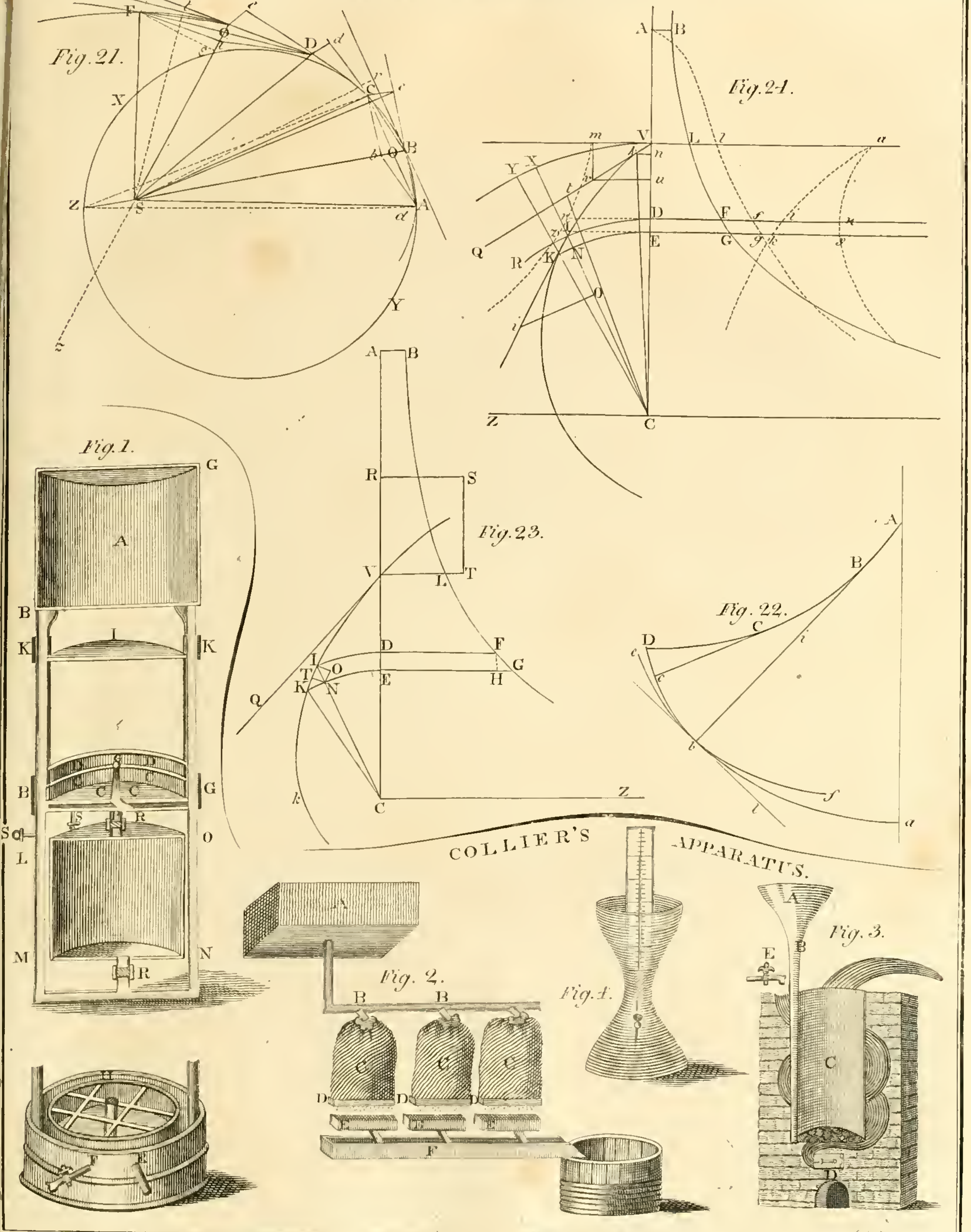
Remark. We have hitherto supposed that the velocity of projection is acquired by acceleration along AV. But this was merely for greater simplicity of argument, and that the final values of D i and D x might be easier conceived. In whatever way the velocity is acquired, it will still be true, that when in any point V we make V l to V m as the momentary increment V k of the arch is to the perpendicular $k\ n$ on the radius vector, we shall have in every other point, such as I, the line D f to the line D r as the increment IK of the arch to KN. And in the final equation D f will still be expressed by $\sqrt{a\ b - \int y\ \dot{x}}$.

Cor. 1. The angle which the path of the projectile makes with the radius vector is determined by this solution; for I i is to $i\ o$ as radius to the sine of this angle; which sine is therefore $= \frac{a\ c}{x\sqrt{a\ b - \int y\ \dot{x}}}$. 126

Cor. 2. When the magnitude $\frac{a\ c}{x}$ is equal to $\sqrt{a\ b - \int y\ \dot{x}}$, the path is perpendicular to the radius vector, and the body is a tone of the apsides of its orbit, and begins to recede from the centre after having approached to it, or begins to opproach after having receded. 127 Apsides determined; 128 And curvature.

Cor. 3. The curvature of the orbit VIK is also determined in every point; for the curvature of any line is inversely as the radius of the equicurve circle, and this is to the chord which passes through C as radius to the

DYNAMICS, PLATE XXIII.



the fine of the angle CI *i*. Becaufe the velocity in any point I is $= \sqrt{ABFD}$, and is equal to what the centripetal force at I would produce, by impelling the body along $\frac{1}{4}$th of the deflective chord of the equicurve circle, we have this chord $= 4\frac{ABFD}{DF}$. Or we obtain it by taking a third proportional to the momentary deflection and the momentary arch of the curve, or by other proceffes of the higher geometry, all proceeding on the quantities furnifhed in this inveftigation.

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Newton the inventor.

Such is the folution of this celebrated problem given by Sir Ifaac Newton, who may juftly be called the inventor of the fcience of which it is the chief refult, as well as of the geometry, by help of which it is profecuted. For we cannot give this glory to Galileo; for his fimple problem of the motion of bodies affected by uniform and parallel gravity, however juft and elegant his folution may be, was peculiar; and the fame muft be faid of Mr Huyghens's doctrine of centrifugal forces. Befides, thefe theorems had been inveftigated by Newton feveral years before, *fud mathefi facem preferente*, as corollaries which he could not pafs unnoticed, from his general method. This is proved by letters from Huygens. Newton's inveftigation is extremely, but elegantly, concife, and is one of the beft exertions of his fagacious mind.

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Hiftory of this problem.

Whether we confider this problem as a piece of mere mathematical fpeculation, or attend to its confequences, which include the whole of the celeftial motions in all their extent and complication, we muft allow it to be highly interefting, and likely to engage much attention in the period of ardent inquiry which clofed the laft century. Accordingly, it was no fooner known, by the publication of the *Mathematical Principles of Natural Philofophy* in 1686, than it occupied the talents of the moft eminent mathematicians; and many folutions were publifhed, fome of which differ confiderably from Newton's; fome are more expeditious, and better fitted for computation. Of thefe, the moft remarkable for originality and ingenuity are thofe of de Moivre, Hermann, Keill, and Stewart. The laft differs moft from the methods purfued by others. M'Laurin's propofitions on this fubject, and in that part of his fluxions which treats of curvature, are highly valuable, claffing the chief affections of curvilineal motions geometrically, as they are fuggefted by the fluxionary method; and then fhewing, in a very inftructive manner, the connection between thefe mathematical affections of motion and the powers of nature which produce them. This part of his excellent work is a fine example of the real nature of all inquiries in dynamics; fhewing that it differs from geometry little more than in the language, in which the word *force* is fubftituted for *acceleration*, *retardation*, or *deflection*. We recommend the careful perufal of thefe propofitions to all who wifh to have clear conceptions of the fubject. Dr John Keill and Dr Horfeley (bifhop of Rochefter) have given particular treatifes on the motions of bodies deflected by centripetal forces inverfely proportional to the cubes of the diftances; induced by the fingular motions which refult from this law of action, and the multitude of beautiful propofitions which they fuggeft to the mathematician. Newton, indeed, firft perceived both of thefe peculiarities, and has begun this branch of the general problem. He firft demonftrated the defcription of the logarithmic and hyperbolic fpirals, and indicated a variety of curious recurring elliptical fpirals, which would be defcribed by means of this force, and fhewing that they are all fufceptible of accurate quadrature. Several of thofe authors affect to confider their folutions as more perfect than Newton's, and as more immediately indicating the remarkable properties of fuch motions; and alfo affect to have deduced them from different and original principles. But we cannot help faying, that their claims to fuperiority are very ill founded; there is not a principle made ufe of in their folutions which was not pointed out by Newton, and employed by him. The appearance of originality arifes from their having taken a more particular concern in fome general property of curvilineal motions; fuch as the curvature, the centrifugal force, &c. and the making that the leading ftep of their procefs. But Newton's is ftill the beft; becaufe it is ftrictly elementary, aiming at the two leading circumftances, the motion to or from the centre, and the motion of revolution round that centre. To thefe two purpofes he adapted his two fubfidiary curves. This procedure became Newton, *pater, et rerum inventor*, who was teaching the world, and who might fay,

Avia Pieridum peragro loca, nullius ante
Trita pede——

Singular boaft of John Bernoulli.

Is it not furprifing, that 25 years after the publication of Newton's *Principia*, a mathematician on the continent fhould publifh a folution in the Memoires of the French academy, and boaft that he had given the firft demonftration of it? Yet John Bernoulli did this in 1710. Is it not more remarkable that this fhould be precifely the folution given by Newton, beginning from the fame theorem, the 40th I. Prin. following Newton in every ftep, and ufing the fame fubfidiary lines? Yet fo it is. Bernoulli actually reduces the whole to two functions; namely, $\frac{ac}{\sqrt{ab - \int \varphi \dot{x} - \frac{a^2 c^2}{x^2}}}$ and $\frac{a^2 c}{\sqrt{abx^4 - \int \varphi x^4 - a^2 c^2 x^2}}$; which laft is plainly the fame with Newton's $\frac{Q \times CX^2}{A^2\sqrt{ABDF - Z^2}}$; becaufe Newton's $\frac{Q}{A}$ is the fame with $\frac{ac}{x}$, and Newton's $A^2\sqrt{ABFD - Z^2}$ is the fame with $x^2\sqrt{ab - \int \varphi \dot{x} - \frac{a^2 c^2}{x^2}}$, which Bernoulli has changed (apparently to hide the borrowing) into $\sqrt{abx^4 - \int \varphi x^4 \dot{x} - a^2 c^2 x^2}$.

This publication of Bernoulli is perhaps the moft impudent piece of literary *robbery*, for theft is too mild a term, that has ever appeared; and is the more deferving of fevere reprehenfion, becaufe it is full of reflections on the fimple and fupremely elegant method of Newton. It is hardly conceivable that a perfon of Bernoulli's confummate mathematical knowledge was fo much

Of Deflecting Forces.

much blinded by the mechanical procedure of the symbolical calculus (which indeed is rarely accompanied by any ideas of the subject in hand) as not to perceive the perfect sameness of his solution. No; he shews, from time to time, that the physical ideas of motion and force were present to his mind; for he affects to shew, that all Newton's brightest discoveries, such as the proportionality of the areas and times, &c. flow as corollaries from his procedure.

Bernoulli's chief boast in this dissertation is, that *now* philosophers may be assured that the planets will always describe conic sections; a truth of which they had not as yet received any proof: because, says he, Newton's argument for it in the corollary of the 13th proposition is inconclusive, and because he had not been able to accommodate his demonstration of the 41st and 42d proposition to the particular case of the planetary gravitation. Two assertions that border on insolence. Newton's demonstration in the corollary of the 13th proposition is just, founded on the principle on which the very demonstration of the 42d, adopted by Bernoulli, proceeds, and without which that demonstration is of no force; namely, that a body, in given circumstances of situation, velocity, direction, and centripetal force, can describe no other figure than what it really describes. Newton did not accommodate the demonstration of the 42d proposition to the planetary motions, because he had already demonstrated the nature of their orbits; but mentions the case of a force proportional to the reciprocal of the cubes of the distance; not as a deduction from the 42d, but because it *was not* a deduction from it, and admitted a very singular and beautiful investigation by methods totally and essentially different.

Bernoulli also says, that Newton's solution does not give us the notion of a continuous path, as his own does, but only informs us how to ascertain points of this path. This is the boldest of all his assertions. Bernoulli uses the differential calculus. It is the *essential* character of this calculus that it exhibits, and *can* exhibit, nothing but detached points. This is undeniable. And this has been objected to Newton's first proposition. But Newton's fluxionary *geometry*, of which the calculus exhibits only elements (being the same with the differential), supposes the continuity of all magnitudes; and when applied to dynamics, is no substitution whatever, but the *ipsa corpora*. This geometry offered itself to the mind of Newton, the accomplished and darling scholar of Barrow, whose geometry flashed on Newton's mind as the torch which was to shew him the steps of this yet untrodden path.

We trust that our readers will not be displeased with our repeated endeavours to defend our great philosopher from the injurious attacks that have been made on him. During his own illustrious life, while he was diffusing light and knowledge around him, and never contended for fame, happy in being the instructor of mankind, he was injured by those who envied his reputation, while they derived their chief honours from being his best commentators. Now, since he has left this world, he has been more grossly injured by those who avail themselves of that very reputation; and who, by crude and contemptible inferences from his doctrine of elastic undulations, and gross misrepresentations of his notions of an etherial fluid, have pretended to support a system of materialism; and thus have set Newton at the head of the atheistical sect, which he held in abhorrence. For our part, we always think with pleasure on the wonderful energy of that great mind; because it gives us a foretaste of those pleasures that await the wise and good, when the sorrows flowing from the infirmities, the vices, and the arrogant vanity of man are past;

Usque in hoc infelici campo,
Ubi luctus regnat, et pavor,
Mortalibus prorsus non absit solatium.
Hujus enim scripta evolvas,
Mentemque tantarum rerum capacem
Corpori caduco superstitem credas.

131 Conclusion.

It cannot be expected that, in the narrow limits prescribed to a work like ours, we can proceed to consider the various departments of this celebrated problem. We are only giving the outlines of the general doctrines of dynamics; and we have bestowed more time on those which are purely elementary than some readers may think they deserve. We were anxious to give just conceptions of the fundamental principles of dynamics; because we know that nothing else can intitle it to the name of a demonstrative science, and because we see much indistinctness and uncertainty, and a general vagueness or want of precision, in several elementary works which are put into the hands of persons entering on the study. This leads to errors of more consequence than a person is apt to think; because they effect our leading thoughts of mechanism itself, and our notions of the intimate nature of the visible universe.

132 Reasons for omissions.

But we must conclude the article with this great problem. Many very general doctrines of dynamics remain untouched; all, namely, that relate to the rotative motion of rigid bodies, and all that relate to the mutual action of bodies on each other in the way of impulse.

The rotative motions, with the doctrine of mechanic momenta, have been considered at large in the article Rotation of the *Encycl.* and we propose to offer some important considerations on the same subject in our supplement to the articles Machine and Mechanics. In the article Impulsion will be considered such doctrines as are truly general, and independent of the specific differences of the bodies. Dynamics professes to involve no notions but those of force, and its marks and measures.

Notwithstanding these great omissions, we must observe that no new principle remains to be considered. We have given all that are necessary; and there is no question that occurs in the cases omitted, which cannot be completely answered by means of the propositions already established. We have taught how to discover the existence and agency of a mechanical force, to measure and characterise it, and then to state what will be its various effects, according to the circumstances of the case.

133 *Universal reaction* is a law of the material world.

Proceeding by these principles, men have discovered an universal fact, that every action of one body on another is accompanied by an equal reaction of that other on the first, in the opposite direction; that is, to express it in the language of dynamics, "all the phenomena which make us infer that the body A possesses a force by which it changes the motion of the body B, shew, at the same time, that B possesses a force by which it makes an equal and opposite alteration in the motion

Conclusion.

motion of A.'' This, however, is not a doctrine of abstract dynamics: it does not flow from our idea of force; therefore it was not included in our list of the LAWS OF MOTION. It is a part of the mechanical history of nature, just as the law of universal gravitation is; and it might be called the law of UNIVERSAL REACTION. Sir Isaac Newton has, in our humble apprehension, deviated from his accustomed logical accuracy, when he admits, as a third *axiom* or law of motion, that reaction is always equal and contrary to action. It is a physical law, in as far as it is *observed* to obtain through the whole extent of the solar system. But Newton himself did not, in the subsequent part of his noble work, treat it as a logical axiom; that is, as a law of human thought with respect to motion: for he labours with much solicitude, and with equal sagacity, to prove, by *fact and observation*, that it really obtains through the whole extent of the solar system; and it is in this discovery that his chief claim to unequalled penetration and discernment appears.

134 Impulsion explained by it;

Availing ourselves of this fact, we, with very little trouble, state all the laws of impulsion. The body A, for example, moving to the westward at the rate of eight feet per minute, overtakes the double body B, moving at the rate of four feet per minute. What must be the consequence of their mutual impenetrability, and of the equality and contrariety of action and reaction? Their motions must be such that both sustain equal and opposite changes. They must give, in some way or other, *this* indication of possessing equal and opposite forces. This will be the case if, when the changes are completed, A and B move on in contact at the rate of four feet per minute: for here A has produced in each half of B a change of motion two; and therefore a totality of change equal to four. This is the effect, the mark, the measure, of the *impulsive* force of A; for it is the whole *impulsion*. B has produced in A a change of motion four, equal to the former, and in the opposite direction. This is the effect, mark, and measure of the *repulsive* force of A; for it is the whole *repulsion*. And this is all that we observe in the collision of two lumps of clay; and the observation is one of the facts on which the reality of the physical law of equal action and reaction is founded: and we can make no farther inference from *this* fact.

But the event might have been very different. A and B may be two magnets floating on corks on water, with their north poles fronting each other. We know, by other means, that they really possess forces by which they equally repel each other. The dynamical principles already established tell us also what must happen in this case. That both conditions of equal reaction and sensible repulsion may be fulfilled, A must come to rest, and B must move forward at the rate of four feet per minute. The same thing must happen in the meeting of perfectly elastic bodies, such as billiard balls. If elasticities are known to be imperfect in any degree, our dynamical principles will still state the effect of their collision, in conformity to the law of equal reaction.

135 And rotation.

In like manner, all the motions of rotation are explained or predicted by means of the same principles of dynamics applied to the force of cohesion. This is considered as a moving force, because, when the attraction of a magnet acts on a bit of iron attached to one end of a long lath floating on water, the whole lath is moved, although the magnet does not act on it at all: some other force acts on it; it is its cohesion; which is therefore a moving force, and the subject of dynamical discussion.

And thus it appears that these subjects do not come necessarily, nor, perhaps, with scientific propriety, under the category of dynamics, but are parts of the mechanical history of nature. Yet, did a work like ours give room in this place, the study of mechanical nature might be considerably improved, by giving a system of such *general* doctrines as involve no other notions but those of force and its measures, and the hypothesis of equal reaction. Some very general, nay universal, consequences of this combination might be established, which would greatly assist the mechanician in the solution of difficult and complicated problems. Such is the proposition, that *the mutual actions of bodies depend on their relative motions only, and require no knowledge of their real motions.* This principle simplifies in a wonderful manner the most difficult and the most frequent cases of action which nature presents to our view; but at the same time gives a severe blow to human vanity, by forcing us to acknowledge that we know nothing of the real motion of any thing in the universe, and never shall know any thing of it, till our intellectual constitution, or our opportunities of observation, are completely changed. 136

Mr D'Alembert has made this principle still more serviceable for extricating ourselves from the immense complication of actions that occurs in all the spontaneous phenomena of nature, by presenting it to us in a different form, which more distinctly expresses what may be called the *elements* of the actions of bodies on each other. His proposition is as follows (*see his Dynamique*, page 73.): 137

D'Alembert's general principle of dynamics.

"In whatever manner a number of bodies change their motions, if we suppose that the motion which each body would have in the following moment, if it were perfectly free, is decomposed into two others, one of which is the motion which it really takes in consequence of their mutual actions, the other will be such, that if each body were impressed by this force alone (that is, by the force which would produce this motion) the whole system of bodies would be in equilibrio."

This is almost self-evident; for if these second constituent forces be not such as would put the system in equilibrio, the other constituent motions could not be those which the bodies really take by the mutual action, but would be changed by the first.

For example, let there be three bodies P, Q, R, and let the forces A, B, C, act on them, such as would give them the velocities p, q, r, in any directions whatever, producing the momenta, or quantities of motion, $P\times p$, $Q\times q$, $R\times r$, which we may call A, B, C, because they are the proper measures of the moving force. Let us moreover suppose, that, by striking each other, or by being any how connected with each other, they cannot take these motions A, B, and C, but really take the motions a, b, and c. It is plain that we may conceive the motion A impressed on the body P, to be composed of the motion a, which it really takes, and of another motion α. In like manner, B may be resolved into b, which it takes, and another β; and C into c and $\underline{\varkappa}$. The motions will be the same whether

we

Conclusion. we act on P with the force A, or with the two forces a and α; whether we act on Q with the force B, or with b and β; and on R with the force C, or with c and κ. Now by the supposition, the bodies actually take the Motions a, b, and c; therefore the motions α, β, and κ, must be such as will not derange the motions a, b, and c; that is to say, that if the bodies had only the motions α, β, and κ, impressed on them, they would destroy each other, and the system would remain at rest.

Mr D'Alembert has applied this proposition with great address and success to the very difficult questions that occur in the motions and actions of fluids, and many other most difficult problems, such as the precession of the equinoxes, &c. The cause of its utility is, that in most cases it is not difficult to find what forces will put a system in equilibrio; and, combining these with the known extraneous forces whose effects we are interested to discover, we obtain the motions which really follow the mutual action of the bodies.

This is not, properly speaking, a principle: it is a form in which a general fact may be conceived. In the same way the celebrated mathematician De la Grange observed, that a system of bodies, acting on each other in any way, is in equilibrio, if there be impressed on its parts forces in the inverse proportion of the velocities which each body takes in consequence of their action or connection; and he expresses this universal fact by a very simple formula; and, calling this also a principle, he solves every question with ease and neatness, by reducing it to the investigation of those velocities. In this way he has written a complete system of dynamics, to which he gives the title of *Mechanique Analytique*, full of the most ingenious and elegant solutions of very interesting and difficult problems; and all this without drawing a line or figure, but accomplishing the whole by algebraic operations.

138 But this is not teaching mechanical philosophy; it is merely employing the reader in algebraic operations, each of which he perfectly understands in its quality of an algebraic or arithmetical operation, and where he may have the fullest conviction of the justness of his procedure. But all this may be (and, in the hands of an expert algebraist, it generally is,) without any notions, distinct or indistinct, of the things, or the processes of reasoning that are represented by the symbols made use of. It is precisely like the occupation of a banker's clerk, when he carries his eye up and down the columns of pounds shillings and pence, calculates the compound interest, reversionary values, &c.

Disadvantages of the symbolical method. It were well if this were all, although it greatly diminishes the pleasure which an accomplished mathematician might receive; but this total absence of ideas exposes even the most eminent anylist to frequent risks of paralogism and physical absurdity. Euler, who was perhaps the most expert algebraist of this century, making use of the Newtonian theorem for ascertaining the motion of a body impelled along a straight line AC (fig. 24.) by a centripetal force, by comparing it with the motion in an ellipse, of which the shorter axis was diminished till it vanished altogether, expresses his surprise at finding, that when he computes the place of the body for a time subsequent to that of its arrival at C, the body is back again, and in some place between C and A; in short, that the body comes back again to A, and plays backward and forward. He says, that this is somewhat wonderful, and seems inconsistent with sound reason: "*sed anylisi magis fidendum.*" It must be so, and he goes on to another problem.

In like manner Mr Maupertuis, an accomplished man, and good philosopher and geometer, finding the symbol MVS, or the quantity of matter multiplied by the velocity and by the distance run over during the action, always present itself to him as a mathematical *minimum* in the actions of bodies on each other; he was amused by the observation, and presumed that there was some reason for it in the nature of things. Finding that it gave him very neat solutions of many elementary problems in dynamics, he thought of trying whether it would assist him in accounting for the constant ratio of the sines of incidence and refraction; he found that it gave an immediate and very neat solution. This problem had, before his time, occupied the minds of Des Cartes and Fermat. Each of these gentlemen solved the problem by saying, that the light did not take the *shortest* way from a point in the air to a point under water, but the *easiest* way, in conformity with the acknowledged economy of nature and consummate wisdom of its adorable Author. But how was this the easiest way, the course that economised the labour of nature? One of these gentlemen proved it to be so, if light move faster in air than in water; the other proved it to be so if light move faster in water than in air. Both could not be right. Maupertuis was convinced that he had discovered what it was that nature was so chary of, and grudged to waste—it was MVS! Therefore MVS can mean nothing but labour; nothing but natural exertion, mechanical action; therefore MVS is the proper measure of action. He kept this great discovery a profound secret; and, being President of the royal academy of Berlin, he proposed for the annual prize question, "Are the laws of motion necessary or contingent truths?" He could not compete for the prize, by the laws of the academy; but before the time of decision, he published at Paris his *dissertation on the principle of the least action*; in which he pointed out the singular fact of MVS being always a minimum; and therefore, in fact, the object of nature's economical care. He solved a number of problems by making the minimum state of $\frac{f\,v\,\dot{s}}{m}$ a condition of the problems; and, to crown the whole, shewed that the laws of motion which obtain in the universe could not be but what they are, because this economy was worthy of infinite wisdom; and *therefore* any other laws were impossible. The reputation of Maupertuis was already established as a good mathematician and a worthy and amiable man, and he was a favourite of Frederic. The principle of least action become a mode; and it drew attention for some time, till it went out of fashion. It is no mechanical principle, but a necessary mathematical truth, as any person must see who recollects that v is the same with $\dot{s}$, and that f is the same with $m\,\dot{v}$.

Great advantages of the geometrical method. To avoid such paralogisms and such whims, we are convinced that it is prudent to deviate as little as possible in our discussions from the *geometrical* method. This has surely the advantage of keeping the real subject of discussion close in view; for motion includes the notion of lines, with all their qualities of magnitude and position. It is needless to take a representative when

Conclusion. when the original itſelf is in our hands, and affords a much more comprehenſible object than one of its abſtract qualities, mere magnitude. Let any perſon candidly compare the lunar theory by Mayer or Euler with that by its illuſtrious inventor Sir Iſaac Newton, and ſay which of the two is moſt luminous and moſt pleaſing to the mind. No perſon will deny that theſe later performances are incomparably more adapted to all practical purpoſes, and lead to corrections which it would be extremely difficult and tedious to inveſtigate geometrically; but it muſt be acknowledged, at the ſame time, that *till this be done*, we have no idea whatever of the deviation of the tract which this correction aſcertains from the path which the moon would follow, independent of the diſturbance expreſſed by the correction. In like manner, Dan. Bernoulli, by mixing as much as poſſible the linear method with the algebraic, in his diſſertations on muſical chords, made the beautiful diſcovery of the ſecondary trochoids, and demonſtrated the co-exiſtence of the harmonic ſounds in a full muſical note. Let the accompliſhed mathematician puſh forward our knowledge of dynamics by the employment of the ſymbolical analyſis; but let him be followed as cloſe as poſſible by the geometer, that we may not be robbed of ideas, and that the ſtudent may have light to direct his ſteps. But,—*manum e tabulâ.*

Dynanometer. DYNANOMETER, an inſtrument for aſcertaining the relative muſcular ſtrength of men and other animals. That it would be deſirable to know our relative ſtrengths at the different periods of life, and in different ſtates of health, will hardly be denied; and there can be no doubt but that it would be highly uſeful to have a portable inſtrument by which we could aſcertain the relative ſtrength of horſes or oxen intended for the plough or the waggon. Such an inſtrument was invented, many years ago, by Graham, and improved by Deſaguliers; but being conſtructed of wooden work it was too bulky to be portable, and therefore it was limited in its uſe.

M. Leroy of the Academy of Sciences at Paris conſtructed a much more convenient Dynanometer than Graham's, conſiſting of a metal tube ten or twelve inches in length, placed vertically on a foot like that of a candleſtick, and containing in the inſide a ſpiral ſpring, having above it a graduated ſhank terminating in a globe. This ſhank, together with the ſpring, ſunk into the tube in proportion to the weight acting upon it, and thus pointed in degrees the ſtrength of the perſon who preſſed on the ball with his hand.

This was a very ſimple conſtruction, and, we think, a good one; but it did not ſatisfy Buffon and Gueneau. Theſe two philoſophers wiſhed not merely to aſcertain the muſcular force of a finger or a hand, but to eſtimate that of each limb ſeparately, and of all the parts of the body. They therefore employed M. Regnier to contrive a new *dynanometer;* and the account which he gives* of his attempts to fulfil their wiſhes is calculated to enhance the difficulty of the enterprize. The inſtrument, however, which he conſtructed is not ſuch as appears to us to have required any uncommon ſkill in mechanics, or any very great ſtretch of thought. It conſiſts chiefly of an elliptical ſpring twelve inches in length, rather narrow, and covered with leather that it may not hurt the fingers when compreſſed by the hands. This ſpring is compoſed of the beſt ſteel well welded and tempered, and afterwards ſubjected to a ſtronger effort than is likely to be ever applied to it either by men or animals, that it may not loſe any of its elaſticity by uſe.

* *Journal de l' Ecole Polytechnique*, v. 2.

The effects of this machine are eaſily explained. If a perſon compreſſes the ſpring with his hands, or draws it out lengthwiſe by pulling the two extremities in contrary directions, the ſides of the ſpring approach towards each other; and it has an apparatus (we do not think a very ſimple one) appended to it, conſiſting of an index and ſemicircular plate, by which the degree of approach, and conſequently of effort, employed, is aſcertained with great accuracy. The author gives a tedious deſcription of other appendages, by means of which horſes or oxen may be employed to compreſs the ſpring. But as any mechanic may deviſe means for this purpoſe, we do not think it worth while to tranſcribe that deſcription. The Engliſh reader will find a full account of the whole apparatus in the 4th number of the very valuable miſcellany entitled *The Philoſophical Magazine.* The principle of the contrivance, conſiſts in the elliptical ſpring, of which we confeſs ourſelves unable to perceive the ſuperiority to the ſpiral ſpring of M. Leroy, though the author ſees it very clearly.

Dyſentery. DYSENTERY (See Medicine *Index*, Encycl.). For the cure of this diſeaſe we have the following ſimple preſcription by Dr Perkins and Dr B. Lynde Oliver, of the ſtate of Maſſachuſetts in North America.

Saturate any quantity of the beſt vinegar with common marine ſalt; to one large table ſpoonful of this ſolution add four times the quantity of boiling water; let the patient take of this preparation, as hot as it can be ſwallowed, one ſpoonful once in half a minute until the whole is drank: this for an adult. The quantity may be varied according to the age, ſize, and conſtitution of the patient. If neceſſary, repeat the doſe once in ſix or eight hours. Conſiderable evacuations I conceive (ſays Dr Perkins) to be not only unneceſſary, but injurious, as they ſerve to debilitate and prolong the diſeaſe. A tea of plantain, or ſome other cooling, ſimple drink, may be uſeful; and if a thirſt for cyder be diſcovered, it may be gratified. Carefully avoid keeping this preparation in veſſels partaking of the qualities of lead or copper, as the poiſon produced by that means may prove dangerous.

The ſucceſs of the remedy depends much on preparing and giving the doſe as above directed.—The ſimplicity of this treatment renders it the more valuable, as all perſons have it in their power to avail themſelves of its uſe.

Dr Perkins ſays, that he has found it uſeful in agues, diarrhœas, and the yellow fever.

E.

EARL, a townſhip in Lancaſter co. Pennſylvania.—*Morse.*

EARTH, in chemiſtry. See CHEMISTRY-*Index* in this Supplement.

EARTH, in aſtronomy and geography. See *Encyclopædia.*

EARTH, in ancient philoſophy, one of the elements, the ſubſtance of which this globe is compoſed. To aſcertain the denſity of that ſubſtance many experiments have been made; but perhaps none more ingenious than thoſe of Mr Cavendiſh, which are detailed at full length in Part II. of the Tranſactions of the Royal Society of London for 1798. They were projected by the late Rev. John Michell, F. R. S but he did not live to carry them into effect. After his death the apparatus came to the Rev. F. J. H. Wollaſton, Jackſonian Profeſſor at Cambridge, who transferred them to Mr Cavendiſh. The apparatus contrived for making ſenſible the attraction of ſmall quantities of matter, and which has been improved by Mr Cavendiſh, is very ſimple: it conſiſts of a wooden arm 6 feet long, ſuſpended by the middle in an horrizontal poſition by a ſlender wire 40 inches long; to each extremity is hung a leaden ball about two inches in diameter; and the whole is incloſed in a wooden caſe to defend it from the wind.

As no more force is required to turn this balance on its centre than is neceſſary to twiſt the ſlender ſuſpending wire, the ſmalleſt degree of attraction of a leaden weight or weights, a few (eight) inches in diameter, brought near to the ſmall ſuſpended ball or balls of the balance, will be ſufficient to move it ſenſibly aſide.

To determine from hence the denſity of the earth, all that is neceſſary is, to aſcertain what force is required to draw the arm aſide through a given ſpace, and then to have recourſe to calculation.

To prevent any diſturbance from currents that might be produced within the box that contained the balance, by even the difference of temperature that might be occaſioned by heat being communicated by the bodies of the experimenters to one ſide of it more than another, it was ſupported in the middle of a cloſe room; the operators, from adjoining apartments, viewed the operation through holes in the wall by means of teleſcopes; and the apparatus had a ſtrong light thrown upon its two ends (an opening being left at each end of the box for the purpoſe) by means of two lamps, alſo in the adjoining apartments, the rays from which were likewiſe made to paſs through the holes formed in the wall.

The two large balls were ſuſpended from a beam near the cieling, which could be moved in an horrizontal direction, by means of a ſtring and pulley, ſo as to be brought near to the ſmall balls of the balance, or made to recede again, without requiring any perſon to be in the room.

From this deſcription it will be eaſily ſeen, that on the two large balls being brought near to the two ſmall ones, but on oppoſite ſides of each, that their forces may not counteract each other—the ſmall ſuſpending wire of the balance muſt be twiſted by the movements of the arms, occaſioned by attraction, which carries the ſmall towards the large balls; and that the wire, endeavouring to untwiſt itſelf, will again in its turn carry the ſmall balls away from the large ones. Vibrations are thus occaſioned, which would continue a long time before the ſmall balls would ſettle between the firſt point of reſt and the large balls: but it is not neceſſary to wait for this; an ivory ſcale at each end of the balance enables the experimenters, by means of their teleſcopes, to ſee the two extreme diviſions to which the ſmall balls move in their vibrations, and thus to determine the middle point. The time neceſſary for each vibration is alſo noticed.

A full account of theſe experiments, and of the calculations founded on them, would be little intereſting to the great majority of our readers. We ſhall therefore only mention the reſult. By a mean of the experiments the denſity of the earth comes out 5·48 times greater than that of water.

By the experiments made by Dr Maſkelyne on the attraction of the hill Schehallien, the denſity of the earth was computed to be only 4½ times that of water. The difference of reſult, therefore, is almoſt one-fifth, which no doubt muſt leſſen our confidence in either ſet of experiments, or in the principle on which they were deviſed.

EARTH-Worm (ſee LUMBRICUS, *Encycl.)* is an animal which occaſions ſuch deſtruction in gardens, by gnawing the tender roots of ſhrubs and plants, that various methods have been propoſed for remedying this evil. One of the lateſt, and that which promiſes to prove the moſt ſucceſsful, is given by M. SOCOLOFF in the fifth volume of the New Tranſactions of the Imperial Academy of Sciences at Peterſburgh. As the deſtructive power of quick-lime, heightened by a fixed alkali, which corrods or diſſolves all the tender parts of animals, has been long known, it occurred to our author that this mixture would be the beſt means for accompliſhing the object which he had in view. He therefore took three parts of quick-lime, newly made, and two parts of a ſaturated ſolution of fixed alkali in water, and thence obtained a ſomewhat milky liquor ſufficiently cauſtic, highly hoſtile and poiſonous to earth-worms and other ſmall animals; for as ſoon as it touched any part of their bodies, it occaſioned in them violent ſymptoms of great uneaſineſs. If this liquor be poured into thoſe holes in which the earth-worms reſide under ground, they immediately throw themſelves out as if driven by ſome force; and, after various contorſions, either languiſh or die. If the leaves of plants or fruit-trees, frequented by the voracious caterpillars, which are ſo deſtructive to them, be ſprinkled over with this liquor, theſe inſects ſuddenly contract their bodies and drop to the ground. For though Nature has defended them tolerably well by their hairy ſkins from any thing that might injure their delicate bodies, yet as ſoon as they touch with their feet or mouths leaves which

which have been moiftened by this liquor, they become as if it were ftupified, inftantly contract themfelves, and fall down.

With regard to plants or corn, thefe fuftain no injury from the liquor, becaufe it has no power over the productions of the vegetable kingdom, as our author has fully learned from experience; or if any hurt is to be fufpected, all the danger will be removed by the firft fhower that falls. This liquor may be procured in abundance in every place where lime is burnt. If the lime be frefh, one part of it infufed into about feventy parts of common water will produce real lime-water. The want of the fixed alkali may be fupplied by boiling wood afhes in water, and thickening the ley by evaporation.

This liquor might be employed alfo to kill bugs and other domeftic infects; but on account of its ftrong lixivious fmell, M. Socoloff thinks it could not be ufed with fafety in houfes that are inhabited. Nothing, however, more fpeedily or more effectually deftroys bugs, as our author fays he has repeatedly experienced, than the oily pickle that remains in cafks in which falted herrings have been packed.

EASTANALLE, the north-eaft head branch of Alabama river in Georgia, on which ftands the town of Eaftanallee.—*Morse.*

EAST BETHLEHEM, a townfhip in Wafhington co. Pennfylvania.—*ib.*

EAST CHESTER, a townfhip in Weft Chefter co. New-York, on Long-Ifland found, about 8 miles S. W. of Rye, 5 northerly of Weft Chefter, and 17 N. E. of New-York. It contains 740 inhabitants; of whom 106 are electors, and 75 flaves.—*ib.*

EASTER, an ifle in the Pacific ocean. S. lat. 27. 8. W. long. 109. 41. It is barren and has no frefh water.—*ib.*

EASTERN *Ifland* on the E. fide of Chefapeak bay, at the mouth of Chefter river.—*ib.*

EASTERN-PRECINCT, in Somerfet co. New-Jerfey, contains 2068 inhabitants, of whom 468 are flaves.—*ib.*

EASTERN-RIVER, a fettlement in Hancock co. diftrict of Maine, containing 240 inhabitants.—*ib.*

EASTERTON, a village in Dauphin co. Pennfylvania, on the E. fide of Sufquehanna river 4 miles N. by W. of Harrifburg, and 111 N. W. by W. of Philadelphia.—*ib.*

EAST GREENWICH, a poft town, and the chief townfhip in Kent co. Rhode-Ifland; 16 miles S. of Providence, and 22 N. N. W. of Newport, and contains 1824 inhabitants. The compact part called Greenwich town, has a number of dwelling-houfes, a meeting-houfe, and handfome court-houfe; and although its commerce is greatly reduced, carries on the fifheries to advantage, and fends fome veffels to the Weft-Indies. It is fituated on the N. W. part of Narraganfet bay. Both this town and Warwick are noted for making good cider; and formerly for raifing tobacco for exportation.—*ib.*

EAST HADDAM, a townfhip in Middlefex co. Connecticut, fituated on the E. fide of Connecticut river, oppofite to Haddam, of which it was formerly a part. It was fettled in 1704, and lies 14 miles fouthwardly of Middleton, and 21 N. W. of New-London.—*ib.*

EASTHAM, a townfhip in Barnftable co. Maffachufetts, about 10 miles long, fituated on the peninfula of Cape Cod, between Chatham and Wellfleet, and 95 or 100 miles S. E. of Bofton. It contains 1834 inhabitants.—*ib.*

EAST HAMPTON, a townfhip in Hampfhire co. Maffachufetts, 6 miles S. of Northampton, and 105 W. by S. of Bofton. It contains 457 inhabitants, and is divided from the W. bank of Connecticut river by the celebrated mountain called *Mount Tom.*—*ib.*

EAST HAMPTON, a handfome town in Suffolk co. New-York, on the S. E. coaft of Long-Ifland, 12 miles E. N. E. of South Hampton, and 105 E. of New-York city. It has a Prefbyterian church, an academy, and about 80 dwelling-houfes in one ftreet. The townfhip contains 1497 inhabitants, of whom 214 are electors. Gardner's Ifland is annexed to this town.—*ib.*

EAST HARTFORD, in Hartford co. Connecticut, lies on the E. bank of Connecticut river oppofite to Hartford. The compact part of it lies in one broad ftreet a mile and a half in length. Here are a number of mills on the different ftreams which water the town; alfo iron and glafs works.—*ib.*

EAST HAVEN, a townfhip in New-Haven co. Connecticut, on the E. fide of New-Haven harbour. There is a fort 2 miles from the mouth of the bay oppofite Smith's point to defend the paffage. The Scotch Captain and other fmall iflots and rocks lie on the S. fhore.—*ib.*

EAST HAVEN, a townfhip in Effex co. Vermont, W. of Maidftone, 11 miles S. E. of the fouthern end of of Willoughby's lake, and 18 N. by W. of the upper bar of the 15 mile falls on Connecticut river.—*ib.*

EAST KINGSTON, in Rockingham co. New-Hampfhire, a part of Kingfton. In 1790 it contained 358 inhabitants; and now 906.—*ib.*

EAST MAIN, is that part of New-Britain, or Labrador, in North America, which lies on the E fide of James's bay; as part of New South Wales on the W. fide of the fame bay is called WEST-MAIN.

The Hudfon's bay factory called Eaft Main, is fituated on the S. part of Eaft-Main, between Rupert and Slade rivers, both of which run weftward into James's bay.—*ib.*

EASTON, a poft town of Pennfylvania, and capital of Northampton co.; pleafantly fituated at the mouth of the Lehigh; and on the W. fide of Delaware river. It is regularly laid out, and contains about 150 dwelling houfes, a church, court-houfe, regifter's office, and an academy. It is 12 miles N. E. of Bethlehem, and 70 N. of Philadelphia.

EASTON, the chief town of Talbot co. Maryland, formerly called Talbot Court-Houfe, is on the E. fide of Chefapeak bay, near the forks of Treadhaven river, 12 miles from its junction with Choptank river. It has a handfome court-houfe and market-houfe; about 150 dwelling-houfes, and feveral ftores for the fupply of the adjacent country. It is 5 miles S. wefterly of Williamfburg, 37 S. of Cheftertown, and 118 S. W. of Philadelphia.—*ib.*

EASTON, a townfhip in Wafhington co. New-York. In 1790 it contained 2539 inhabitants, of whom 48 were flaves. By the ftate cenfus of 1796, it appears that 347 of its prefent inhabitants are electors.—*ib.*

EASTON, or *Eaftown*, a townfhip important for its iron

iron manufactures, situated in Bristol co. Massachusetts, near the head of Raynham river; 6 miles N. W. of Raynham, and 12 W. of Bridgewater. It contains 1466 inhabitants. The best mill-saws in the state are made here. The art of making steel was introduced here by Capt. Eliphalet Leonard, in 1786. It is made in quantities; and is cheaper than imported steel, and equal in quality for large work, such as plough shares, horse-shoes, &c. which require large quantities of hard steel. But for edge tools, in general, it is found to be of inferior quality to what is imported. The manufacture of linseed oil began here in 1792, and from an annual stock of 3000 bushels of seed, there has been annually produced near 5000 gallons of oil.—*ib.*

Easton's *Beach* and *Bay*, in the state of Rhode-Island, is separated from Sachueast beach and bay by Easton's point. Both lie at the southern end of Rhode-Island. —*ib.*

EAST *River* in the state of New-York, and the waters of North or Hudson river, form York I. The communication between North river and Long-Island sound is by the East river along the eastern side of New-York Island.—*ib.*

East or North Haven, or *Quinepauge River* in Connecticut, rises in Southington, not far from a bend in Farmington river and passing through Wallingford and North-Haven, empties into New-Haven harbour. It has been contemplated to connect the source of this river with Farmington river.—*ib.*

EAST-TOWN, in Chester co. Pennsylvania.—*ib.*

EAST-WHITELAND, a township in Chester co. Pennsylvania.—*ib.*

EAST-WINDSOR, a township in Hartford co. Connecticut: separated from Windsor by Connecticut river, and about 7 miles N. E. of Hartford. The compact part of the town lies on one broad street of about 2 miles in length. In the township are 3 Congregational churches. The lands are fertile; and besides those articles common to the state, produce large quantities of good tobacco.—*ib.*

EATON, a small town in the northern part of Strafford co. New-Hampshire; 3 miles N. of the Great-Ossipee lake, and about 56 N. by W. of Portsmouth. It was incorporated in 1766, and contains 253 inhabitants.—*ib.*

EATONTOWN, improperly called Edentown, a pleasant village in New-Jersey, about a mile S. of the town of Shrewsbury in the same township. It is a place of some business and thriving.—*ib.*

EAU de Luce, a fragrant alkaline liquor which was some years ago in great repute, especially among the fair sex, and of which the leading perfection is, that it shall possess and retain a milky opacity.

Mr Nicholson, in the second number of his valuable journal, tells us, that being informed by a philosophical friend, that the usual recipes for making this compound (see Chemistry, *Encycl.* n° 1037.) do not succeed, and that the use of mastic in it has hitherto been kept a secret, he made the following trials to procure a good eau de luce.

One dram of the rectified oil of amber was dissolved in four ounces of the strongest ardent spirit of the shops; its specific gravity being .840 at 60 degrees of Fahrenheit. A portion of the clear spirit was poured upon a larger quantity of fine powdered mastic than it was judged could be taken up. This was occasionally agitated without heat; by which means the gum resin was for the most part gradually dissolved. One part of the oily solution was poured into a phial, and to this was added one part of the solution of mastic. No opacity or other change appeared. Four parts of strong caustic volatile alkali were then poured in, and immediately shaken. The fluid was of a dense opake white colour, affording a slight ruddy tinge when the light was seen through a thin portion of it. In a second mixture, four parts of the alkali were added to one of the solution of mastic; it appeared of a less dense and more yellowish white than the former mixture. More of the gum resinous solution was then poured in; but it still appeared less opake than that mixture. It was ruddy by transmitted light. The last experiment was repeated with the oily solution instead of that of mastic. The white was much less dense than either of the foregoing compounds, and the requisite opacity was not given by augmenting the dose of the oily solution. No ruddiness nor other remakable appearance was seen by transmitted light. These mixtures were left at repose for two days; no separation appeared in either of the compounds containing mastic; the compound consisting of the oily solution and alkali became paler by the separation of a cream at the top.

It appears, therefore, that the first of these three mixtures, subject to variation of the quantity of its ingredients, and the odorant additions which may be made, is a good eau de luce.

In a subsequent number of the same Journal, we have the following recipe by one of the author's correspondents, who had often proved its value by experience. "Digest ten or twelve grains of the whitest pieces of mastic, selected for this purpose and powdered, in two ounces of alcohol; and, when nearly dissolved, add twenty grains of elemi (see Amyris, *Encycl.*). When both the resins are dissolved, add ten or fifteen drops of rectified oil of amber, and fifteen or twenty of essence of bergamot: shake the whole well together, and let the fæces subside. The solution will be of a pale amber colour. It is to be added in very small portions to the best aqua ammoniæ puræ, until it assumes a milky whiteness shaking the phial well after each addition, as directed by Macquer. The strength and causticity of the ammoniac are of most essential consequence. If, upon the addition of the first drop or two of the tincture, a dense opake coagulated precipitate is formed, not much unlike that which appears on dropping a solution of silver into water slightly impregnated with common salt, it is too strong, and must be diluted with alcohol. A considerable proportion of the tincture, perhaps one to four, ought to be requisite to give the liquor the proper degree of opacity."

EAVES-Board, or Eaves-Lath, a thick feather-edged board, usually nailed round the eaves of a house for the lowermost tiles, slate, or shingles, to rest upon.

EBENEZER, a post town, and the capital of Effingham co. Georgia, seated on the S. W. bank of Savannah river, 5 miles from Abercorn, 25 N. N. W. of Savannah, 75 S. E. of Louisville, and 860 S. W. of Philadelphia. It contains but a few houses; and was settled in 1735, by a number of Protestants driven out of Saltsburg, in the electorate of Bavaria, by persecution.—*Morse.*

ECLIP-

ECLIPSAREON, an instrument invented by Mr Ferguson for shewing the phenomena of eclipses; as their time, quantity, duration, progress, &c.

ECLIPTIC. See *Encycl.* both under ECLIPTIC and in ASTRONOMY-*Index*. It was observed in ASTRONOMY, *Encycl.* n° 407. that the obliquity of the ecliptic has been found gradually to decrease. This was observed, among others, by *La Lande*, who, in the third edition of his astronomy, reckoned the secular diminution of this obliquity at 50 seconds. From a new examination, however, of ancient observations, he has since found reason to estimate it at only 36 seconds; but whether this be perfectly accurate, is very doubtful. The mean obliquity was determined for the 1st of January 1793, with circular instruments, by *Mechain* at Barcelona, and *Piazzi* at Palermo, to be 23° 27′ 53″.3. Yet the observation of the summer solstice of 1796, by *Mechain* and *Le Francais*, gave 11 seconds more; which was justly considered as a perplexing circumstance. But, as one of the ablest of our literary journalists observes, might not this difference arise from the uncertainty of our tables of refraction, as affected by the hygroscopic variations of the atmosphere?

ECLIPTIC-Bounds, or *Limits*, are the greatest distances from the nodes at which the sun or moon can be eclipsed, namely, near 18 degrees for the sun, and 12 degrees for the moon.

EDEN, a township in Hancock co. district of Maine, incorporated in 1796, taken from the northerly part of Mount Desert.—*Morse*.

EDEN, a township in Orleans co. Vermont, N. W. of Craftsbury, adjoining.—*ib.*

EDENTON, a district on the sea-coast of North-Carolina, bounded N. by the state of Virginia; E. by the ocean; W. by Halifax district, and S. by Newbern. It is subdivided into 9 counties, viz. Chowan, Pasquotank, Perquimins, Gates, Hertford, Bertie, and Tyrrel. It contains 53,770 inhabitants, of whom 19,198 are slaves. Its chief town is Edenton. The wood is chiefly pine, oak, cypress, and juniper; of all which there is abundance.—*ib.*

EDENTON, the capital of the above district, is a post town, and port of entry, at the head of a bay on the N. side of Albemarle sound, and at the N. E. side of the opening of Chowan river. It contains above 150 indifferent wooden buildings, and a few handsome ones. The public buildings are an ancient brick Episcopal church, a court house and gaol. In or near the town lived the proprietary, and the first of the royal governors. Its situation is advantageous for trade, but unhealthy; which doubtless has tended to retard its prosperity. Its exports in the year ending September 30, 1794, amounted to the value of 50,646 dollars. It is 97 miles N. of Newbern, 257 N. N. E. of Wilmington, 139 S. E. of Petersburgh, and 440 S. S. W. of Philadelphia. N. lat. 36. 6. W. long. 77. 11.—*ib.*

EDESTON, a plantation in Hancock co. district of Maine, containing 110 inhabitants.—*ib.*

EDGARTON, a port of entry and post town of Massachusetts, and the chief town of Duke's co. situated on the E. side of the island of Martha's Vineyard. The fertile island of Chabaquidick is within the jurisdiction of Edgarton; which has a small trade to the West-Indies. The exports in 1794 for one year ending Sept. 30th, amounted to 2,257 dollars value. It lies about 14 miles S. of Barnstable co. on the main, and 94 miles S. S. E. of Boston. It was incorporated in 1671, and contains 1352 inhabitants.—*ib.*

EDGCOMB, a township in Lincoln co. district of Maine, containing 855 inhabitants. It was incorporated in 1774, and lies 180 miles N. by E. of Boston. —*ib.*

EDGCOMB, a county of Halifax district, N. Carolina, bounded S. by Pitt co. S. W. by Wayne co. and Tar river, which affords it communication with several counties in the state; W. by Nash co. and E. by Martin and Halifax counties. It contains 10,255 inhabitants, of whom 2,009 are slaves.—*ib.*

EDGEFIELD *Co.* in S. Carolina, is the southernmost in the district of Ninety Six; bounded N. by Saluda river which divides it from Newbury co.; S. W. by Savannah river, which separates it from the state of Georgia; E. by Orangeburg district, and W. by Abbeville co. The ridge of elevated land, which divides the waters of Saluda from those of Savannah river passes nearly through the middle of the county. Edgefield co. is about 54 miles long and 24 broad, and contains 13,289 inhabitants, of whom 3619 are slaves. —*ib.*

EDGEFIELD COURT-HOUSE, in the above county, where is a post-office, is 20 miles from Abbeville court-house; 25 from Augusta, and 60 from Columbia.—*ib.*

EDGEMONT, a township in Delaware co. Pennsylvania.—*ib.*

EDWARD, a fort in Nova-Scotia, in the town of Windsor, in Hants co. said to be large enough to contain 200 men. It is situated on Avon river which is navigable thus far for vessels of 400 tons; those of 60 tons can go 2 miles higher.—*ib.*

EDWARD, a fortification in Washington co. New-York, now in ruins. It is situated on the E. bank of Hudson river about 14 miles S. by E. of Fort George, on the southern extremity of Lake George, and 19 S. by W. of Skenesborough, on South bay, an arm of lake Champlain, N. lat. 43. 7. W. long. 74. —*ib.*

EDYSTONE ROCKS, so remarkable for the light-house built on them, obtained their name from the great variety of contrary sets of the tide or current in their vicinity. They are situated nearly S. S. W. from the middle of Plymouth Sound, according to the true meridian. The distance from the port of Plymouth is nearly 14 miles, and from the promontory called *Ram-head* about 10 miles. They are almost in the line, but somewhat within it, which joins the Start and the Lizard points; and as they lie nearly in the direction of vessels coasting up and down the channel, they were necessarily, before the establishment of a light house, very dangerous, and often fatal to ships under such circumstances. Their situation, likewise, with regard to the Bay of Biscay and Atlantic ocean, is such, that they lie open to the swells of the Bay and ocean from all the south-western points of the compass: which swells are generally allowed by mariners to be very great and heavy in those seas, and particularly in the Bay of Biscay. It is to be observed, that the soundings of the sea from the south westward toward the Edystone are from 80 fathoms to 40, and everywhere till you come near the Edystone the sea is full 30 fathoms in depth; so that all the heavy seas from the south-west

Smeaton's Account of the Edystone Light-house.

Edyſtone. ſout-hweſt come uncontrouled upon the Edyſtone rocks, and break on them with the utmoſt fury.

The force and height of theſe ſeas is increaſed by the circumſtance of the rocks ſtretching acroſs the Channel, in a north and ſouth direction, to the length of above 100 fathoms, and by their lying in a ſloping manner toward the ſouth-weſt quarter. This *ſliving* of the rocks, as it is technically called, does not ceaſe at low water, but ſtill goes on progreſſively; ſo that, at 50 fathoms weſtward, there are 12 fathoms water; nor do they terminate altogether at the diſtance of a mile. From this configuration it happens, that the ſeas are ſwelled to ſuch a degree in ſtorms and hard gales of wind, as to break on the rocks with the utmoſt violence.

The effect of this ſlope is likewiſe ſenſibly felt in moderate, and even in calm weather; for the libration of the water, cauſed in the Bay of Biſcay in hard gales at ſouth-weſt, continues in thoſe deep waters for many days, though ſucceeded by a calm; inſomuch, that when the ſea is to all appearance ſmooth and even, and its ſurface unruffled by the ſlighteſt breeze, yet thoſe librations ſtill continuing, which are called the *ground-ſwell*, and meeting the ſlope of the rocks, the ſea breaks upon them in a frightful manner, ſo as not only to obſtruct any work being done on the rock, but even the landing upon it, when, figuratively ſpeaking, you might go to ſea in a walnut ſhell. A circumſtance which ſtill farther increaſes the difficulty of working on the rock is, there being a ſudden drop of the ſurface of the rock, forming a ſtep of about four and a half, or five feet high; ſo that the ſeas, which in moderate weather come ſwelling to this part, meet ſo ſudden a check that they frequently fly to the height of 30 or 40 feet.

Notwithſtanding theſe difficulties, it is not ſurpiſing that the dangers to which navigators were expoſed by the Edyſtone rocks ſhould make a commercial nation deſirous of having a light-houſe on them. The wonder is, that any one ſhould be found hardy enough to undertake the building. Such a man was firſt found in the perſon of *Henry Winſtanley* of Littlebury in Eſſex, Gent. who, in the year 1696, was furniſhed by the maſter, wardens, and aſſiſtants, of the Trinity-houſe of Deptford Strond with the neceſſary powers to carry the deſign into execution.

Mr Winſtanley had diſtinguiſhed himſelf in a certain branch of mechanics, the tendency of which is to raiſe wonder and ſurpriſe. He had at his houſe at Littlebury a ſet of contrivances, ſuch as the following: Being taken into one particular room of his houſe, and there obſerving an old ſlipper careleſsly lying on the floor; if, as was natural, you gave it a kick with your foot, up ſtarted a *ghoſt* before you. If you ſat down in a certain chair, a couple of arms would immediately claſp you in, ſo as to render it impoſſible to diſentangle yourſelf till your attendant ſet you at liberty. And if you ſat down in a certain arbour by the ſide of a canal, you were forthwith ſent out *afloat* to the middle of the canal, from whence it was impoſſible for you to eſcape till the manager returned you to your former place.—Whether thoſe things were ſhewn to ſtrangers at his houſe for money, or were done by way of amuſement to thoſe that came to viſit the place, is uncertain, as Mr Winſtanley is ſaid to have been a man of ſome property; but it is at leaſt certain, that he eſtabliſhed a place of public exhibition at Hyde Park-corner, called *Winſtanley's water-works*, which were ſhewn at ſtated times at one ſhilling each perſon. The particulars of thoſe water-works are not now known; but, according to the taſte of the times, we muſt naturally ſuppoſe a great variety of *jets d'eau*, &c.

Theſe particulars are at preſent of no other importance than that they ſerve to give a ſketch of the talents and turn of mind of the original undertaker, and to account for the whimſical kind of buildings which he erected on the Edyſtone; from the deſign of which, it ſeems as if it were not ſufficient for his enterpriſing genius to erect a building on the ſpot, where, of all others, it was leaſt likely to ſtand unhurt; but that he would alſo give it an elevation, in appearance the moſt liable to ſubject it to damage from the violence of the wind and waves.

This ingenious man entered upon his great undertaking in 1696, and completed it in ſomething more than four years. The firſt ſummer was occupied with making 12 holes in the rock, and in faſtening 12 great irons, which were to hold the work that was afterwards to be done. The next ſummer was ſpent in making a ſolid body, or round pillar, 12 feet high and 14 feet in diameter. In the third year, the aforeſaid pillar or work was made good at the foundation, from the rock, to 16 feet in diameter; and all the work was raiſed, which, to the vane, was 80 feet high. Being all finiſhed, with the lantern, and all the rooms that were in it, we "ventured (ſays Mr Winſtanley) to lodge there ſoon after midſummer, for the greater diſpatch of this work: but the firſt night the weather came bad, and ſo continued, that it was eleven days before any boats could come near us again; and not being acquainted with the height of the ſeas riſing, we were almoſt all the time drowned with wet, and our proviſions in as bad a condition, though we worked night and day, as much as poſſible, to make ſhelter for ourſelves."

Mr Winſtanley, however, ſucceeded in ſetting up the light on the 14th of November in that year (1698); but he was detained till within three days of Chriſtmas before he could return to ſhore, being almoſt at the laſt extremity for want of proviſions.

In the fourth year, obſerving the effects that the ſea produced on the houſe, burying the lantern at times, although more than 60 feet high. Mr Winſtanley encompaſſed the aforeſaid building early in the ſpring with a new work of four feet thickneſs from the foundation, making all ſolid for near 20 feet high; and taking down the upper part of the firſt building, and enlarging every part in its proportion, he raiſed it 40 feet higher than it was at firſt: Yet, he obſerves, "the ſea in times of ſtorms, flies in appearance *one hundred feet above the vane*, and at times doth cover half the ſide of the houſe and the lantern as if it were under water."

No material occurrences concerning this building happened till November 1703, when the fabric, needing ſome repairs, Mr Winſtanley went down to Plymouth to ſuperintend the work. And "we muſt not wonder (ſays Mr Smeaton), if, from the preceding accounts of the violence of the ſeas, and the ſtructure of the light-houſe, the common ſenſe of the public led them to ſuppoſe this building would not be of long duration. The following is an anecdote which I received to the ſame effect from ſo many perſons that I can have no doubt of

Edyſtone.

of the truth of it: Mr Winſtanley being among his friends previous to his going off with his workmen on account of thoſe reparations, the danger being intimated to him, and that one day or other the light-houſe would certainly be overſet; he replied, "He was ſo very well aſſured of the ſtrength of his building, he ſhould only wiſh to be there in the greateſt ſtorm that ever blew under the face of the heavens, that he might ſee what effect it would have on the ſtructure."—It happened that Mr Winſtanley was but too amply gratified in this wiſh; for while he was there with his workmen and light-keepers, that dreadful ſtorm began, which raged moſt violently on the 26th of November 1703, in the night; and of all the accounts of the kind which hiſtory furniſhes us with, we have none that has exceeded this in Great Britain, or was more injurious or extenſive in its devaſtation. The next morning, November 27th, when the violence of the ſtorm was ſo much abated that it could be ſeen whether the light-houſe had ſuffered by it, nothing appeared ſtanding, but, upon a nearer inſpection, ſome of the large irons by which the work was fixed upon the rock; nor were any of the people, or any of the materials of the building, ever found afterwards, ſave only part of an iron chain, which had got ſo faſt jambed into a chink of the rock, that it could never afterwards be diſengaged till it was cut out in the year 1756."

Thus periſhed Mr Winſtanley, together with his building: but ſo great was the utility of that building while it ſtood, that the public could not fail to be deſirous of having another in its place. Accordingly, in 1706, an act of parliament of the 4th of Queen Anne was paſſed, for the better enabling the maſter, &c. of the Trinity-houſe of Deptford ſtrond to rebuild the ſame. By this act, the duties payable by ſhipping paſſing the light-houſe were veſted in the corporation of the Trinity-houſe, who were empowered to grant a leaſe to ſuch undertaker or undertakers as they ſhould approve. In conſequence, they agreed with a Captain *Lovel* or *Lovet* for a term of 99 years, commencing from the day on which a light ſhould be exhibited, and continuing ſo long as that exhibition ſhould laſt during the ſaid term. On this foundation Captain Lovet engaged Mr John Rudyerd to be his engineer or architect and ſurveyor.

It does not appear that Mr Rudyerd was bred to any mechanical buſineſs or ſcientific profeſſion, being at that time a ſilk mercer on Ludgate-hill; nor is it known that, in any other inſtance, he had diſtinguiſhed himſelf by any mechanical performance before or after. His want of perſonal experience, however, was in a degree aſſiſted by Mr Smith and Mr Norcutt, both ſhipwrights in the king's yard at Woolwich.

It is not, as Mr Smeaton obſerves, very material in what way this gentleman became qualified for the execution of his work; it is ſufficient that he directed the performance in a maſterly manner, and ſo as perfectly to anſwer the end for which it was intended. He ſaw the errors in the former building, and avoided them; inſtead of a polygon he choſe a circle for the outline of his building, and carried up the elevation in that form. His principal aim appears to have been *uſe* and *ſimplicity*; and indeed, in a building ſo ſituated, the former could hardly be acquired in its full extent without the latter. He ſeems to have adopted ideas the very reverſe of his predeceſſor; for all the unwieldy ornaments at top, the open gallery, the projecting cranes, and other contrivances, more for ornament and pleaſure than uſe, Mr Rudyerd laid totally aſide. He ſaw, that how beautiful ſoever ornaments might be in themſelves, yet when they are improperly applied and out of place, by affecting to ſhew a taſte, they betray ignorance of its firſt principle, *judgment*; for whatever deviates from propriety is erroneous, and at beſt inſipid.

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It is impoſſible for us to give an accurate account of the conſtruction of Mr Rudyerd's light-houſe. We can only ſay, in general terms, that it was altogether built of wood; for the courſes of moorſtone, which Mr Rudyerd, adverting to the maxim, that *weight* is beſt reſiſted by *weight*, introduced into the ſolid part of his building, muſt be conſidered as being of the nature of ballaſt; the weight of theſe amounted to above 270 tons. The main column of the building conſiſted of one ſimple figure, being an elegant fruſtum of a cone, unbroken by any projecting ornament, or any thing on which the violence of the ſtorms could lay hold; meaſuring, excluſively of its ſloping foundation, 22 feet and eight inches on its largeſt circular baſe; 61 feet high above that circular baſe; and 14 feet and three inches in diameter at the top: ſo that the circular baſe was ſomewhat greater than one-third of the total height, and the diameter at the top was leſs than two-thirds of the baſe at the greateſt circle. On the flat roof of this main column, as a platform, Mr Rudyerd fixed his lantern, which was an octagon of ten feet and ſix inches diameter externally. The mean height of the window-frames of the lantern above the balcony floor was nearly nine feet; ſo that the elevation of the centre of the light above the higheſt ſide of the baſe was 70 feet; that is, lower than the centre of Mr Winſtanley's ſecond lantern by ſeven feet, but higher than that of his firſt by 24 feet. The width of Mr Rudyerd's lantern was, however, nearly the ſame as that of Mr Winſtanley's ſecond: but inſtead of the towering ornaments of iron-work, and a vane that roſe above the top of the cupola no leſs than 21 feet, Mr Rudyerd judiciouſly contented himſelf with finiſhing his building with a round ball of two feet and three inches diameter, which terminated at three feet above the top of his cupola. The whole height of Mr Rudyerd's light-houſe, from the loweſt ſide to the top of the ball, was 92 feet, on a baſe of 23 feet and four inches, taken at a medium between the higheſt and loweſt part of the rock that it covered. The whole building was completed in the year 1709, three years from its commencement.

This great work, after having braved the elements for forty-ſix years, was burnt to the ground in 1755. On the 2d of December of that year, when the light-keeper, then on the watch, went, about two o'clock in the morning, into the lantern, to ſnuff the candles according to cuſtom, he found it in a ſmoke; and in ſpite of all that he and his companions could do, the whole edifice was on fire in the compaſs of little more than eight hours, and in a few days was burnt to its foundation. The three light-men were with much difficulty got on ſhore, when one of them immediately ran off, and has never ſince been heard of. Another, who had been dreadfully burned by melted lead, of which, according to his own account, he had ſwallowed a quantity, Edystone. tity, lingered in agony for twelve days, and then expired. His stomach being opened, there was found in it a solid piece of lead of a flat oval form, which weighed seven ounces and five drachms; and thus was verified an assertion which, to the surgeon and others who attended him, appeared altogether incredible, *viz.* that any human being could live after receiving melted lead into the stomach.

On the destruction of Mr Rudyerd's light-house, Mr Smeaton (see Smeaton in this Supplement) was recommended by Lord Macclesfield, then president of the Royal Society, as the fittest person in England to build another. It was with some difficulty that he was able to persuade the proprietors that a stone building, properly constructed, would in all respects be preferable to one of wood; but having at last convinced them, he turned his thoughts to the shape which was most suitable to a building so critically situated. Reflecting on the structure of the former buildings, it seemed a material improvement to procure, if possible, an enlargement of the base, without increasing the size of the *waist*, or that part of the building which is between the top of the rock and the top of the solid work. Hence he thought a greater degree of strength and stiffness would be gained, accompanied with less resistance to the acting power. On this occasion, the natural figure of the waist or bole of a large spreading oak occurred to Mr Smeaton.

"Let us (says he) consider its particular figure.—Connected with its roots, which lie hid below ground, it rises from the surface with a large swelling base, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter less by at least one third, and sometimes to half its original base. From thence, its taper diminishing more slowly, its sides by degrees come into a perpendicular, and for some height form a cylinder. After that, a preparation of more circumference becomes necessary, for the strong insertion and establishment of the principal boughs, which produces a swelling of its diameter.—Now we can hardly doubt but that every section of the tree is nearly of an equal strength in proportion to what it has to resist; and were we to lop off its principal boughs, and expose it in that state to a rapid current of water, we should find it as capable of resisting the action of the heavier fluid, when divested of the greater part of its clothing, as it was that of the lighter, when all its spreading ornaments were exposed to the fury of the wind: and hence we may derive an idea of what the proper shape of a column of the greatest stability ought to be, to resist the action of external violence, when the quantity of matter is given of which it is to be composed."

The next thing to be considered was, how the blocks of stone could be bonded to the rock, and to one another, in so firm a manner as that not only the whole together, but every individual piece, when connected with what preceded, should be proof against the greatest violence of the sea. For this purpose, cramping was the first idea, but was rejected on account of the great quantity of iron which was necessary, and from the trouble and loss of time which would attend that operation. In its place was substituted the method of dovetailing. From some specimens which Mr Smeaton had seen in Belidor's description of the stone floor of the great sluice at Cherburgh, (where the tails of the upright headers are cut into dovetails for their insertion into the mass of rough masonry below,) he was led to think, that if the blocks themselves were, both inside and outside, formed into large dovetails, they might be managed so as to lock one another together, being primarily engrafted into the rock; and in the round or entire courses above the top of the rock, they might all proceed from, and be locked to, one large centre stone. These particulars being digested in his own mind, he explained his design by the help of drawings: with which, after mature deliberation, the proprietors were perfectly satisfied; and declared, that the scheme was not only in itself practicable, but, as appeared to them, the only means of doing the business effectually.

During this time Mr Smeaton had never visited the rock on which he was to be employed: he therefore resolved to go to Plymouth early in the spring of 1756, that he might lose no opportunity of viewing it. At Plymouth he met Mr Josias Jessop, to whom he was referred for information and assistance, and who afterwards proved of great service: he was not only an approved workman in his branch as a shipwright, but a competent draughtsman and an excellent modeller; 'in which last (says the author) he was accurate to a great degree: he therefore appeared to be a very fit person to overlook the exact execution of a design given.' Mr Jessop, like others, expressed his doubts that a stone building could stand on the Edystone: but they were removed by the proposed mode of its construction.—As Mr Smeaton was impatient to go to the rock, he seized the first opportunity that seemed to promise any chance of landing on it. On the 2d of April he got within a stone's throw of it, but could not land: on the 5th he was more fortunate; he now landed, and staid on the rock for two hours and a half. This time was employed in taking a general view of the whole. No remains of the house could be perceived either on the rock, or about it, except the greatest part of the iron branches that had been fixed by Mr Rudyerd; and some of the moorstones were discerned lying in the bottom of the gut. Such traces were also observed of the situation of the irons fixed by Mr Winstanley, as to render it no very difficult task to make out his plan, and the position of the edifice; whence it appeared very probable, that Mr Winstanley's building was overset altogether, and that it had torn up a portion of the rock itself, as far as the irons had been fastened in it. With regard to the steps, which were said to have been cut in the rock by Mr Rudyerd, the traces of only five were remaining; these were faintly cut, and without much regularity. It was next tried in what degree the rock was workable; and Mr Smeaton had the satisfaction of finding every thing succeed to his wishes.

Having thus determined that there was no impracticability in fixing a stone building, it became of the greatest importance to secure a more safe and certain landing on the rock; as it would frequently happen, while the vessels were lying off the rock, waiting for a favourable time to enter the gut, that tides might change, ground swells come on, winds shift, and storms arise, which would of course make it desirable to return to Plymouth, if possible, though the purpose of the voyage was unperformed. In addition to this, when

Edyſtone. when veſſels had got with ſome facility into the gut, they frequently could not get out again without extreme danger; for as the larger ſort had not room to turn in it, they were in reality obliged to go out ſtern forward; the Sugar loaf rock being ſo critically placed, with ſhallow water on both ſides of it, that it prohibits a thorough paſſage. It was true, indeed, that by the ſkill and expertneſs of thoſe ſeamen who had frequently attended the ſervice of the Edyſtone, not only row boats, but the attendant veſſels, after having delivered their cargoes, had been carried quite through, at the top of an high tide, with a fair wind and ſmooth water: but this was not an experiment to be commonly repeated. The two voyages which Mr Smeaton had made were in a ſmall ſailing veſſel of about ten or twelve tons burthen, which was built for the ſervice, and called the Edyſtone Boat. It occurred to him, that while the light-houſe was ſtanding, if the boat had been ſtaved on the rocks while lying in the gut, there was a poſſibility of the men being ſaved by getting into the houſe, as the light-keepers would have been ready to throw out a rope to their aſſiſtance: but that if any accident of the kind were to happen now that the houſe was down, and no protection nor ſhelter to be had, there was little chance of their eſcape;—and theſe conſiderations being likely to caſt a damp on every exertion to land, he determined to go out no more without another ſailing boat to attend.

The weather being unfavourable for viſiting the rock, all exertions were uſed to forward the work on ſhore; and, firſt, a work-yard was choſen in a field adjacent to Mill Bay, about a mile weſt from Plymouth. The next object was to procure moor-ſtone, or granite; and with this view the author viſited Hingſtone Downs, and obſerved the manner of working the ſtone, which is curious. He next went to Lanlivery, near Fowey harbour, from which place the ſtone-work for the late light-houſe had been furniſhed.

During this time he had made five voyages to the rock with little ſucceſs: the event of the laſt had ſtrongly pointed out, that the much greater tonnage of the ſtone which muſt be neceſſary to be carried out and fixed, in caſe of a ſtone building, than was requiſite in the compoſitions of his predeceſſors, would make the uncertainty and delay which they had deſcribed as being attendant on their voyages, in order to fix their work, bear far heavier on the ſcheme; and would thus occaſion the whole time of the performance to be lengthened. It appeared, therefore, that had a veſſel been fixed within a quarter of a mile, or ſome ſuch competent diſtance from the rocks, and which ſhould be capable of lodging the workmen, all their tools and looſe materials, the ſeveral pieces of wrought ſtone only excepted, that then the workmen might, by means of ſmall row-boats or yawls, have effected a landing both of themſelves and of their materials, and have been at work on the rock during the greateſt part of thoſe days which otherwiſe as voyagers, they would have loſt in fruitleſs endeavours to get to the place of action. Agreeably to this opinion, it was propoſed to build a ſtrong and very well found ſloop of about fifty tons, with iron chains for mooring her on the rocky ground near the Edyſtone. A veſſel was in fact afterward moored in this ſituation: but it was one not built for the ſervice, but originally intended to have been ſtationed as a temporary floating light during the rebuilding of the light-houſe.

Mr Smeaton now made a ſixth voyage to the rock, on which he employed himſelf for nineteen hours in taking ſuch dimenſions as would enable him to make an accurate model of its ſurface. He likewiſe attempted a ſeventh voyage: but being unable to reach the Edyſtone, he bore away for Falmouth, in order to examine the moor-ſtone works at Conſtantine in that neighbourhood. From the difficulties which occurred here, as well as at other places, he was convinced that a ſufficient quantity of moor-ſtone could not be readily and expeditiouſly procured, in order to complete the whole building; and that he muſt therefore confine the moor-ſtone to the outſide, as being more durable, and content himſelf with the uſe of Portland, or ſome other free-working ſtone, for the inſide work. In conſequence, after making three more voyages to the rock, and completing all the obſervations which he was deſirous of taking there, he viſited the iſle of Portland in his return to London, and made the neceſſary agreements for carrying on his work.

On his arrival in London, Mr Smeaton again met the proprietors, from whom he experienced the greateſt liberality and confidence: they declared, that as he was now apprized of what was to be done, they left both the time and the means of its accompliſhment to him.

'On this occaſion (he obſerves), I found myſelf totally unfettered; and perhaps no reſolution of the proprietors ever more conduced to the ultimate ſucceſs of the work than this, which ſet me ſo much at liberty. Had they been of the ſame temper and diſpoſition of by far the greateſt part of thoſe who have employed me, both before and ſince, their language would have been, Get on, Get on, for God's ſake, get on! the public is in expectation; get us ſomething ſpeedily to ſhew, by which we may gain credit with the public!—This, however, was not their tone, which I looked upon as a happy earneſt from the proprietors in the outſet.'

During his ſtay in London, he reſolved, as an abſolutely neceſſary preliminary ſtep, to form models of the rock, both in its preſent ſtate and as cut to the intended ſhape for receiving the building. Connected with the laſt was a model of the building itſelf, ſhewing diſtinctly how the work was to be adapted to each ſeparate ſtep in the aſcent of the rock, and particularly exhibiting the conſtruction of the firſt entire courſe after riſing to the level of the upper ſurface of the rock: to this a ſolid being fitted, the model ſhewed the external form of the whole building, including the lantern; while, by a ſection on paper, the whole inſide work was repreſented. Theſe models, as well, indeed, as moſt of the material parts of the buſineſs, were the entire work of Mr Smeaton's own hands. After exhibiting theſe to the Lords of the Admiralty, who expreſſed their warmeſt approbation, he returned to Plymouth on the 23d of July 1756.

On his arrival at Plymouth, he found that Mr Jeſſop had completely fitted up, for preſent ſervice, the ſloop, which had before been uſed as an attendant; as well as the Edyſtone boat, and a large yawl, with ſails and oars. Another ſeaman was now taken into the ſervice, which made the number of the crew ſix. The Neptune Buſs, which had been built for the purpoſe of exhibiting a temporary light, but which was afterward moored

Edystone. moored near to the rock, was arrived: but as her distination was not known, all orders for mooring-chains were suspended, and Mr Smeaton was obliged to content himself with preparing cables in the best manner that he could for mooring the sloop in that situation. As the weather was unfavourable, he had but one opportunity of visiting the rock; he therefore applied vigorously to prepare every thing on shore. The first business was to establish the working companies, which were to consist of two complete sets of hands, to relieve each other by turns; so that, whenever winds and tides would permit, the work might be pursued by day and night. In his distribution and management of these people he appears to have acted with great judgment. He made choice of, and agreed with, Mr Thomas Richardson, a master mason of Plymouth, to act as foreman of one of the companies; and also with William Hill, who had been some time foreman to another master mason of the same place, to act as the other foreman. He likewise entered three masons, and nine tinners (Cornish miners), as a company, to go out with Mr Richardson to take the first turn, or week, commencing from Saturday the 31st of July. Mr Jessop was appointed general assistant. The wages of the foremen, while at sea, were to be 5s. per day certain; and for every hour spent on the rock, the farther premium of 1s.—but when employed in the work-yard or otherwise on shore, their wages were to be 3s. 6d. per day. The wages of the masons were to be 2s. 6d. per day certain at sea, with a premium of 9d. per hour; and the tinners were to have 2s. per day certain at sea, and 8d. per hour. In the work-yard, or at shore, the masons were to have 20d. and the tinners 18d. per day, and to be paid for over-time when required to work; —and that the seamen might not want inducement to do their utmost in landing the workmen at the Edystone as early as possible at every opportunity, and in supplying them with what was necessary for keeping them at work, over and above their weekly wages, which were settled at 8s. per week, they were all to receive a premium for every landing on the rock; the master seamen having 2s. 6d. and the ordinary men 2s. to make their advantage equivalent to that of the other workmen, in whatever service the seamen, who were constantly on duty, were employed. Mr Jessop, as general assistant, was to have 10s. 6d. per day at sea, and 5s. per day on land; and every one was to supply himself with victuals.—Mr Smeaton likewise agreed for half an acre of ground on the west side of Mill-bay for a work-yard, as before mentioned, which he marked out, and ordered to be fenced with boards. At this time arrived Mr John Harrison, who was to act as clerk to the Edystone works, with whom a plan was digested for keeping the accounts and correspondence; and for the distinct noting of so great a variety of articles, it was found expedient to open fourteen different books.

Matters being thus settled on shore, and the weather having become more promising, Mr Richardson and his company embarked in the sloop, with her ground tackle on board, attended by the author and Mr Jessop, and having also the yawl properly manned. Having landed on the rock, Mr Smeaton proceeded to fix the centre, and to lay down the lines of the intended work on its surface; and being followed by Mr Richardson, he, with sharp picks, left indelible traces of those lines, so as that the workmen might proceed on them whenever they should be able to land. The roughness of the sea, however, soon rendered it advisable to return to the sloop; and from the same cause it was thought unsafe to attempt to moor her that evening. On the next day, the wind continued to blow very fresh: but on the following day they were able to moor the sloop; and every one being anxious to make a beginning, the whole company landed on the rock, and immediately began the work, which was pursued for about four hours, when they were driven off by the sea. On the following day, all hands landed before sun-rise, and worked, during that tide, for six hours; and in the afternoon's tide they again landed, and continued the work, by the help of links, till ten o'clock at night. They pursued this course for some time with very little interruption, working, at an average, for about five hours in each tide.

The weather had now been fair from August 27th to the 14th of September; and in this space they had worked for 177 hours on the rock. During this interval, also, Mr Jessop had prevented a West Indiaman homeward bound, and a man of war's tender from driving on the rocks, to which they were approaching, though they themselves were not aware of it. On the 16th, the work on the rock was in the following situation: The lowest new step (the most difficult to work because the lowest,), with its dovetails, was quite completed.—The second step was rough bedded, and all its dovetails scapelled out.—The third step (being the lowest in Mr Rudyerd's work) was smooth bedded, and all the dovetails roughed out.—The fourth was in the like state.—The fifth was rough bedded, and its dovetails were scapelled out; and the sixth was smooth bedded, and all the dovetails roughed out.—Lastly, the top of the rock, the greatest part of the bulk whereof had been previously taken down as low as it could be done with propriety, was now to be reduced to a level with the upper surface of the sixth step; the top of that step being necessarily to form a part of the bed for the seventh or first regular course: so that what now remained, was to bring the top of the rock to a regular floor by picks; and from what now appeared (as all the upper parts that had been damaged by the fire were cut off) the new building was likely to rest on a basis even more solid than the former light-houses had done.

The equinoctial winds that were now reigning, afforded little prospect of doing much more work on the rock for this season: for though a more moderate interval of weather might be expected, yet that must be employed in weighing the Buss's moorings. To prevent the necessity of this, however, it was an object of consideration, whether they could not dispense with that operation, and thereby have a little more time for work on the rock. Mr Smeaton's contrivance for this purpose was admirable; but it was rendered vain by the bad sailing of the buss. After overcoming many difficulties, the buss with Mr Smeaton on board was driven at a great rate towards the bay of Biscay, in danger every hour of being swallowed up by the waves, or dashed in pieces on the rocks of Scilly. At last, on Friday morning the 26th of November, they reached Plymouth Sound, and relinquished all thoughts of returning to their work on the rock that season.

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Edyſtone.

The winter therefore of 1756, and the following ſpring, were employed in preparing materials for the outwork: the maſonry particularly required great attention. It was a deſirable object to uſe large and heavy pieces of ſtone in the building; yet their ſize muſt neceſſarily be limited by the practicability of landing them with ſafety. Now ſmall veſſels only could deliver their cargoes alongſide of this hazardous rock; and theſe could not deliver very large ſtones, becauſe the ſudden riſing and falling of the veſſels in the gut amounted frequently to the difference of three or four feet, even in moderate weather; ſo that in caſe after a ſtone was raiſed from the floor of the veſſel, her gunwale ſhould take a ſwing, ſo as to hitch under the ſtone, one of a very large magnitude muſt, on the veſſel's riſing, infallibly ſink her. From this conſideration, it was determined that ſuch ſtones ſhould be uſed as did not much exceed a ton weight; though occaſionally particular pieces might amount to two tons. That they might attain a certainty in putting the work together on the rock, the ſtones of each courſe were tried together in their real ſituation with reſpect to each other; and they were ſo exactly marked, that every ſtone, after the courſe was taken aſunder, could be replaced in the identical poſition in which it lay on the platform, within the fortieth part of an inch:—nor was this judged ſufficient; for every courſe was not only tried ſingly together on the platform and marked, but the courſe above it was put on it, and marked in the ſame way; ſo that every two contiguous courſes might fit each other on the outſide, and prevent an irregularity in the outline. This degree of accuracy might ſeem ſuperfluous: but as the nature of the building required the workmen to be in a condition to reſiſt a ſtorm at every ſtep, it became neceſſary to fix the centre ſtone firſt, as being leaſt expoſed to the ſtroke of the ſea; and in order to have ſure means of attaching all the reſt to this, and to one another, it was indiſpenſable that the whole of the two courſes ſhould be tried together; in order that, if any defect appeared at the outſide, by an accumulation of errors from the centre, it might be rectified on the platform.

Another circumſtance, to which Mr Smeaton was particularly attentive, and concerning which his remarks are very valuable, was to aſcertain the moſt proper compoſition for water cements. In making mortar for buildings expoſed to water, *tarras* had been moſt eſteemed: but ſtill there were objections to its uſe. Mr Smeaton was therefore induced to try the *terra puzzolana*, found in Italy, as a ſubſtitute for *tarras*. Fortunately there was a quantity of it in the hands of a merchant at Plymouth, which had been imported as a venture from Civita Vecchia when Weſtminſter-bridge was building; and which he expected to have ſold for that work to a good advantage, but failed in his ſpeculation; for having found that *tarras* anſwered their purpoſe, neither commiſſioners, engineers, nor contractors, would trouble themſelves to make a trial of the other material. This was found in every reſpect equal to *tarras*, as far as concerned the hardening of water-mortar, if not preferable to it; and if made into a mortar with lime produced from a ſtone found at Aberthaw, on the coaſt of Glamorganſhire, it exceeded, in hardneſs, any of the compoſitions commonly uſed in dry work; and in wet and dry, or wholly wet, was far ſuperior to any which Mr Smeaton had ſeen, inſomuch, that he did not doubt its making a cement that would equal the beſt merchantable Portland ſtone in ſolidity and durability.

Theſe preliminary arrangements being ſettled, they proceeded, on the 3d of June 1757, to carry out the Neptune buſs, and to begin the work. After getting up the moorings (a work of no ſmall difficulty and ſome danger), and after fixing the fender piles, the ſhears, windlaſs, &c. the firſt ſtone was landed, got to its place, and fixed, on Sunday the 12th of June; and on the next day the firſt courſe was completed. On the 14th, the ſecond courſe was begun: but, in conſequence of a freſh gale, the workmen were obliged to quit the rock, after ſecuring every thing as well as poſſible. Such was the violence of the gale, that it was impracticable for the boats to get out of the gut, otherwiſe than by paſſing the Sugar loaf rock, in which they providentially ſucceeded. On the 18th, they were again as ſuddenly driven from their work, and ſeveral pieces of ſtone were waſhed away by the violence of the ſea. In the night of the 6th of July, the watch on the deck of the buſs eſpied a ſail on the rocks, and one of the yawls was ſent to her relief, which brought back the whole crew, ſeveral of whom were in their ſhirts, and in great diſtreſs. It was a ſnow of about 130 tons burthen, which was returning in ballaſt from Dartmouth; but not knowing exactly where they were, they had miſtaken the rocks for ſo many fiſhing boats, till it was too late to clear them; and on the veſſel's ſtriking, ſhe filled ſo quickly, that the boat floated on deck before they could get into it.

During this time, the building went on, though its progreſs was retarded by various interruptions and accidents; till, at the latter end of Auguſt, when the ſeventh courſe was nearly finiſhed, a violent ſtorm aroſe, which carried away the ſhears and triangles, together with two of the largeſt ſtones which had been left chained on the rock! yet notwithſtanding theſe and various other difficulties, the ninth courſe was completed by the end of September.

"Being now arrived at the eve of October (ſays Mr Smeaton), I maturely conſidered our ſituation; and finding that we had been 18 days in completing the laſt courſe, whereas the former one was begun and finiſhed in five, though the weather, both on ſhore and above head, had remained to all appearance much the ſame; I from thence concluded it to be very probable, we might not get another courſe completed in the compaſs of the month of October: So that when I reflected on the many diſaſters that we had ſuffered laſt year by continuing out to the month of November, and how little work we in reality did after this time, it appeared to me very problematical whether we might be able, with every poſſible exertion, to get another courſe finiſhed this ſeaſon; and conſidering how very ineligible it was to have a courſe lie open during the winter in this ſtage of the work, and that we had now got three complete courſes eſtabliſhed above the top of the rock, the ſum of whoſe height was four feet ſix inches; and that we could not leave the work in a more defenſible ſtate, whether as relative to the natural violence of the ſea, or the poſſibility of external injuries—from theſe conſiderations, it appeared to me highly proper to put a period to the outwork of the preſent ſeaſon."

 At

Edyſtone.

At the commencement of the following year, 1758, the weather proved very tempeſtuous till March; and on viſiting the rock, they diſcovered that the great buoy on the moorings had been carried away; nor were the mooring chains, though ſought with the greateſt perſeverance, recovered till the middle of May. In conſequence of this delay, and from other accidents, the tenth courſe of the building was not completed till the 5th of July. From this time the progreſs was without any very material interruption; ſo that on the 26th of September the 25th courſe, being the firſt of the ſuperſtructure, was finiſhed. The work was now ſo far advanced, that Mr Smeaton made a propoſal to the Trinity Board and to the proprietors of exhibiting a light during the enſuing winter; and for this purpoſe he continued his operations longer than he otherwiſe would have done, in order to complete the firſt room, and make it habitable; but foul weather coming on, he was obliged to quit the rock, and returned to Plymouth. A ſtorm enſued; and, on the next morning, looking out with his teleſcope, he could diſcern the houſe with the ſea breaking over it, but nothing of the buſs. On the following day, the air being more clear, he had a diſtinct view of the building; but the buſs was really gone. This was a day of double regret, as it likewiſe brought a negative on his propoſal for exhibiting a light from the houſe during the winter. The buſs had run into Dartmouth harbour; ſhe was brought home; and the work on the rock being ſecured againſt the winter, the operations of the third ſeaſon were cloſed.

During the early part of 1759, Mr Smeaton was employed in London in forming and making out the neceſſary deſigns for the iron rails of the balcony, the caſt iron, the wrought iron, and the copper works for the lantern, together with the plate glaſs work. It was not till the 22d of June that he arrived at Plymouth. As the moorings had been again loſt, new chains were provided, and the buſs was once more fixed in her ſituation. On the 5th of July he landed on the rock, and found every thing perfectly ſound and firm, without the leaſt perceptible alteration, excepting that the cement, uſed in the firſt year, now in appearance approached the hardneſs of the moor-ſtone; and that uſed in the laſt year had the full hardneſs of Portland; but on hauling up the ſtones for the next circle from the ſtore-room, where they had been depoſited, he had the mortification to find only ſeven inſtead of eight. It was imagined that a body of falling water, making its way through the open ribs of the centre, had waſhed this ſtone out of the ſtore-room door, though it weighed between four and five hundred weight.

The progreſs of the work, however, was now ſuch, that a whole room, with its vaulted cover, was built complete in ſeven days.

On the 17th of Auguſt the main column was completed.

On the 27th Mr Richardſon and his company left the Edyſtone, and gave an account that they had lived in it ſince the 23d, having found it much more warm than the buſs's hold and cabin.

They had now finiſhed every thing belonging to the maſonry. The work of the cupola was going on briſkly in the yard at Mill-bay, though it was retarded by the ſucceſſive illneſſes of the two principal copperſmiths. However, by the exertions of Mr Smeaton, who was himſelf ready to work at every buſineſs, all matters were put in ſuch forwardneſs, that by the 8th of September there was nothing to prevent the frame of the lantern from being fixed in its place but bad weather, It was not till the 15th that the weather permitted the boats to deliver their cargoes. The 16th was remarkably fine; ſo that by the evening the whole frame of the lantern was ſcrewed together, and fixed in its place. On the 17th, which was alſo exceedingly fine, the cupola was brought out, and the ſhears and tackle were ſet up for hoiſting it.

"This (ſays Mr Smeaton) perhaps may be accounted one of the moſt difficult and hazardous operations of the whole undertaking; not ſo much on account of its weight, being only about 11 cwt. as on account of the great height to which it was to be hoiſted clear of the building, and ſo as, if poſſible, to avoid ſuch blows as might bruiſe it. It was alſo required to be hoiſted a conſiderable height above the balcony floor; which, though the largeſt baſe that we had for the ſhears to ſtand on, was yet but 14 feet within the rails, and therefore narrow in proportion to their height. About noon the whole of our tackle was in readineſs; and in the afternoon the Weſton (boat) was brought into the gut, and in leſs than half an hour her troubleſome cargo was placed on the top of the lantern without the leaſt damage. During the whole of this operation it pleaſed God that not a breath of wind diſcompoſed the ſurface of the water, and there was the leaſt ſwell about the rocks I had obſerved during the ſeaſon.

"Tueſday, September 18th, in the morning, I had the ſatisfaction to perceive the Edyſtone boat, on board of which I expected the ball to be; and which being double gilt, I had ordered the carriage of it to be carefully attended to. The wind and tide were both unfavourable to the veſſel's getting ſoon near us; therefore, being deſirous to get the ball ſcrewed on before the ſhears and tackle were taken down, one of the yawls was diſpatched to bring it away. This being done, and the ball fixed, the ſhears and tackle were taken down, which took up nearly as much time as was employed in ſetting them up; that is, near 12 hours each, in the whole, to do the work of an hour.—I muſt obſerve, that by choice I ſcrewed on the ball with mine own hands, that in caſe any of the ſcrews had not held quite tight and firm, the circumſtance might not have been ſlipped over without my knowledge; being well aware, that even this part would at times come to a conſiderable ſtreſs of wind and ſea, and which could not be replaced without ſome difficulty in caſe any thing ſhould fail.—It may not be amiſs to intimate to thoſe who may in future have to perform the ſame operation, that the ſcaffold on which this was done conſiſted of four boards only, well nailed together, at ſuch diſtances as to permit it to be lifted over the ball when done with. It reſted on the cupola, encompaſſing its neck; and Roger Cornthwaite, one of the maſons, placed himſelf on the oppoſite ſide upon it, to balance me while I moved round to fix the ſcrews."

Reſpecting the diſpoſition of the internal part of the edifice, Mr Smeaton fixed the beds in the uppermoſt room, and the fire-place, which conſtituted the kitchen, in the room below it; whereas, in the late houſe, the upper room was the kitchen, and the beds were placed in in one of the rooms below; the confequence of which was, that the beds and bedding were generally in a very damp and difagreeable ftate. The prefent difpofition has perfectly anfwered the end propofed, as nothing can be more completely dry than the two habitable rooms.

On the 1ft of October, every thing being finifhed, and the chandeliers hung, there was nothing to hinder a trial by lighting the candles in the day time. Accordingly 24 candles were put into their proper places, and were continued burning for three hours, during which time it blew a hard gale; and a fire being kept at the fame time in the kitchen, they both operated without any interference; not any degree of fmoke appearing in the lantern nor in any of the rooms; and by opening the vent holes, which had been made in the bottom of the lantern for occafional ufe, it could be kept quite cool; whereas, in the late light-houfe, it ufed to be fo hot, efpecially in the fummer, as to give much trouble by the running of the candles.

All being thus in readinefs, and a conductor, in cafe of lightning being adapted to the building, notice was given to the Trinity-houfe that the light would be exhibited on the 16th of October 1759. The feafon of the year being now advanced to that which was always very precarious, the Neptune bufs was unmoored, and on the 9th of October fhe came to an anchor in Plymouth harbour.—"And thus (fays Mr Smeaton), after innumerable difficulties and dangers, was a happy period put to this undertaking, without the lofs of life or limb to any one concerned in it, or accident, by which the work could be faid to be materially retarded."

With regard to fubfequent occurrences, it is truly obferved, that the beft account is, that, after a trial of 40 years, which have elapfed fince the finifhing of the building, it ftill remains in its original good condition. A few particulars are however interefting. On the 19th of October Mr Smeaton, with Mr Jeffop, &c. vifited the houfe, and, landing, found all well. Henry Edwards, one of the light keepers, gave an account that they lighted the houfe as they were directed, and found the lights to burn fteadily, notwithftanding it blew very hard; that they had the greateft feas on the days immediately preceding the lighting; and that then the waves broke up fo high, that had they not been thrown off by the cove courfe, they would have endangered breaking the glafs in the lantern: that when the feas broke the higheft, they had experienced a fenfible motion; but that, as it was barely perceptible, it had occafioned them neither fear nor furprize.

During his ftay at Plymouth, in the times of ftormy weather, Mr Smeaton took feveral opportunities of viewing the light-houfe with his telefcope from the Hoa; and alfo from the garrifon, both which places were fufficiently elevated to fee the bafe of the building, and the whole of the rock at low water in clear weather; and though he had many occafions of viewing the unfinifhed building when buried in the waves in a ftorm at fouth-weft; yet having never before had a view of it under this circumftance in its finifhed ftate, he was aftonifhed to find that the account given by Mr Winftanley did not appear to be at all exaggerated. At intervals of a minute, and fometimes of two or three, when a combination happened to produce one overgrown wave, it would ftrike the rock and the building conjointly, and fly up in a white column, enwrapping it like a fheet, rifing at leaft to double the height of the houfe, and totally intercepting it from the fight; and this appearance being momentary, both as to its rifing and falling, he was enabled to judge of the comparative height very nearly by the comparative fpaces, alternately occupied by the houfe and by the column of water in the field of the telefcope.

The year 1759 concluded with fome very ftormy weather; and in January 1760, Mr Jeffop vifited the houfe, but could not land. He got a letter, however, from Henry Edwards, acquainting him that there had been fuch very bad weather that the fea frequently ran over the houfe; fo that for 12 days together they could not open the door of the lantern nor any other. He faid, "the houfe did fhake as if a man had been up in a great tree. The old men were almoft frighted out of their lives, wifhing they had never feen the place, and curfing thofe that firft perfuaded them to go there. The fear feized them in the back; but rubbing them with oil of turpentine gave them relief." He farther mentioned, that on the 5th of December, at night, they had a very great ftorm; fo that the ladder, which was lafhed below the entry door, broke loofe, and was wafhed away. Alfo, on the 13th, there was fo violent a ftorm of wind that he thought the houfe would overfet; and at midnight the fea broke one pane of glafs in the lantern. They had a very melancholy time of it, having alfo had a great deal of thunder and lightning.—"The ftorms (obferves Mr Smeaton) which the building has now fuftained without material damage, convince us, and every one, of the ftability of the ftone light-houfe, except thofe (who were not a few) who had taken a notion that nothing but *wood* could refift the fea upon the Edyftone rocks; who faid, that though they allowed it was built very ftrong, yet if fuch a ftorm as had deftroyed Winftanley's light-houfe was again to happen, they doubted not but it muft fhare the fame fate. The year 1762 was ufhered in with ftormy weather, and indeed produced a tempeft of the firft magnitude; the rage of which was fo great, that one of thofe who had been ufed to predict its downfall was heard to fay, If the Edyftone light-houfe is ftanding now, it will ftand till the day of judgment. And, in reality, from this time, its exiftence has been fo entirely laid out of mens minds, that whatever ftorms have happened fince, no inquiry has ever been made concerning it."

For the length of this detail we cannot bring ourfelves to make any apology. If there be a few of our readers to whom it may appear tedious, we are perfuaded that there are many more to whom it will be in a high degree interefting; while fuch of them as are engineers will derive inftruction even from this very abridged hiftory of the Edyftone light-houfe.

EEL RIVER *Indians*, inhabit the lands on Eel river, a head branch of Wabafh river. They were lately hoftile; but ceded fome land at the mouth of the river to the United States, at the treaty of Greenville, in 1795; when government paid them a fum of money, and engaged to pay them in goods, to the value of 500 dollars annually forever.—*Morse.*

EFFECTION, denotes the geometrical conftruction of a propofition. The term is alfo ufed in reference to problems and practices, which, when they are deducible from,

from, or founded upon, fome general propofitions, are called the *geometrical effection* of them.

EFFINGHAM, formerly Leavitftown, a townfhip in Strafford co. New-Hampfhire, S. E. of Offipee pond, on Offipee river, incorporated in 1766, and has 154 inhabitants.—*Morse.*

Effingham *Co.* in the lower diftrict of Georgia, is bounded by Savannah river on the N. eaftward, which feparates it from S. Carolina; by Ogeechee river on the S. weftward, which divides it from Liberty co. It contains 2424 inhabitants, including 750 flaves. Chief towns, Ebenezer and Elberton.—*ib.*

EGG-HARBOUR, a town in Gloucefter co. New-Jerfey, on Great Egg Harbour: famous for the exportation of pine and cedar.—*ib.*

Egg Harbour R. Great and Little. Great Egg Harbour river rifes between Gloucefter and Cumberland counties, in New-Jerfey. After running E. S. E. a few miles it becomes the divifional line between Cape May and Gloucefter counties, and falls into the bay of its own name. The inlet from the Atlantic ocean lies in 39. 22. The river abounds with fheepfhead, rock-fifh, perch, oyfters, clams, &c. which find a ready market at Philadelphia. This river is navigable 20 miles for veffels of 200 tons.—*ib.*

Little Egg Harbour Inlet, lies about 17 miles N. E. of Great Egg Harbour Inlet. It receives Mulicus river which rifes in Gloucefter and Burlington counties, and forms part of the divifional line a few miles from the bay. It is navigable 20 miles for veffels of 60 tons. The townfhip of *Little Egg Harbour,* in Burlington co. confifts of about 23,000 acres; the moft of which being thin and barren, is not under improvement. The compact part of the townfhip is called *Clam Town,* where there is a meeting-houfe for Friends, and about a dozen houfes. It has a fmall trade to the Weft-Indies. During the late war captains Fergufon and Collins burnt a number of privateers and other veffels in Little Egg Harbour, and deftroyed the place.—*ib.*

Egg *Ifland,* a fmall ifland on the N. E. fide of Delaware bay, in Cumberland co.—*ib.*

EGLANTINE (Fabre de), was born at Chalons in Champagne. He was early educated, by the care of his parents, in polite literature and natural philofophy. From his youth he felt an invincible inclination to court the mufes; and in the year 1786 he publifhed, in a French periodical work, intitled *Les Etrennes du Parnaffe,* a little poem called *Chalons fur Marne,* in which he drew a very charming picture of the moral pleafures that were to be found in that place and its neighbourhood. This piece, however, was then confidered as a juvenile compofition, and fell very fhort of that high degree of celebrity which the author afterwards attained to. In the years 1789 and 1790 he publifhed two well-known comedies, *Le Philinte,* and *L'Intrigue Epiftolaire.* Befides his talents for writing comedies, he felt, like Moliere, an inclination to perform parts on the ftage. He accordingly acted his own plays in the theatres of Lyons and Nimes.

Being, like the greater part of French wits and philofophers, an avowed enemy to religion and civil fubordination, he was thought to have fufficient merit to be removed from the office of fabricating comedies to that of fabricating conftitutions. Accordingly, in 1792, he was chofen (we believe by the influence of the Girondine faction) a deputy to the National Convention. In that affembly, during the winter and the fpring of 1793, he acted a part certainly not very commendable, though every way worthy of the pupil of the economifts. At that period the Girondine party was the moft powerful; and it was very generally reported among the beft informed people at Paris, that Fabre contributed, together with Danton and Robefpierre, to the famous maffacre of the 31ft of May, when the Girondine faction was overthrown by a popular infurrection. What gives the appearance of authenticity to this report is, that Fabre himfelf fome days afterwards obferved to a friend, that the domineering fpirit of the Girondines, who had engroffed all power and office, had induced him and his colleagues, in order to fhake off the yoke, to throw themfelves into the hands of the *Sanfculoterie;* that he could not help, however, foreboding dangerous confequences from that day, 31ft of May, as the fame mob which they had taught to defpife the legiflature might, at the inftigation of another faction, overthrow him in his turn. Thus Fabre appeared to have a prefentiment of his own future deftiny.

On the overthrow of the Girondine party, and the eftablifhment in power of the Sanfculoterie, Fabre began to act a confiderable part. He was appointed member of the Committee of Public Inftruction; in which ftation, in the month of Auguft 1793, he gave his vote for fuppreffing all academies and literary corporations which, from their privileges and ariftocratic fpirit, were confidered as unfriendly to a truly republican government. In October 1793, he fubmitted to the National Convention the plan of a new calendar, which was afterwards adopted.

The reader who will take the trouble to turn to the article Revolution, n° 184, *Encycl.* may fee that calendar, and be able to judge for himfelf whether it evinces the childifhnefs or the fcience of its author. A journalift of our own indeed, who feems to admire every thing that is new and odd, fays, that the accuracy and regularity with which it was executed, evinced an *uncommon* degree of knowledge in mathematics and natural philofophy, and failed not to reflect on its author great reputation! Indeed! Had the Sanfculotes fo foon forgotten their "guides, philofophers, and friends," D'Alembert, and Condorcet, as to confider this exploit as fufficient to place its author in the temple of fame among the fons of fcience? Our journalift, however, admits, that it gave birth to a pleafant pamphlet, intitled *Le Légiflateur à la Mode;* in which it was demonftrated, that the 31ft chapter of the travels of Anacharfis, by the Abbe Barthelemy, where the defcription of the ancient Greek calendar is introduced, had furnifhed no inconfiderable part of the plan of the new Fabrine calendar.

The Sanculoterie had now become too powerful to be tolerated any longer. In the winter of 1794, that faction was divided into two parts, the *Jacobins* and the *Cordeliers,* or, in other words, the *Robefpierrifts* and the *Dantonifts.* Fabre was of the faction of Danton, and was confined with Danton's adherents in the prifon of the Luxemburg. From that prifon he wrote a number of letters, which were afterwards printed. Thefe letters are highly extolled as beautiful defcriptions of fenfibility and talents in diftrefs. After a month's imprifonment, Fabre was, with many others, executed

executed in the *place de la Revolution*, in April 1794, in the 35th year of his age. His sentence, we believe, was unjust; but death he had more than merited.

EGMONT, an island in the South Pacific ocean, discovered by capt. Carteret. The Spaniards called it Santa Cruz. S. lat. 19. 20. E. long. from Greenwich 164. 30.—*Morse*.

EGREMONT, a township in Berkshire co. Massachusetts, containing 759 inhabitants, incorporated in 1760—15 miles S. W. of Stockbridge, and 145 W. of Boston.—*ib*.

EIGHTEEN-MILE, or *Long Beach*, on the coast of New-Jersey, lies between Little Egg Harbour inlet, and that of Barnegat.—*ib*.

ELASTICITY. In addition to the article in the *Encyclopædia*, see, in this *Supplement*, the view of Boscovich's theory of natural philosophy, n° 26.

ELBERT, a new county in the upper district of Georgia, on the tract of land between Tugulo and Broad rivers. The S. E. corner of the county is at their confluence, at the town of Petersburg. On the N. W. it is bounded by Franklin county.—*Morse*.

ELBERTON, the seat of justice in the above co. is 23 miles N. W. of Petersburg, and 30 S. E. of Franklin court-house.—*ib*.

ELBERTON, a post town in Effingham co. Georgia, on the N. E. bank of Ogeechee river, containing about 30 houses. It is about 19 miles W. of Ebenezer, 48 N. W. of Savannah, and 55 S. E. of Louisville. N. lat. 32 18. 45. W. long. 80. 30.—*ib*.

ELECTIONS, or CHOICE, signify the several different ways of taking any number of things proposed, either separately, or as combined in pairs, in threes, in fours, &c.; not as to the order, but only as to the number and variety of them. Thus, of the things *a*, *b*, *c*, *d*, *e*, &c. the elections of
one thing are $(a)\ 1 = 2^1 - 1$,
two things are $(a, b, ab,)\ 3 = 2^2 - 1$,
three things are $(a, b, c, ab, ac, bc, abc,)\ 7 = 2^3 - 1$,
&c.; and of any number n, all the elections are $2^n - 1$; that is, one less than the power of 2 whose exponent is n, the number of single things to be chosen, either separately or in combination.

ELECTRICITY.

WE cannot but be somewhat surprised that, among the many attempts which have been made by the philosophers of Britain to explain the wonderful phenomena which are classed under this name, no author of eminence, besides the Hon. Mr Cavendish and Lord Mahon, have availed themselves of their susceptibility of mathematical discussion; and our wonder is the greater, because it was by a mathematical view of the subject, in the phenomena of attraction and repulsion, that the celebrated philosopher Franklin was led to the only knowledge of electricity that deserves the name of science; for we had scarcely any leading facts, by which we could class the phenomena, till he published his theory of *positive* and *negative*, or *plus* and *minus* electricity. This is founded entirely on the phenomena of attraction and repulsion. These furnish us with all the indications of the presence of the mighty agent, and the marks of its kind, and the measures of its force. Mechanical force accompanies every other appearance; and this accompanyment is regulated in a determinate manner. Many of the effects of electricity are strictly mechanical, producing local motion in the same manner as magnetism or gravitation produce it. One should have expected that the countrymen of Newton, prompted by his success and his fame, would take to this mode of examination, and would have endeavoured to deduce, from the laws observed in the action of this motive force, an explanation of other wonderful phenomena, which are inseparably connected with those of attraction and repulsion.

But this has not been the case, if we except the labours of the two philosophers above mentioned, and a few very obvious positions which must occur to all the inventors and improvers of electrometers, batteries, and other things of measurable nature.

This view has, however, been taken of the subject by a philosopher of unquestioned merit, Mr Æpinus of the Imperial Academy of St Petersburgh. This gentleman, struck with the resemblance of the electrical properties of the tourmalin to the properties of a magnet, which have always been considered as the subject of mathematical discussion, fortunately remarked a wonderful similarity in the whole series of electrical and magnetical attractions and repulsions, and set himself seriously to the classification of them. Having done this with great success, and having maturely reflected on Dr Franklin's happy thought of plus and minus electricity, and his consequent theory of the Leyden phial, he at last hit on a mode of conceiving the whole subject of magnetism and electricity, that bids fair for leading us to a full explanation of all the phenomena; in as far, at least, as it enables us to class them with precision, and to predict what will be the result of any proposed treatment. He candidly gives it the modest name of a hypothesis.

This was published at St Petersburg in 1759, under the title of *Theoria Electritatis et Magnetismi*, and is unquestionably one of the most ingenious and brilliant performances of this century. It is indeed most surprising that it is so little known in this country. This, we imagine, has been chiefly owing to the very slight and almost unintelligible account which Dr Priestley has given of it in his history of electricity; a work which professes to comprehend every thing that has been done by the philosophers of Europe and America for the advancement of this part of natural science, and which indeed contains a great deal of instructive information, and, at the same time, so many loose conjectures and insignificant observations, that the reader (especially if acquainted with the Doctor's character as an unwearied bookmaker) reasonably believes that he has let nothing slip that was worthy of notice. We do not pretend to account for the manner in which Dr Priestley has mentioned this work, so much, and so

deservedly

defervedly celebrated on the continent. We cannot think that he has read it fo as to comprehend it, and imagine, that feeing fo much algebraic notation in every page, and being at that time a novice in mathematical learning, he contented himfelf with a few fcattered paragraphs which were free of thofe embarraffments; and thus could only get a very imperfect notion of the fyftem. The Hon. Mr Cavendifh has done it more juftice in the 61ft volume of the Philofophical Tranfactions, and confiders his own moft excellent differtation only as an extenfion and more accurate application of Æpinus's Theory. That we have not an account of this expofition of the Franklinian theory of electricity in our language, is a material want in Britifh literature; and we truft, therefore, that our readers will be highly pleafed with having the ingenious difcoveries of the great American philofopher put into a form fo nearly approaching to a fyftem of demonftrative fcience.

We propofe, therefore, in this place, to give fuch a brief account of Æpinus's theory of electricity, as will enable the reader to reduce to a very fimple and eafily remembered law all the phenomena of electricity which have any clofe dependence on the mechanical effects of this powerful agent of nature; referring for a demonftration of what is purely mathematical to Sir Ifaac Newton's Principia, and the Differtation by Mr Cavendifh already mentioned, except in fuch important articles as we think ourfelves able to prefent in a new, and, we hope, a more familiar form. We do not mean, in this place, to give a fyftem of philofophical electricity, nor even to narrate and explain the more remarkable phenomena. Of thefe we have already given a vaft collection in the article Electricity, *Encycl.* We confine ourfelves to the phenomena which may be called *mechanical*, producing meafurable motion as their *immediate* effect; and thus giving us a principle for the mathematical examination of the caufe of electrical phenomena. We fhall confider the reader as acquainted with the other phyfical effects of electricity, and fhall frequently refer to them for proofs.

Moreover, as our intention is merely to give a fynoptical view of this elaborate and copious performance of Mr Æpinus, hoping that it will excite our countrymen to a careful perufal of fo valuable a work, we fhall omit moft of the algebraic inveftigations contained in it, and prefent the conclufions in a more familiar, and not lefs convincing, form. At the fame time we will infert the valuable additions made by Mr Cavendifh, and many important particulars not noticed by either of thofe gentlemen.

Hypothesis of Æpinus.

1 Hypothefis. The phenomena of electricity are produced by a fluid of peculiar nature, and therefore called the electric fluid, having the following properties:

2 1. Its particles repel each other, with a force decreafing as the diftances increafe.

3 2. Its particles attract the particles of fome ingredient in all other bodies, with a force decreafing, according to the fame law, with an increafe of diftance; and this attraction is mutual.

4 3. The electric fluid is difperfed in the pores of other bodies, and moves with various degrees of facility through the pores of different kinds of matter. In thofe bodies which we call *non-electrics*, fuch as water or metals, it moves without any perceivable obftruction; but in glafs, rofins, and all bodies called *electrics*, it moves with very great difficulty, or is altogether immoveable.

4. The phenomena of electricity are of two kinds; 5
1. Such as arife from the actual motion of the fluid from a body containing more into one containing lefs of it. 2. Such as do not immediately arife from this transference, but are inftances of its attraction and repulfion.

Thefe things being fuppofed, certain confequences neceffarily refult from them, which ought to be analogous to the obferved phenomena of electricity, if this hypothefis be complete, or fome farther modification of the affumed properties is neceffary, in order to make the analogy perfect. 6

Suppofe the body A (fig. 1.) to contain a certain quantity of fluid. Its particles adjoining to the furface, fuch as P, are attracted by the particles of common matter in the body, but repelled by the other particles of the fluid. The totality of the attractive forces acting on P may be equal to the totality of the repulfive forces, or may be unequal. If thefe two fums are equal, P is in equilibrio, and has no tendency to change its place. But there may be fuch a quantity of fluid in the body, that the repulfions of the fluid exceed the attractions of the common matter. In this cafe, P has a tendency to quit the body, or there is an expulfive force acting on it, and it *will* quit the body if it be moveable. Becaufe the fame muft be admitted in refpect of every other particle of moveable fluid, it is plain that there will be an efflux, till the attraction of the common matter for the particles of fluid is equal to the repulfion of the remaining fluid. On the other hand, if the primitive repulfion of the fluid acting on the particle P be lefs than the attractions of the common matter, there will be the fame, or at leaft a fimilar, fuperiority of attraction acting on the fluid refiding in the circumambient bodies; and there will be an influx from all hands, till an equilibrium be reftored. 7

(Plate XXIV.)

Hence it follows, that there may always be affigned to any body fuch a quantity of fluid that there fhall be no tendency either to efflux or influx. But if the quantity be increafed, and nothing prevent the motion, the redundant fluid will flow out; and if the proper quantity be diminifhed, there will be an influx of the furrounding fluid, if not prevented by fome external force. This may be called the body's natural quantity; becaufe the body, when left to itfelf, will always be reduced to this ftate.

(Natural quantity, why fo called.)

If two bodies, A and B, contain each its natural quantity, they will not exert any fenfible action on each other: for, becaufe the fluid contained in B is united by attraction to the common matter, and is alfo repelled by the fluid in A, it neceffarily follows, that the whole body B is repelled by the fluid in A. But, on the other hand, the matter in A attracts the fluid in B, and confequently attracts the whole body B: Similar action is exerted by B on A. Thefe contrary forces are either equal, and deftroy each other, or unequal, and one of them prevails. This equality or inequality evidently depends on the quantity of fluid contained in one or both of the bodies (n° 7.). Now it is known that bodies left entirely to themfelves neither attract nor repel; and it follows from the hypothetical properties 8 perties of the fluid, that if there be either a redundancy or deficiency of fluid, there will be an efflux or influx, till the attractions and repulſions balance each other. Therefore the internal ſtate of two bodies which neither attract nor repel each other, is that where each contains its natural quantity of electric fluid.

9 In order, therefore, to conceive diſtinctly the ſtate of a body containing its natural quantity, and to have a diſtinct notion of this natural quantity, we muſt ſuppoſe that the quantity of fluid competent to a particle of matter in A repels the fluid competent to a particle of matter in B, juſt as much as it attracts that particle of matter; and alſo, that the fluid belonging to a particle of matter in A, repels the fluid belonging to a particle of matter in B, juſt as much as the particle of matter in A attracts it. Thus the whole fluid in the one repels the whole fluid in the other as much as it attracts the whole matter.

Since this muſt be conceived of every particle of common matter in a body, we muſt admit, that when a body is in its natural ſtate, the quantity of electric fluid in it is proportional to the quantity of matter, every particle being united with an equal quantity of fluid. This, however, does not neceſſarily require that different kinds of matter, in their natural or ſaturated ſtate, ſhall contain the ſame proportion of fluid. It is ſufficient that each contains ſuch a quantity, uniformly diſtributed among its particles, that its repulſion for the fluid in another body is equal to its attraction for the common matter in it. It is, however, more probable, for reaſons to be given afterwards, that the quantity of electric fluid attached, or competent, to a particle of all kinds of matter is the ſame.

We ſhall now conſider more particularly the immediate reſults of this hypotheſis, in the moſt ſimple caſes, from which we may derive ſome elementary propoſitions.

10 Electric phenomena ariſe from redundancy or deficiency in fluid, total or partial.

Since our hypotheſis is accommodated to the fact, that bodies in their natural ſtate, having their natural quantity of electric fluid, are altogether inactive on each other, by making this natural quantity ſuch, that its mutual repulſion exactly balances its attraction for the common matter—it follows, that we muſt deduce all the electric phenomena from a redundancy or deficiency of electric fluid. This accordingly is the Franklinian doctrine. The redundant ſtate of a body is called by Dr Franklin POSITIVE OR PLUS ELECTRICITY, and the deficient ſtate is called NEGATIVE OR MINUS ELECTRICITY.

A body may contain more than its natural quantity, or leſs, in every part, or it may be redundant in one place and deficient in another. Theſe different conditions will exhibit different appearances, which muſt be conſidered firſt of all.

11 Action of the redundant fluid or matter, how computed.

Let the body A (fig. 1.) be ſuppoſed in its natural ſtate throughout, which we ſhall generally expreſs by ſaying that it is SATURATED; and let us expreſs the quantity of fluid required for its ſaturation by the ſymbol Q. Let P be a ſuperficial particle of the fluid. It is attracted by the common matter of the body (which we ſhall in future call ſimply the *matter)*, and it is repelled equally by the fluid. Let us call the attraction a, and the repulſion r. Then the force with which the ſuperficial particle is attracted by the body, muſt be $= a - r$, and $a - r$ muſt be $= 0$, becauſe $a = r$. Let the quantity f of fluid be added to the body, and uniformly diſtributed through its ſubſtance. Then, becauſe we muſt admit that the action is in proportion to the quantity of acting fluid, and this is now $Q + f$, we have $Q : Q + f = r : \frac{\overline{Q+f} \times r}{Q}$; and therefore P is repelled by the whole fluid with the force $\frac{\overline{Q+f} \times r}{Q}$ or $\frac{Q r}{Q} + \frac{f r}{Q}$, or $r + \frac{f r}{Q}$. But it is attracted by the common matter in the ſame manner as before, that is, with a force $= a$. Therefore the whole action on P is $= a - r - \frac{f r}{Q}$. But $a - r = 0$. Therefore the whole action on P is $= -\frac{f r}{Q}$; that is, P is repelled with the force $\frac{f r}{Q}$.

This will perhaps be as diſtinctly conceived by recollecting, that as much of the fluid as was neceſſary for ſaturation, that is, the quantity Q, puts the particle P in equilibrio; and therefore we need only conſider the action of the redundant fluid f. To find the repulſive force of this, ſay $Q : f = r : \frac{f r}{Q}$, and prefix the ſign $-$; becauſe we are to conſider attractions as poſitive, and repulſions as negative, quantities.

12 States of a body cauſing efflux or influx.

Unleſs, therefore, the particle P be withheld by ſome other force, it will quit the body, being expelled by a force $\frac{f r}{Q}$. And as every ſuperficial particle is in a ſimilar ſituation, we ſee that there will be an efflux from an overcharged body, till all the redundant fluid has quitted it. This efflux will indeed gradually diminiſh as the expelling force $\frac{f r}{Q}$ diminiſhes; that is, as f diminiſhes, but will never ceaſe till f be reduced to nothing. But if there be either an external force acting on the ſuperficial fluid in the oppoſite direction, or ſome internal obſtruction to its motion, the efflux will ſtop when the remaining expelling force is juſt in equilibrio with this external force, or this obſtruction.

13 On the other hand, if the body contains leſs than its natural quantity of fluid, there will be an influx from without; for if there be a deficiency of fluid $= f$, the particle P will be repelled with the force $\frac{\overline{Q-f} \times r}{Q}$, $= r - \frac{f r}{Q}$. It is attracted with the force a; and therefore the whole action is $= a - r + \frac{f r}{Q}$, $= +\frac{f r}{Q}$ (becauſe $a - r = 0$); that is, P is attracted with the force $\frac{f r}{Q}$. Fluid will therefore enter from all quarters, as long as there is any deficiency of the quantity neceſſary for ſaturation, unleſs it be oppoſed by ſome external force, or hindered by ſome internal obſtruction.

When there is a deficiency of fluid, there is a redundancy of matter, ſuch that its attractiou for external fluid

fluid is equal to the repulſion of a quantity f of fluid. This confirms the aſſumption in nº 10, that *the action of a body on the electric fluid depends entirely on the redundant fluid, or the redundant matter of the body.*

14 How bodies are ideo electrics or non-electrics. The efflux or influx may be prevented, either by ſurrounding the body with ſubſtances, through the pores of which the fluid cannot move at all, or by the body itſelf being of this conſtitution. And thus we ſee, that the very circumſtance of being impervious to the fluid, or completely permeable, renders the body capable or incapable of permanently exhibiting electrical phenomena, if ſurrounded by permeable bodies. This circumſtance alone, therefore, is ſufficient to conſtitute the difference between *electrics per ſe*, and *non-electrics.*—Here, then, is a numerous claſs of phenomena, which receive an explanation by this hypothetical conſtitution of the electric fluid. All electrics *per ſe* are bodies fit for confining electricity in bodies which are rendered capable (by whatever means) of producing electrical phenomena; and no conductor, or ſubſtance which allows the electricity to paſs through it, can be made electric by any of the means which produce that effect in *inſulators*. And it is well known, that the electricity of electrics is vaſtly more durable that that of non-electrics in ſimilar ſituations. It is true, indeed, that an electric, which has been excited ſo as to exhibit electric phenomena with great vivacity, loſes this power very quickly if plunged into water, or any other conducting body. But this is owing to the redundancy or deficiency being quite ſuperficial, ſo that the parts which are diſpoſed to give out or to take in the fluid are in immediate contact with the conducting matter. That the redundancy or deficiency is ſuperficial, follows from this hypotheſis; for when the ſurface is overcharged by the means employed for exciting, the impermeability of the electric *per ſe* prevents this redundant fluid from penetrating to any depth; and when the ſurface has been rendered deficient in fluid, the ſame impermeability prevents the fluid from expanding from the interior parts, ſo as to contribute to the repleniſhing the ſuperficial ſtratum with fluid. If, indeed, we could fall on any way of overcharging the interior parts of a glaſs ball, or of abſtracting the natural quantity from them, it is highly probable, that it would continue to attract or repel even after it had been plunged in water. Although the ſurrounding water would inſtantly take off the fluid redundant contained in the very ſurface, the repulſion of the fluid in the internal parts would ſtill be ſenſible: nay, if a very ſmall permeability be ſuppoſed, the body would again become overcharged at the ſurface; juſt as we ſee, that when we plunge a red-hot ball of iron into water, and take it out again immediately, it is black on the ſurface, and may be touched with the finger; but in half a minute after, it again becomes red-hot. Perhaps this may be accompliſhed with a globe of ſealing wax, which is permeable while liquid, by electrifying it in a particular way while in that ſtate, and allowing it to freeze. But the reader is not far enough advanced in the hypotheſis to underſtand the proceſs which muſt be followed. He cannot but recollect, however, many examples in coated glaſs, &c. where the electricity is moſt pertinaciouſly retained by a ſurface in very cloſe contact with conductors.

15 Conſequences of unequable diſtribution of fluid. 1. Action on external fluid. Let us now ſuppoſe a body NS (fig. 2.), containing in the half NA a quantity f of redundant fluid, and in the half AS let there be a deficiency g of fluid; that is, let there be a quantity of matter unſaturated, and ſuch as will attract fluid as much as the quantity g of fluid would repel it. Let the fluid neceſſary for the ſaturation of each half of NS be Q, as before. Let the attraction of the whole matter of NA for a particle of fluid at N be a; and let r be the repulſion exerted on the ſame particle N by the whole uniformly diſtributed fluid in NA and let r' be the repulſion exerted by the *ſame quantity* of fluid in the remote part SA. Then the force with which the particle N or S is attracted by the merely ſaturated body NS muſt be $= a - r - r'$. This is evidently nothing, if the body be in its natural ſtate. But as NA contains the redundant fluid f, and SA is deficient by the quantity g, the whole action muſt be $a - \frac{\overline{Q+f} \times r}{Q} - \frac{\overline{Q-g} \times r'}{Q}$. But becauſe $a - r - r' = o$, the action becomes $= \frac{gr' - fr}{Q}$, or becauſe r is greater than r', the particle N is repelled with the force $\frac{fr - gr'}{Q}$. In like manner, the particle S is attracted with the force $\frac{gr - fr'}{Q}$.

16 2. Action on the contained fluid. In the mean time, a particle C, ſituated at the middle, muſt be in equilibrio, if the body be in its natural ſtate, being equally attracted, and alſo equally repelled, on both ſides. But as we ſuppoſe that NA is overcharged with the quantity f, C muſt be repelled in the direction CS with the force $\frac{fr}{Q}$. And if we alſo ſuppoſe that AS is deficient by the quantity g, C is attracted in the direction CS with a force $\frac{gr}{Q}$. Therefore, on the whole, it is urged in the direction CS with the force $\frac{fr+gr}{Q}$, or $\frac{\overline{f+g} \times r}{Q}$.

17 It will be uniformly diffuſed, unleſs obſtructed. Hence we learn, that as long as there is any redundancy in AN, and deficiency in AS, there is a tendency of the redundant fluid to move from N toward S; and, if the body be altogether permeable by the electric fluid, we cannot have a permanent ſtate till the fluid is ſimilarly diſtributed, and equally divided, between the two halves of NS. Therefore a ſtate like that aſſumed in this example cannot be permanent in a conducting body, unleſs an external force act on it; but it may ſubſiſt in a non-conductor, and in a leſſer degree, in all imperfect conductors.

18 Nature of the obſtruction. It is neceſſary, in this place, to conſider a little the nature of that reſiſtance which muſt be aſſigned to the motion of the electric fluid through the pores of the body. If it reſemble the reſiſtance oppoſed by a perfect fluid, ariſing ſolely from the inertia of its particles, then there is no inequality of force ſo minute but that it will operate a uniform diſtribution of the fluid, or at leaſt a diſtribution which will make the exceſs of the mutual attractions and repulſions preciſely equal and oppoſite to the external force which keeps it in any ſtate of

of unequal distribution. But it may resemble the resistance to the descent of a parcel of small shot disseminated among a quantity of grain, or the resistance to motion through the pores of a plastic or ductile body, such as clay or lead. Here, in order that a particle may change its place, it must overcome the tenacity of the adjoining particles of the body. Therefore, when an unequal distribution has been produced by an external force, the removal or alteration of that force will not be followed by an equable distribution of the fluid. In every part there will remain such an inequality of distribution, that the want of equilibrium between the electric attractions or repulsions is balanced by the tenacity of the parts.

19 We learn farther from the foregoing propositions, that a particle at N is less repelled than if the part AS were overcharged as AN is: for in that case, it would be expelled by a force $\frac{f\times\overline{r+r'}}{Q}$, which is much greater than $\frac{fr-gr'}{Q}$. And, in like manner, the particle S is attracted with less force than it would be if NA were equally undercharged with SA.

20 The condition of the body now described may be changed by different methods. The redundant fluid in AN may flow into AS, where it is deficient, till the whole be uniformly distributed; or fluid may escape from AN, and fluid may enter into AS, till the body be in its natural state. The first method will be so much the slower, as the body is less permeable, or more remarkably *electric per se*; and the second method will be slower than if the whole body were overcharged or undercharged.

21 What we have been now saying of a body NS that is overcharged at one end, and undercharged at the other, and capable of retaining this state, is applicable, in every particular, to two conducting bodies, NA and SA′, having a non-conducting body Z interposed between them, as in fig. 3. All the formulas or expressions of the forces which tend to expel or to draw in fluid, are the same as before. Perhaps this is the best way of forming to ourselves a distinct notion of the body that is redundant in fluid at one end, and deficient at the other. And we perceive, that the state of the two bodies, separated by the electric Z, will be more permanent when one is overcharged, and the other undercharged, than if both are either over or undercharged.

22 A body may be inactive, or neutral, where it is redundant or deficient.

It must be remarked, that the quantities f and g were taken at random. They may be so taken, that the force with which the fluid tends to escape at N, or to enter at S, may be nothing, or may even be changed to their opposite. Thus, in order that there may be no tendency to escape from N, we have only to suppose $gr'-fr=0$, or $g:f=r:r'$, and $g=\frac{fr}{r'}$. In this case, the particle at N is as much attracted by the redundant matter in SA as it is repelled by the redundant fluid in NA.

23 Conditions necessary for this

When the extremity N is rendered inactive in this manner, the condition of the other extremity S is considerably changed. To discover this condition, put $\frac{fr}{r'}$ in place of g in the formula $\frac{gr-fr'}{Q}$, which expresses the attraction for a particle at S, and we obtain $\frac{f\times\overline{r^2-r'^2}}{Qr'}$.

On the other hand, we may have the redundancy and deficiency so balanced, that there shall be no tendency to influx at S. For this purpose, we must make $g=\frac{fr'}{r}$. When this obtains at S, the action at N will be had by putting $\frac{fr'}{r}$ in place of g in the formula $\frac{fr-gr'}{Q}$, and this will give us $\frac{f\times\overline{r'^2-r^2}}{Qr}$ for the force repelling a particle at N. 24

When the tendency to efflux or influx is induced in this manner, by a due proportion of the redundancy and deficiency of electric fluid, the part of the body where this obtains is by no means in its natural state, and may contain either more or less than its natural quantity. But it neither acts like an overcharged, nor like an undercharged body, and may therefore be called NEUTRAL. The reader who is conversant with electrical experiments, will recollect numberless instances of this, and will also recollect that they are important ones. Such, for example, is the case with the plates and covers of the electrophorus. These circumstances, therefore, claim particular attention. 25

As the quantities f and g may be so chosen, that the apparatus shall be *neutral*, either at S or at N; they may likewise be so, that either end shall exhibit either the appearance of *redundancy* or *deficiency*. Thus, instead of neutrality at N, we may have repulsion, as at the first, by making g less in any degree than $\frac{fr}{r'}$. If, on the contrary, g be greater than $\frac{fr}{r'}$, the extremity N, though overcharged, will attract fluid. In like manner, if g be less than $\frac{fr'}{r}$, the extremity S, although undercharged, will repel fluid.—We may make the following general remarks. 26

1. Both extremities N and S cannot be neutral at the same time: for since the neutrality arises from the increased quantity of redundancy or deficiency at the other extremity, so as to compensate for its greater distance, the activity of that extremity must be proportionably greater on the fluid adjoining to its surface, whether externally or internally. When an overcharged extremity is rendered neutral, the other extremity attracts fluid more strongly; and when a deficient extremity is rendered neutral, the other repels fluid more strongly. All these elementary corollaries will be fully verified afterwards, and give clear explanations of the most curious phenomena. 27 Both ends cannot be neutral at once.

2. We have been supposing, that the redundant fluid is uniformly spread, and that the body is divided into equal portions; but this was merely to simplify the procedure and the formulæ. The reader must see, that the general conclusions are not affected by this, and that similar formulæ will be obtained, whatever is the disposition of the fluid. We cannot tell in what manner the redundant fluid is disposed, even in a body of the simplest form, till we know what is the variation of its attraction and repulsion by a change of distance; and even when this has been discovered, we find it difficult

in moſt caſes, and impoſſible in many, to aſcertain the mode of diſtribution. We ſhall learn it in ſome important caſes, by means of various phenomena judiciouſly ſelected.

28 A body may be conſidered in many diviſions, in ſome of which the fluid is redundant, and in others deficient. We may expreſs the repulſion of the whole of this body in the ſame way as we expreſs that of a body conſidered in two diviſions, uſing the letters f, g, h, &c. to expreſs the quantities of redundant or deficient fluid in each portion, while Q expreſſes the quantity neceſſary for ſaturating each of them; and the repulſion at different diſtances may be expreſſed by r, r', r'', r''', &c. as they are more and more remote; and we may expreſs their action as attractive or repulſive by prefixing the ſign + or —. Thus the attraction may be $\frac{(fr - gr' + hr'' - ir''')}{Q}$, &c.

29 **Senſible actions of electrical bodies.**

Having obtained the expreſſions of the inviſible actions of electrified bodies on the fluid within them, or ſurrounding them, let us now conſider their ſenſible actions on other bodies, producing motion, or tendencies to motion.

Here it is obvious, that the mechanical phenomena exhibited are what may be called *remote effects* of the acting forces. The immediate effects, or the mutual actions of the particles are not obſerved, but hypothetically inferred. The tangible matter of the body is put in motion, in conſequence of its connection with the fluid reſiding in the body, which fluid is the only ſubject of the action of the other body.

In conſidering theſe phenomena, we ſhall content ourſelves with a more general view of the actions which take place between the fluid or tangible matter of the one body, and the fluid or matter of the other, ſo as to gain our purpoſe by more ſimple formulæ than thoſe hitherto employed. They were premiſed, however, becauſe we *muſt* have recourſe to them on many very important particular occaſions.

30 Let there be two bodies, A and B, in their natural ſtate. Let the tangible matter in A be called M, and let the fluid neceſſary for its ſaturation be called F, and let m and f be the tangible matter and the fluid in B. Let the mutual action between a ſingle particle of fluid and the matter neceſſary for its ſaturation be expreſſed by the intermediate ſymbol z, becauſe it varies by a change of diſtance.

The actions are mutual and equal. Therefore when the motion of B by the action of A is determined, the motion of A is alſo aſcertained. We ſhall therefore only conſider how A is affected. 1. Every particle of fluid in A tends toward every particle of matter in B with the force z. The whole tendency of A toward B may therefore be expreſſed by z, multiplied by the product F and m. 2. Every particle of fluid in A is repelled by every particle of fluid in B, with the ſame force z. 3. Every particle of matter in A is attracted by every particle of fluid in B, with the ſame force. We may expreſs this more purely and briefly thus:

1. F tends *toward* m with the force $+ \mathrm{F}mz$
2. F tends *from* f with the force $- \mathrm{F}fz$
3. M tends *toward* f with the force $+ \mathrm{M}fz$

Therefore the ſenſible tendency of A to or from B will be $= z \times \overline{\mathrm{F}m + \mathrm{M}f - \mathrm{F}f}$. But, by the hypotheſis, the attraction of a particle of the fluid in A for a particle of the matter in B, is equal to its repulſion for the particle or parcel of the fluid attached or competent to that particle of matter. Therefore the attraction $\mathrm{F}mz$ is balanced by the repulſion $\mathrm{F}fz$. Therefore there remains the attraction of the matter in A for the fluid in B unbalanced, and the body A will tend toward the body B with the force $\mathrm{M}fz$, or B attracts A with the force $\mathrm{M}fz$. A muſt therefore move toward B. And, by the 3d law of motion, B muſt move toward A with equal force.

31 **Completion of the hypotheſis of Æpinus.**

But the fact is, that no tendency of any kind is obſerved between bodies in their natural ſtate. The hypotheſis, therefore, is not complete. If we abide by it, as far as it is already expreſſed, we muſt farther ſuppoſe, that there is ſome repulſive force exerted between the bodies to balance the attraction of M for f. Mr Æpinus, therefore, ſuppoſes, that every particle of tangible matter repels another particle as much as it attracts the fluid neceſſary for its ſaturation. The whole action of B on A will now be $= z \times \overline{\mathrm{F}m - \mathrm{F}f - \mathrm{M}m + \mathrm{M}f}$. $\mathrm{F}mz$ is balanced by $\mathrm{F}fz$, and $\mathrm{M}mz$ by $\mathrm{M}fz$, and no exceſs remains on either ſide.

32 **Objections anſwered.**

Æpinus acknowledges, that this circumſtance appeared to himſelf to be hardly admiſſible; it ſeeming inconceivable, that a particle in A ſhall repel a particle in B, or tend from it, electrically, while it attracts it, or tends toward it, by planetary gravitation. We cannot conceive this; but more attentive conſideration ſhewed him, that there is nothing in it contrary to the obſerved analogy of natural operations. We muſt acknowledge, that we ſee innumerable inſtances of inherent forces of attraction and repulſion; and nothing hinders us from referring this lately diſcovered power to the claſs of primitive and fundamental powers of nature. Nor is there any difficulty in reconciling this repulſion with univerſal gravitation; for while bodies are in their natural ſtate, the electric attractions and repulſions preciſely balance each other, and there is nothing to diſturb the phenomena of planetary gravitation; and when bodies are not in their natural electrical ſtate, it is a fact that their gravitation is diſturbed. Although we cannot conceive a body to have a tendency to another body, and at the ſame time a tendency from it, when we derive our notion of theſe tendencies entirely from our own conſciouſneſs of effort, endeavour, *conatus*, *niſus accedendi ſeu recedendi*, nothing is more certain than that bodies exhibit at once the appearances which we endeavour to expreſs by theſe words. We can bring the north poles of two magnets near each other, in which caſe they recede from each other; and if this be prevented by ſome obſtacle, they preſs on this obſtacle, and ſeem to endeavour to ſeparate. If, while they are in this ſtate, we electriſy one of them, we find that they will now approach each other; and we have a diſtinct proof that both tendencies are in actual exertion by varying their diſtances, ſo that one or other force may prevail; or by placing a third body, which ſhall be affected by the one but not by the other, &c. We do not underſtand, nor can conceive in the leaſt, how either force, or how gravity, reſides in a body; but the effects are paſt contradiction. It muſt be granted, therefore, that this additional circumſtance of Æpinus's hypotheſis

hypotheſis has nothing in it that is repugnant to the obſerved phenomena of nature.

N. B. It is not neceſſary to ſuppoſe (although Mr Æpinus does ſuppoſe it), that every atom of tangible matter repels every other atom. It will equally explain all the phenomena, if we ſuppoſe that every particle contains an atom or ingredient having this property, and that it is this atom alone which attracts the particles of electrical fluid. The material atoms having this property, and their correſponding atoms of fluid, may be very few in compariſon with the number of atoms which compoſe the tangible matter. Their mutual ſpecific action being very great in compariſon with the attraction of gravitation (as we certainly obſerve in the action of light), all the phenomena of electricity will be produced without any ſenſible effect on the phenomena of gravitation, even although neither the electric fluid nor its ally, this ingredient of tangible matter, ſhould not gravitate. But this ſuppoſition is by no means neceſſary.

Since we call that the natural electrical ſtate of bodies in which they do not affect each other, and the hypothetical powers of the fluid are accommodated to this condition, we may conſider any body that has more than its natural quantity as conſiſting of a quantity of matter ſaturated with fluid, and a quantity of redundant fluid ſuperadded; and an undercharged body may be conſidered as conſiſting of a quantity of matter ſuperadded. The ſaturated matter of theſe two bodies will be totally inactive on another body in its natural ſtate, and will neither attract nor repel it, nor be attracted nor repelled by it; therefore the action of the overcharged body will depend entirely on the redundant fluid; and that of the undercharged body will depend entirely on the redundant matter; therefore we need only conſider them as conſiſting of this redundant fluid or matter, agreeably to what was ſaid in more vague terms in n° 10. and 13. This will free us from the complicated formulæ which would otherwiſe be neceſſary for expreſſing all the actions of the fluid and tangible matter of two bodies on each other. The reſults will be ſufficiently particular for diſtinguiſhing the ſenſible action of bodies in the chief general caſes; but in ſome particular and important caſes, it is abſolutely neceſſary to employ every term.

33 General expreſſion (ſymbolical) of the mutual action.

1. Suppoſe two bodies A and B, containing the quantities F' and f' of redundant fluid, it is plain that their mutual action is expreſſed by $F' \times f' + z$, and that it is a repulſion; for ſince every particle of redundant fluid in A repels every particle of redundant fluid in B with the force z; and ſince F' and f' are the numbers of ſuch particles in each, the whole repulſion muſt be expreſſed by the product of theſe numbers.

34 2. In like manner, two bodies A and B, containing the redundant matter M' and m', will repel each other with the force $M'\,m'\,z$.

35 3. And two bodies A and B, one of which A contains the redundant fluid F', and the other B contains the redundant matter m', will attract each other with the force $F\,m'\,z$.

36 4. It follows from theſe premiſes, that if either of the bodies be in its natural ſtate, they will neither attract nor repel each other; for, in ſuch a caſe, one of the factors F', or f', or M', or m', which is neceſſary for making a product, is wanting. This may be perceived independent of the mathematical formula; for if A contain redundant fluid, and B be in its natural ſtate, every particle of the redundant fluid in A is as much repelled by the natural fluid in B as it is attracted by the tangible matter.

37 Seeming paradox.

The three firſt propoſitions agree perfectly with the known phenomena of electricity; for bodies repel each other, whether both are poſitively or both are negatively electrified, and bodies always attract each other when the one is poſitively and the other negatively electrified. But the fourth caſe ſeems very inconſiſtent with the moſt familiar phenomena. Dr Franklin and all his followers aſſert, on the contrary, that electrified bodies, whether poſitive or negative, always attract, and are attracted, by all bodies which are in their natural ſtate of electricity. But it will be clearly ſhewn preſently, that they are miſtaken, and that Franklin's theory neceſſarily ſuppoſes the truth of the fourth propoſition, otherwiſe two bodies in their natural ſtate could not be neutral or inactive, as any one may perceive on a very ſlight examination by the Franklinian principles. It will preſently appear, with the fulleſt evidence; and, in the mean time, we proceed to explain the action of bodies which are overcharged in ſome part, and undercharged in another.

38 Action of a body having the fluid unequably diſpoſed.

Let the body B (fig. 4.) be overcharged in the part B n, and undercharged in the part B s, and let f' and m' be the redundant fluid and common matter in thoſe parts; let A be overcharged, and contain the redundant fluid F'; let z and z' expreſs the intenſity of action correſponding with the diſtances of A from the overcharged and undercharged parts of B; the part B n repels A with the force $F'\,f'\,z$, while the part B s attracts it with the force $F'\,m'\,z$: A will therefore be attracted or repelled by B, according as $F\,m'\,z'$ is greater or leſs than $F'\,f'\,z'$; that is, according as $m'\,z'$ is greater or leſs than $f'\,z$. This, again depends on the proportion of f' to m', and on the proportion of z to z'. The firſt depends on many external circumſtances, which may occaſion a greater or leſs redundancy or deficiency of electrical fluid; the ſecond depends entirely on the law of electric attraction and repulſion, or the change produced in its intenſity by a change of diſtance. As we are, at preſent, only aiming at very general notions, it is enough to recollect, that all the electric phenomena, and indeed the general analogy of nature, concur in ſhewing that the intenſity of both forces (attraction and repulſion) decreaſes by an increaſe of diſtance; and to combine this with that circumſtance of the hypotheſis which ſtates the repulſion to be equal to the attraction at the ſame diſtance; therefore both forces vary by the ſame law, and we have z always greater than z'. The viſible action of B on A (which, by the 3d law of motion, is accompanied by a ſimilar action of A on B) may be various, even with one poſition of B, and will be changed by changing this poſition.

Caſes of ſenſible repulſion.

1. We may ſuppoſe that B contains, on the whole, its natural quantity, but that part of it is abſtracted from B s, and is crowded into B n. This is a very common caſe, as we ſhall ſee preſently, and it will be expreſſed in our formula by making $f' = m'$. In this caſe, therefore, we have $F'\,f'\,z$ greater than $F'\,m'\,z$, becauſe

because z is greater than z'. A will therefore be repelled by B, and will repel it; and the repulsion will be $F' f' \times \overline{z - z'}$.

Of attraction. It is evident, that if A be placed on the other side of B, the appearances will be reversed, and the bodies will attract each other with the force $F' f' \times \overline{z - z'}$.

It is also plain, that if A be as much undercharged as we have supposed it overcharged, all the appearances will be reversed; if on the undercharged side of B, it will be repelled; and if on the overcharged side of B, it will be attracted.

39 Of Neutrality. 2. If the redundancy and deficiency in the two portions of B be inversely proportional to the forces, so that $F' : m' = z' : z$, we shall have $f' z = m' z'$, and $m' = \frac{f' z}{z'}$. In this case these two actions balance each other, and A is neither attracted nor repelled when at this precise distance from the overcharged side of B. B may be said to be NEUTRAL with respect to A, although A and the adjoining side of B are both overcharged.

40 Bodies neutral at one end are more active at the other. But if A be placed at the same distance on the other side of B, the effect will be very different: For because $m' = \frac{f' z}{z'}$, and $m' z'$ is now changed into $m' z$, and $f' z$ into $f z'$, we have the action on $A = F' \times \left(\frac{f' z}{z'} - f' z'\right), = F' f' \times \frac{z^2 - z'^2}{z'}$; that is, A is strongly attracted.

In like manner, f' and m' may be so proportioned, that when A, containing redundant fluid, is placed near the undercharged end of *s* B, it shall neither be attracted nor repelled, B becoming neutral with regard to A at that precise distance. For this purpose m' must be $= \frac{f z'}{z}$. And if A be now placed at the same distance on the other side of B, it will be repelled with the force $F' f' \times \frac{z^2 - z'^2}{z}$.

Thus, when the overcharged end is rendered neutral to an overcharged body, the other end strongly attracts it; and when the undercharged end is rendered neutral to the same body, the overcharged end strongly repels it.

Similiar appearances are exhibited when A is undercharged.

These cases are of frequent occurrence, and are important, as will appear afterwards.

41 It is easy now to see what changes will be made on the action of B on A, by changing the proportion of f' and m'. If m' be made greater than $\frac{f' z}{z'}$, A will be attracted in the situation where it was formerly neutral; and if m' be made less, A will be repelled, &c. &c.

Therefore, when we observe B to be neutral, or attractive, or repulsive, we must conclude that m' is equal to $\frac{f z}{z'}$, or greater or less than it, &c.

We have been thus minute, that the reader may perceive the agreement between this action on a body containing redundant fluid, and the action on the superficial fluid formerly considered in n° 21, 22, 23, 24. When these things are attended to, we shall explain, with great ease, all the curious phenomena of the electrophorus.

42 Neutrality generally limited to a precise distance. Important information obtained from this. There is another circumstance to be attended to here, which will also explain some electrical appearances that seem very puzzling. We limited the inactivity of B to a certain precise distance of the body A. This inactivity required that m' should be $= \frac{f z}{z'}$. If A be brought nearer, both z and z' are increased. If they are both increased in the same proportion, the value of $\frac{z}{z'}$ will be the same as before, and the body A will neither be attracted nor repelled at this new distance. But if z increase faster than z', we shall have $f' z$ greater than $m' z'$, and A will be repelled; and if z increases more slowly than z', A will be attracted by bringing it nearer. The contrary effects will be observed if A be removed farther from the overcharged end of B. This explains many curious phenomena; and those phenomena become instructive, because they enable us to discover the law of electric action, by shewing us the manner in which it diminishes by a change of distance. Electricians cannot but recollect many instances, in which the motion of the electrometer appeared very capricious. The general fact is, that when an overcharged pith ball is so situated near the overcharged side of the electrophorus as to be neutral, it is repelled when brought nearer, but attracted when removed to a greater distance. This shews that z increases faster than z' when A is brought nearer to B. Now, since the bodies may be again rendered neutral at a greater distance than before, and the same appearances are still observed, it follows, that the law of action is such, that *every* diminution of distance causes z to increase faster than z'. We shall find this to be valuable information.

43 Action when the fluid is unequably disposed in both bodies. Let us, in the last place, inquire into the sensible effect on A when it also is partly overcharged and partly undercharged. This is a much more complicated case, and is susceptible of great variety of external appearances, according to the degrees of redundancy and deficiency, and according to the kind of electricity (positive or negative) of the ends which front each other.

44 First, then, let the overcharged end of A (fig. 5.) front the undercharged end of B, they being overcharged in N and *n*, but undercharged in S and *s*. Let F and f be the quantity of fluid natural to each; and let F' and f' be the redundancy in N and *n*, and M' and m' the deficiency in S and *s*. Moreover, let Z and Z′ represent the intensity of actions of a particle in N on a particle in *n* and *s*; and let z and z' represent the actions of a particle in S on a particle in *n* and in *s*; or, in other words, let Z, Z', z, z', represent the intensity of action between particle and particle, corresponding to the distances N *s*, N *n*, S *s*, S *n*.

Proceeding in the same manner as in the former examples, we easily see, that the action of B on A is $= \frac{F' m' Z - F' f' Z' - M' m' z + M' f' z'}{F f}$; the attractions are considered as positive quantities, having the sign + prefixed to them, and the repulsions are negative, having the sign —.

This action will be either attractive or repulsive, according as the sum of the first and last terms of the numerator exceeds or falls short of the sum of the second and third: And the value of each term will be greater

or

or lefs, according to the quantity of redundant fluid and matter, and alfo according to the intenfity of the electric action. It would require feveral pages to ftate all thofe poffible varieties. We fhall therefore content ourfelves at prefent with ftating the fimpleft cafe; becaufe a clear conception of this will enable the reader to form a pretty diftinct notion of the other poffible cafes; and alfo, becaufe this cafe is very frequent, and is the moft ufeful for the explanation of phenomena.

We fhall fuppofe, that the redundant part of each body is juft as much overcharged as the deficient part is undercharged; fo that $F' = M'$, and $f' = m'$. In this cafe, the formula becomes $\frac{F'f'(Z - Z' - z + z')}{F f}$.

Ufeful reprefentation of the mutual forces by ordinates to a curve.

Here we fee that the fenfible or external effect on A depends entirely on the law of electric action, or the variation of its intenfity by a change of diftance. If the fum of Z and z' exceed the fum of Z' and z, A will be attracted; but if $Z + z'$ be lefs than $Z' + z$, A will be repelled. This circumftance fuggefts to us a very perfpicuous method of expreffing thefe actions between particle and particle, fo that the imagination fhall have a ready conception of the circumftance which determines the external complicated effect of this internal action. This will be obtained by meafuring off from a fixed point of a ftraight line portions refpectively equal to the diftances N *s*, N *n*, S *s*, and S *n*, between the points of the two bodies A and B, where we fuppofe the forces of the redundant fluid and redundant matter to be concentrated, and erect ordinates having the proportion of thofe forces. If the law of action be known, even though very imperfectly, we fhall fee, with one glance, of which kind the movements or tendencies of the bodies will be. Thus, in fig. 5. drawing the line C *z*, take C *p* = N *s*, C *q* = N *n*, C *r* = S *s*, and C *t* = S *n*, and erect the ordinates P *p*, Q *q*, R *r*, and T *t*. If the electric action be like all the other attractions and repulfions which we are familiarly acquainted with, decreafing with an increafe of diftance, and decreafing more flowly as the diftances are greater, thefe ordinates will be bounded by a curve PQRTZ, which has its convexity turned toward the axis. We fhall prefently get full proof that this is the cafe here; but we premife this general view of the fubject, that we may avoid the more tedious, but more philofophical, procefs of deducing the nature of the curve from the phenomena now under confideration.

45 General character of the fcale of electric force.

This conftruction evidently makes the pair of ordinates P *p*, Q *q*, equidiftant with the pair R *r*, T *t*. Alfo, P *p*, R *r*, and Q *q*, T *t*, are equidiftant pairs. It is no lefs clear, that the fum of P *p* and T *t*, exceeds the fum of Q *q* and R *r*. For if C *z* be bifected in V, and V *v* be drawn perpendicular to it, cutting the ftraight lines PT and QR in *x* and *y*, then *x v* is the half fum of P *p* and T *t*, and *y v* is the half fum of Q *q* and R *r*. Moreover, if Q *m* and T *n* are drawn parallel to the bafe, we fee that P *m* exceeds R *r*; and, in general, that if any pair of equidiftant ordinates are brought nearer to C, their difference increafes, and *vice verfa*. Alfo, if two pairs of equidiftant ordinates be brought nearer to C, each pair by the fame quantity, the difference of the neareft pair will increafe more than the difference of the more remote pair. And this will hold true, although the firft of the remote pair fhould ftand between the two ordinates of the firft pair. If the reader will take the trouble of confidering thefe fimple confequences with a little attention, he will have a notion of all the effects that are to be expected in the mutual actions of the two bodies, fufficiently precife for our prefent purpofe. We fhall give a much more accurate account of thefe mathematical truths in treating the article MAGNETISM, where precifion is abfolutely neceffary, and where it will be attended with the greateft fuccefs in the explanation of phenomena.

Now let us apply this to our prefent purpofe. *Firft*, then, When the overcharged end of A is turned toward the undercharged end of B, A muft be attracted; for P *p* + T *t* is greater than Q *q* + R *r*. 46

Secondly, This attraction muft increafe by bringing the bodies nearer; for this will increafe the difference between P *m* and R *n*. 47

Thirdly, The attraction will increafe by increafing the length either of A or of B (the diftance N *s* remaining the fame); for by increafing the length of A, which is reprefented by *p r* or *q t*, R *r* is more diminifhed than T *t* is. In like manner, by increafing B, whofe length is reprefented by *p q* or *r t*, we diminifh Q *q* more than T *t*. 48

49 Ufe of this picture of the forces.

On the other hand, if the overcharged end of B front the overcharged end of A, their mutual action will be

$$\frac{F'f'(-Pp + Qq + Rr - Tt),}{Ff}$$

and A will be repelled, and the repulfion will increafe or diminifh, by change of diftance or magnitude, precifely in the fame manner that the attractions did. It is hardly neceffary to obferve, that all thefe confequences will refult equally from bringing an apparatus fimilar to that reprefented in fig. 3. near to another of the fame kind; and that they will be various according to the pofition and the redundancy or deficiency of the two parts of each apparatus.

50 Curious phenomena which fhould refult from the hypothefis refembling magnetifm.

If the body B of fig. 5, is not at liberty to approach toward A, nor to recede from it, and can only turn round its centre B, it will arrange itfelf in a certain determinate pofition with refpect to that of A. For example, if the centre B (fig. 7.) be placed in the line paffing through S and N of the body A, B will arrange itfelf in the fame ftraight line: for if we forcibly give it another pofition, fuch as *s* B *n*, N will attract *s* and repel *n*, and thefe actions will concur in putting B into the pofition *s'* B *n'*. S, however, will repel *s* and attract *n*; and thefe forces tend to give the contrary pofition. But S being more remote than N, the former forces will prevail, and B will take the pofition *s'* B *n'*.

If the centre B be placed fomewhere on the line AD, drawn through a certain point of the body NAS (which will be determined afterwards), at right angles to NAS, the body B will affume the pofition *n'* B *s'*, parallel to NAS, but fubcontrary. For if we forcibly give it any other pofition *n* B *s*, it is plain that N repels *n* and attracts *s*, while S attracts *n* and repels *s*. Thefe four forces evidently combine to turn the body round its centre, and cannot balance each other till B affume the pofition *n'* B *s'*, where *n'* is next to S, and *s'* is next to N.

Form of the electric meridian.

If the centre of B have any other fituation, fuch as B', the body will arrange itfelf in fome fuch pofition as *n'* B' *s'*. It may be demonftrated, that if B be infinitely fmall, fo that the action of the end of A on each of of its extremities may be confidered as equal, B will arrange itfelf in the tangent BT of a curve NB'S, fuch that if we draw NB', SB, and from any point T of the tangent draw TE parallel to BN, and TF parallel to B'S, we fhall have BE to BF, as the force of S to the force of N. This arrangement of B will be ftill more remarkable and diftinct if N be an overcharged fphere, and S an undercharged one, and both be infulated. We muft leave it to the reader's reflection to fee the changes which will arife from the inequality of the redundancy and deficiency in A or B, or both, and proceed to confider the confequences of the mobility of the electric fluid. Thefe will remove all the difficulty and paradox that appears in fome of the foregoing propofitions.

51 Confequence (fundamental) of the mobility of the fluid in the pores of bodies.

Let the body A (fig. 4.) contain redundant fluid, and let B be in its natural ftate, but let the fluid in A be fixed, and that in B perfectly moveable; it is evident that the redundant fluid in A will repel the moveable fluid in B, toward its remote extremity *n*, and leave it undercharged in *s*. The fluid will be rarefied in *s*, and conftipated in *n*. We need only confider the mutual actions of the redundant fluid and redundant matter. It is plain that things are now in the fituation defcribed in n° 15.: A muft be attracted by B, becaufe $f' = m'$, and z is greater than z'. The attractive force is $F'f' \times (z - z')$.

Bodies containing the natural quantity, in the natural ftate, attract and are attracted by electrified bodies,

Thus we fee that the hypothefis is accommodated to the phenomena in the cafe in which it appeared to differ fo widely from it. Had the fluid been immoveable, the mutual actions would have fo balanced each other that no external effects would have appeared. But now the greater vicinity of the redundant matter prevails, A is attracted by B, and, the actions being all mutual, B is attracted by A, and approaches it.

52 And change the ftate of thofe bodies, which increafes attraction.

We have fuppofed that the fluid in A is immoveable; but this was for the fake of greater fimplicity. Suppofe it moveable. Then, as foon as the uniform diftribution of the fluid in B is changed, and B becomes undercharged at *s*, and overcharged at *n*, there are forces acting on the fluid in A, and tending to change its ftate of diftribution. The redundant matter in S attracts the redundant fluid in A more than the more remote redundant fluid in *n* repels it, becaufe z' is lefs than z. This tends to conftipate the redundant fluid of A in the nearer parts, and render N more redundant, and S lefs redundant in fluid than before. It is plain, that this muft increafe their mutual action, without changing its nature. It can be ftrictly demonftrated, that however fmall the redundancy in A may be, it can never be rendered deficient in its remote extremity by the action of the unequally difpofed fluid in B, if the fluid in B be no more nor lefs than its natural quantity. It is alfo plain, that this change in the difpofition of the fluid in A muft increafe the fimilar change in B. It will be ftill more rarefied in *s*, and condenfed in *n*; and this will go on in both till all is in equilibrio. When things are in this ftate, a particle of fluid in B is in equilibrio by the combined action of feveral forces. The particle B is propelled toward *n* by the action of the redundant fluid in A. But it is urged toward S by the repulfion of the redundant fluid on the fide of *n*, and alfo by the attraction of the redundant matter on the fide of *s*; and the repulfion of the redundant fluid in A muft be conceived as balancing the united action of thofe two forces refiding in B.

53 General notion of the forced difpofition of electric fluid in a body.

Hence we may conclude, that the denfity of the fluid in B will increafe gradually from *s* to *n*. It will be extremely difficult to obtain any more precife idea of its denfity in the different parts of B, even although we knew the law of action between fingle particles.

This muft depend very much on the form and dimenfions of B; for any individual particle fuftains the fenfible action of all the redundant fluid and redundant matter in it, fince we fuppofe it affected by the more remote fluid in A. All that we can fay of it in general is, that the denfity in the vicinity of *s* is lefs than the natural denfity; but in the vicinity of *n* it is greater; and therefore there muft be fome point between *s* and *n* where the fluid will have its natural denfity. This point may be called a NEUTRAL point. We do not mean by this that a particle of fuperficial fluid will neither be attracted nor repelled in this place. This will not always be the cafe (although it will never be *greatly* otherwife); nor will the variation of the denfity in the different parts of B be proportional to the force of A on thofe parts. Some eminent naturalifts have been of this opinion; and, having made experiments in which it appeared to be otherwife, they have rejected the whole theory. But a little reflection will convince the mathematician, that the fum of the internal forces which tend to urge a particle of fluid from its place, and which are balanced by the action of A, are *not* proportional to the variations of denfity, although they increafe and decreafe together. We fhall take the proper opportunity of explaining thofe experiments; and will alfo confider fome fimple, but important cafes, where we think the law of diftribution of the fluid afcertained with tolerable precifion.

Neutral point.

If we fuppofe, on the other hand, that A is undercharged, the redundant matter in A will attract the moveable fluid in B, and will abftract it from the remote extremity, and crowd it into the adjacent extremity. Moreover, the fluid now becoming redundant in the nearer extremity of B, will act more ftrongly on the moveable fluid in A than the more remote redundant matter of B; and thus fluid will be propelled toward the remote fide of A, which will become now undercharged in its nearer fide, and lefs undercharged in its remote fide than if B were taken away. This muft increafe the inequability of diftribution of the fluid in B, and both will be put farther from their natural ftate; but A will never become overcharged in its remote extremity.

Things being in this ftate, it is plain that A and B will mutually attract each other in the fame manner, and with the fame force, as when A was as much overcharged as it is now undercharged.

54 Electric atmofphere is not adequate to the explanation of the phenomena.

Thus, then, we fee how the attraction obtains, whether A be over or undercharged. A fact which Dr Franklin could never explain to his own fatisfaction; nor will it ever be explained confiftently with the acknowledged principles and obferved laws of mechanics by any perfon who employs electric atmofpheres for this purpofe. It is indeed a fufficient objection to the employment of fuch electric or other atmofpheres, that the fame extent of attraction and repulfion between the particles of the atmofphere is neceffary, as is employed here between the particles of the fluid refiding in the body; and therefore they ceafe to give any explanation, even

even although their supposed actions were legitimately deduced from their constitution. This is by no means the case. Let any person examine seriously the *modus operandi* of the electric atmospheres employed by Lord Mahon (the only person who has written mathematically on the subject), and he will see, that the whole is nothing but figurative language, without any distinct perception of what is meant by these atmospheres, as distinct from the fluid moveable in the conducting bodies, or any perception how the unequal density of these atmospheres protrudes the fluid along the conductor. Besides, it is well known that a conducting wire becomes positive at one end, and negative at the other, by the mere vicinity of an overcharged or undercharged body, and this in an instant, although it be surrounded with sealing-wax, or other nonconductors, to any thickness: in this case there can be no atmospheres to operate on the included fluid. To this we may add Dr Franklin's judicious experiment of whirling an electrified ball many times round his head, with great rapidity, by means of a silk line, without any sensible diminution of its electricity. It is not conceivable that an electric atmosphere could remain attached to the ball; nor could it be instantaneously formed round the ball; in every point of its motion, so as to be operative the moment he stopped it and tried it; for this would have exhausted or greatly diminished the electricity of the ball; whereas that sagacious philosopher affirms (and any person will find it true), that when the air is dry, he did not observe the electricity more diminished than that of another ball which remained all the while in the same place.

55 Induced electricity.

Let the overcharged body A (fig. 6.) be brought near the ends of two oblong conductors B and C in their natural state, and lying parallel to each other; the fluid will be propelled toward their remote ends N, *n*, where it will be condensed, while it will be rarefied in the ends S and *s*, adjacent to A. Both will be attracted by A, and will attract it. But the redundant fluid in NB will repel the redundant fluid in *n* C; and the redundant matter in SB will repel the redundant matter in *s* C. For this reason the bodies B and C will repel each other, and will separate; but SB attracts *n* C, and NB attracts *s* C; and on this account the bodies should approach: but the distances of the attracting parts being greater than those of the repelling parts, the repulsions must prevail, and the bodies must really separate.

It is equally clear that the very same *sensible* appearance will result from bringing an undercharged body near the ends of B and C, although the internal motions are just the opposite to the former.

If another body D, electrified in the same way with A, be brought near the opposite ends of B and C, it will prevent or diminish the internal motions, and it should therefore prevent or diminish the external effects.

If another conducting body be brought near to the end *s* of C that fronts A, it will be affected as C is, and the end *f* will repel *s*; but if it be brought near the remote end, as is the case with the body F, it will attract this remote end. As the body A, containing more or less than its natural share of electric fluid, affects every other body, while they do not (when out of its neighbourhood) affect each other, it is usually said to be the electrified body, and the others are said to be electrified by it; and since these bodies, when perfect conductors, cannot retain their power of exhibiting electrical appearances (see n° 17.), it will be convenient to distinguish this last electrical state by a particular name. We shall call it ELECTRICITY BY POSITION, OT INDUCED ELECTRICITY. It is induced by position with regard to the permanently electrical body.

56 Consequences of obstructions.

We have supposed, in these last propositions, that the fluid was perfectly moveable in B, and, at last also, in A: but let us examine the consequences of some obstruction to this motion. Without entering into a minute enquiry on this head, we may state the obstruction as uniform, and such that a certain small force is necessary for causing a particle of fluid to get through between two particles of the common matter, just as we conceive to happen in tenacious bodies of uniform texture (see n° 18.).

It is evident, that when an overcharged body A (fig. 4. or 5.) is brought near such an imperfect conductor B, the fluid cannot be so copiously propelled to the remote extremity *n*. We may conceive the state of distribution by taking a constant quantity from the intensities of the force of A at every point of B. This circumstance alone shews us, that there will not be so unequable a distribution of the fluid, and therefore *there will not be such a strong attraction between imperfect as between perfect conductors.* But besides this, we see that an incomparably longer time must elapse before things come to a state of equilibrium. Each particle of fluid employs time to evercome the obstacle to its motion, and it cannot advance till after the succeeding ones, each escaping in its turn, have again come up with the foremost. An important consequence results from this. The neutral point, where the fluid is of the natural density, will not be so far from the other body as it would have been without these obstructions; and this point will be a considerable while of advancing along the imperfect conductor. At the first approach of the overcharged electric, the near extremity of the imperfect conductor becomes a little undercharged, and the neutral point advances from the very extremity a small way, the displaced fluid being crowded a little before it, and giving way by degrees as its foremost particles get past the obstructions. The motion forward takes place over a considerable extent at the very first; namely, in that part of the conductor where the propelling power of the neighbouring electric is just able to push a particle over the obstruction. As the propulsion goes on, the neutral point must gradually advance, and at last reach a certain distance, determined by the degree of the obstruction. It is plain, that the final accumulation at the remote end of the imperfect conductor will be less than in a perfect conductor, and the neutral point will be nearer to the other end.

57 Irregular distribution.

There is another remarkable consequence of the obstruction. It must always happen that, at the beginning of the action, the greatest constipation will not be towards the remote extremity, but in a place much nearer to the disturbing cause. Beyond this, the constipation will diminish. As time elapses during this operation, this constipated fluid acts on the fluid beyond it by repulsion, and may do this with sufficient force to displace some of it, and render a part of the imperfect conductor deficient, with a small constipation beyond it.

it. This may, in like manner, produce a rarefaction farther on, followed by another condenfation; and this may be frequently repeated when the obftruction is very great, and the repulfion of the overcharged body very great alfo. This can be ftrictly demonftrated in fome very fimple cafes, but the demonftration is very tedious: As the refult, however, is of the firft importance in the theory of electricity, and ferves to explain fome of the moft abftrufe phenomena, we wifh the reader to have fome ftronger ground of confidence than the above bare affertion. He may obferve fimilar effects of caufes precifely fimilar. If we dip the end of a flat ruler into water, and if, after allowing the water to become perfectly ftill, we move the ruler gently along in a direction perpendicular to the face, we fhall obferve a fingle wave heap up before the ruler, and keep before it, all the reft of the water before it remaining ftill: but if we do the fame thing in a veffel of clammy fluid, efpecially if the clammy part is fwimming on the furface of a more perfect fluid, like a cream, we fhall obferve a feries of fuch waves to curl up before the ruler, and form before it in fucceffion; and if we have previoufly fpotted the furface of the cream, we fhall fee that it is not the fame individual waves that are pufhed before the ruler, but that they are fucceffively formed out of different parts of the furface, and that the particles which, at one time, form the fummit of a wave, are, immediately after, at the bottom, &c. In like manner, when a cannon is fired in clear air, at no great diftance, we hear a fingle fnap; but, in a thick fog, we hear the fnap both preceded and followed by a quivering noife, refembling the rufhing of a fluttering wind, which lafts perhaps half a fecond. A flight reflection on thefe facts will fhew that they are neceffary refults of the mechanical laws of fuch obftruction.

Several neutral points.

The confequence of this mode of action muft be, that an imperfect conductor may have more than one neutral point, and more than one overcharged and undercharged portion, fo that its action on diftant bodies may be extremely various. The formula of n° 28. was accomodated to this cafe, and will be found to have very curious refults. Another body may be placed in the direction of the axis, and will be attracted at one diftance, repelled when this diftance is increafed, and again attracted when at a ftill greater diftance, &c. &c.

Suppofe the obftruction not to be confiderable: The immediate operation of the neighbouring overcharged body will be the production of an undercharged part in the adjoining extremity, an overcharged part beyond this, an undercharged portion farther on, &c. In a little while thefe will fhift along the conductor; one after another will difappear at the farther end, and the body will have at laft but one neutral point. A greater obftruction will leave the body, finally, with more than one neutral point, and their ultimate number will be greater in proportion as the obftruction to the fluid's motion is fuppofed greater.

58
Induced electricity rendered permanent.

Now, let the overcharged body, the caufe of this unequal diftribution, be removed. We have feen, n° 17. that when a body contains its natural quantity of fluid, but unequally diftributed, there is a force acting on every particle, and tending to reftore the original equable diftribution; and that fuch a force remains as long as there is any inequality in this refpect. If, therefore, there be no obftruction, the uniform diftribution will take place immediately; for it is well known, that the fpeed with which electricity is propagated is immenfe. The elafticity, or the attractive and repulfive forces, muft be very great indeed when compared with any that we know, except, perhaps, the force which impels the particles of light. The electricity, therefore, of a perfect conductor, that is, its power of acting on other bodies in the fame way that an original electric acts on them, muft be quite momentary, and ceafe as foon as the inducing caufe is removed. The conductor is electrical merely in confequence of its pofition. Hence the propriety of our denominations. Nothing material is fuppofed in this theory to be communicated from the overcharged body: Nay, this theory teaches, that the fenfible electricity of the overcharged body is augmented in fome refpects; for it becomes more overcharged in the part neareft to the conductor. Indeed it becomes lefs overcharged on the other end, and will act lefs forcibly on that fide than if the conductor were away. It may be remarked here (it fhould have been mentioned in n° 55.), that when F is prefented in the manner fhewn in fig. 6. the body B becomes more ftrongly overcharged at the end remote from A, and more ftrongly undercharged at the end next to A, than when F is away. The contrary *may* happen, by prefenting a body in the manner of E. We wifh thefe particulars to be kept in mind. In the mean time, all thefe circumftances are neceffary confequences of the fuppofition, that nothing is communicated from A to B or C. The electricity induced on perfect conductors is momentary, requiring the continual prefence of a body that is electrified in fome way or other.

But the cafe is quite otherwife in imperfect conductors. When the overcharged, or otherwife electrical body A is removed, the forces which tend to reftore the uniform diftribution of the fluid immediately operate and muft reftore it in part. They cannot, however, do it completely: For when the force which urges any particle from an overcharged to an undercharged part is juft in equilibrio with the obftruction, it will remain, juft as a number of grains of fmall fhot may lie, uniformly mixed with a mafs of clammy fluid, or, as fuch fluids retain heavy mud, in a ftate of equable or inequable diffufion. If the refiftance arife merely from the inertia of the tangible matter, there is no force fo fmall but it will in time reftore the uniform diftribution. But this cannot be the cafe in folid bodies. Their particles exert lateral forces, by which they maintain themfelves in particular fituations: thefe muft be overcome by *fuperior* forces.

We fhould therefore expect, that imperfect conductors will retain part of their inequable conftitution; and, *in confequence of this*, their power of affecting other bodies like electrics; that is, their Electricity. For we muft obferve (having neglected to do it in the beginning), that the term *electricity* is as often ufed to exprefs this power of producing electrical phenomena as it is ufed for expreffing a fubftance fuppofed to be the original caufe of all thefe appearances. It is neceffary to keep this diftinction in mind; becaufe there are many phenomena which clearly indicate the transference of this caufe, and they muft not be confounded with others, where the exhibition of electric phenomena is evidently propagated to a diftance. We

muft

muſt not always ſuppoſe, that when the electric appearances are exhibited in an inſtant at the far end of a wire $4\frac{1}{2}$ miles long, the ſame numerical particles of the electric fluid have moved over this ſpace. We muſt diſtinguiſh thoſe caſes where this muſt be granted from thoſe in which it certainly has not happened. Of theſe there are innumerable inſtances.

59 Imperfect conductors are neceſſarily idio-electrics.

We have now to obſerve, that by this theory the ſingle circumſtance of perfect and imperfect conducting power is ſufficient for eſtabliſhing the whole difference between idio-electrics and non-electrics. The idio-electrics are ſuſceptible of excitation in various ways, and retain their electricity; and this may be done in any part of them without affecting the reſt in any remarkable degree. This cannot be done in perfect conductors, plainly *becauſe they are perfect conductors*. Any inequality of diſtribution of the electric fluid, which is all that is neceſſary for rendering them electric, is immediately deſtroyed by its uniform diffuſion. We can have no direct proof of their incapability of excitation; but if they can be excited, they cannot ſhew it. We doubt, however, their excitability; becauſe the appearances in the excitation of electrics ſeem to indicate, that oppoſite ſtates of two bodies are neceſſary previous to the appearance of electricity. This is impoſſible in perfect conductors. By this theory, therefore, perfect conductors are neceſſarily non-electrics; and non-conductors are neceſſarily (if excitable) idio-electrics.

With reſpect to the particular phenomena which may be expected on the removal of the original electric; it may juſt be remarked, that the electric appearances of the imperfect conductor will go off in the contrary order to that of their indication. The accumulation and deficiency will diminiſh gradually, and the neutral point or points will gradually approach the end which had fronted the original electric. The imperfect conductor will be finally left with one or more neutral points, according to the magnitude of the obſtructions, and the force which had been employed in its electrification: And their final ſtate will be ſo much the more inequable, and conſequently they will retain ſo much the greater electric powers, as they are leſs perfect conductors.

60 Electrics are only ſuperficially ſo.

The laſt obſervation which we ſhall make on this head at preſent is, that whether electrified by induction, or by friction, or moſt other modes of excitation, the electrification will be nearly ſuperficial in bodies which conduct very imperfectly; and bodies which are altogether impervious (if there be any ſuch) muſt have the accumulation or deficiency altogether at their ſurface. If a glaſs globe be ſuch a body, it will hardly be poſſible to electrify it to any depth; and all that we can expect is alternate ſtrata of overcharged and undercharged glaſs. If theſe ſtrata are once formed, they tend greatly to make the body retain its ſuperficial electricity. A ſuperficial ſtratum of redundant fluid, tending, by the mutual repulſion of its particles, to eſcape, is retained by the ſtratum of redundant matter immediately below it: And the almoſt inſuperable obſtruction prevents the fluid of the ſtratum beyond this from coming up to ſupply the vacancy. If we can fall on any contrivance to produce ſuch deficient ſtrata within the glaſs, we ſhall make it much more retentive, and capable of holding faſt a much greater quantity. We have already mentioned ſomething of this in n° 14. and we recommend the caſe to the attentive conſideration of the reader.

61 Compariſon of the theory with experiment.

Thus have we given a ſketch of the leading doctrines of this elegant theory of Mr Æpinus, all legitimately deduced from the circumſtances aſſumed in the hypotheſis concerning the *mechanical* properties of that ſubſtance which he calls *the electric fluid*. Let us now ſee with what ſucceſs this hypotheſis may be applied to account for the phenomena. It would have been more philoſophical to have arranged the phenomena, and from the compariſon to have deduced the hypotheſis. But this would have required much more room than can be afforded in a Work like ours.

We preſume, that many of our readers, namely, all ſuch as are already converſant with electrical phenomena and with electric experiments, have ſeen, as we went along, the perfect agreement of the hypotheſis with the various phenomena of attraction and repulſion, and all thoſe which are uſually claſſed under the name of electric atmoſpheres: and we are confident, that when they compare the conſequences that ſhould neceſſarily reſult from ſuch a fluid with the legitimate conſequences of the mechanical action of elaſtic atmoſpheres, they will acknowledge the great ſuperiority of this hypotheſis in point of ſimplicity, perſpicuity, and analogy with other general operations of nature. To ſuch readers it would not be neceſſary to ſtate any farther compariſon; but there are many who have not yet formed any diſtinct *ſyſtematic* view of the appearances called *electrical*. We do not know any way of giving ſuch a view of them as by means of this hypotheſis; and we may venture to ſay, that it will enable the ſtudent of Nature to claſs them all, with hardly a ſingle exception. After which, the hypotheſis may be thrown aſide by the faſtidious philoſopher; and the uſeful claſſification, and general laws of the electric phenomena, will remain ready foundations for a more perfect theory. For the ſake of ſuch readers, therefore, we ſhall take a ſhort review of thoſe general appearances which are accompanied by attractions and repulſions, and compare them with this Æpinian theory.

We ſhall not at preſent conſider the various modes of excitation, although this theory alſo affords much inſtruction on the ſubject, but confine ourſelves entirely to the facts which are moſt immediately dependent on it, and ſhould be employed to ſupport or overturn it; and we ſhall ſuppoſe the reader acquainted with moſt parts of the common apparatus; ſuch as electrometers, inſulation, &c. We alſo preſume that he knows, that when a ſmall pith-ball has been electrified by touching a piece of glaſs which has been excited by rubbing with dry flannel, it will repel another body ſo electrified; and that balls, which have received their electricity in this manner from ſealing-wax excited by the ſame rubber, alſo repel each other; but that balls, thus electrified by glaſs, attract thoſe which are electrified by ſealing-wax.

The following ſimple apparatus will ſerve for all the experiments which are neceſſary for eſtabliſhing the theory:

62 Apparatus neceſſary for this compariſon.

1. Two ſlender glaſs rods A (fig. 8.) having a braſs ball B at the end, about a quarter of an inch in diameter, ſuſpending a very ſmall and delicate pith-ball electrometer C.

2. Some

2. Some electrometers (fig. 9.), consisting of two pieces of rush pith, about four inches long, nicely suspended, and hanging parallel, and almost in contact with each other. It is proper to have them as smooth as possible, and neatly rounded at the ends, to prevent unnecessary dissipation.

3. Some pith-ball electrometers (fig. 10.), whose threads are of silk, about four inches long, and some with flaxen threads moistened with a solution of some deliquescent salt, that they may be always in a good conducting state.

4. Several brass conductors (fig. 11.), each supported on an insulating stalk and foot. They should be about an inch and half or two inches long, and about three-fourths of an inch in diameter, with round ends, and well polished, to prevent all dissipation. The foot must be so narrow as to allow them to touch each other at the ends.

5. Two balls (fig. 12.), one of glass, and the other of glass coated with sealing-wax, each furnished with an insulating handle, the other end of which may be occasionally stuck into a foot or into the side of a block of wood, which can be slid up or down on a wooden pillar, and fixed at any height. These balls should be about three inches in diameter. They must be excited by rubbing with dry warm flannel.

6. Some little pieces of gilt card (fig. 13.), about two inches long, half an inch broad, and rounded at the ends, and made as smooth as possible. Each must have a dimple struck in the middle with a polished blunt point, so that it will traverse freely like a mariner's needle, when set on a glass point, rounded in the flame of a lamp. More artificial needles may be made of some light wood, having small cork balls at the ends, all gilt and polished, and turning, in like manner, on glass stalks: also some similar needles made of sealing-wax, one end of each being black, and the other red.

The mechanical phenomena of electricity may be expressed in a few simple propositions. The most general fact that we know, and from which all the rest may be deduced, is the following:

If any body A is electrified, by any means whatever, and if another body B is brought into its neighbourhood, the last becomes electrical by position.

63 A neutral body attracted, because rendered electrical by induction.

Set the brass conductors in a row, touching each other, as represented in fig. 11. by A, B, C; and let a pith-ball electrometer, having silk threads, be set near one end of the conductors. Excite one of the globes, by rubbing it with dry flannel. When this is brought near the end of the conductor, the pith-ball will approach the other end. But the globe must not be brought so near as to cause the pith-ball to strike against the other end. On removing the globe, the pith-ball will move off and hang perpendicularly. The same effect is produced by both globes.

Thus the mere vicinity of the electric renders the conductor electric, and the electricity ceases on removing the globe. This is perfectly conformable to the theory, whether we suppose the fluid to be made redundant or deficient at the remote end of the conductor. If one should ascribe the approach of the pith-ball to the immediate action of the globe, it is sufficient to observe, that if the ball be suspended near the *side* of the conductor, it will approach the conductor, shewing that it is affected by the conductor, and not by the globe.

State of distribution ascertained experimentally.

Let the globe be held in the position D (fig. 12.), about six inches from the conductor, and a little above the line of its axis. Take the glass rod (fig. 8.), and bring its knob into contact with the under side of the remote end *c* of the conductor. The balls of the electrometer will separate, shewing that they are electrified in the same manner, and repel each other. Slide the brass knob along the under side of the conductors, quite to the end *a*. The balls will gradually collapse as the knob approaches a point near the middle of the conductors, where they will hang parallel. Passing this point, they will again separate, and most of all when the knob is at *a*. In this situation they will deviate toward the globe, and will be directed straight toward it, if it be held too near, or in the direction of the axis. This would disturb the experiment, and must be avoided. These phenomena are conformable to the account given of the disposition of the fluid in the conductor. The electrometer may be considered as making a part of the conductor; and when its threads hang parallel, it is in its natural state, having its fluid of its natural density. This, however, cannot be strictly true, according to the theory; because the balls of the electrometer must be considered as more remote from the electric, and their electrical state must correspond to a point of the conductor more remote than that where the knob of the electrometer touches it. This will be more remarkably the case as the threads are longer. Accordingly, an electrometer with very long threads will never collapse. The place of the neutral point cannot be accurately ascertained in this way.

Lord Mahon's determination of the neutral point not warranted by his explanation.

Lord Mahon imagined, that its situation B was determined (in his experiments with a long conductor) to be such, that D *c* was harmonically divided in B and *a*; and he finds this to be agreeable to the result of an electric atmosphere whose density is inversely proportional to the square of the distance. But we cannot deduce this from his narration of the experiment. He gives no reason for his selection of the point D, nor tells us the form and dimensions of the electric employed, nor takes into account the action of the fluid in the long conductor. It is evident, that no computation can be instituted, even on his Lordship's principles, till all this be done. We have always found, that the neutral point was farther from the electric, in proportion as the conductor was smaller, and when the electricity was stronger: and that the differences in this respect were so very considerable, that no dependence could be had on this experiment for determining the law of action. It should be so, both according to Lord Mahon's and Mr Æpinus's theory. But to proceed with our examination:

Having touched the end *c* of the conductor with the knob of the electrometer, bring it away. The balls will continue to repel each other, and they are attracted by any body that is in its natural state. Touch the same end with the knob of the other electrometer, and bring it also away; the balls of the two electrometers will be found to repel each other: but if one has touched the conductor at *c*, and the other has touched it at *a*, the electrometers will strongly attract each other. All this is quite conformable to the theory. If the fluid has been compressed at *c*, and therefore the balls of that electrometer are overcharged, they must repel each other, and repel any other body electrified in the same way. They must attract and be attracted by by any natural body. But the balls of the other electrometer having touched the conductor at *a*, muſt be undercharged, and the redundant fluid of the one muſt attract the redundant matter of the other.

If the conductor has been electrified by the vicinity of excited glaſs, the electrometer which touched it in the remote end *c*, will be repelled by a piece of excited glaſs, but attracted by excited ſealing-wax. The electrometer which touched the conductor in *a* will be attracted by excited glaſs, and repelled by excited ſealing-wax. The contrary will be obſerved if the conductor has had its electricity induced on it by the vicinity of the globe covered with ſealing-wax. This is a complete proof that Mr Dufuy's doctrine of *vitreous* and *reſinous* electricity is unfounded. Both kinds of electricity are produced in a conducting body, without any material communication, by mere juxta-poſition to a body poſſeſſed of either the vitreous or the reſinous electricity.

64 Conſtant diſtinctions of redundancy and deficiency.

We have not yet mentioned any reaſons which indicate which end of the conductor is electrical by the redundancy of electric fluid, nor is the reader prepared for ſeeing their force. It is generally believed, that the remote end of a conductor which is electrified by glaſs, excited by rubbing it with flannel or amalgamated leather, is electrical by redundancy. No difference has been obſerved in the attractions and repulſions. But there are other marks of diſtinction which are conſtant, and undoubtedly ariſe from a difference in the mode of action of thoſe mechanical forces. If, while the excited glaſs globe remains at D, a glaſs mirror, foiled as uſual with tin leaf, be made to touch the remote end of the conductor, and ſlowly drawn tranſverſely, ſo that the conductor draws a line as it were acroſs it—this mirror being laid down with the foiled ſide undermoſt, the duſt, which ſettles on it in the courſe of a day or two, will be chiefly collected along this line, ſomewhat in the form of the fibres of a feather. But if the conductor was rendered electrical by the globe covered with ſealing-wax, the duſt will be collected along this line in little ſpots like a row of beads. The appearances will be reverſed if the mirror has been paſſed acroſs the end of the conductor which is neareſt to the excited electric. In ſhort, in whatever way the drawing point has been electrified, if it repel a ball which has touched excited glaſs, the line will be feathered; but if it attract ſuch a ball, the line will be ſpotted. There are many ways of making this appearance much more remarkable (ſee Electricity, *Encycl.* Sect. viii. nº 48.) than this; but we have mentioned it on this occaſion, becauſe the circumſtances which occaſion the difference, whatever it is, are the moſt ſimple poſſible. Nothing is communicated; and therefore the effect muſt ariſe from the unnatural ſtate of a ſubſtance or power reſiding in the body. If it be a ſubſtance *ſui generis*, the electric action muſt ariſe from a different diſtribution of this ſubſtance; from a redundancy and deficiency of it in the different portions of the conductor. Without pretending as yet to ſay which is redundant, we ſhall ſuppoſe, with Dr Franklin, that the electricity of excited glaſs is ſo; and we ſhall uſe the words *redundant* and *poſitive* to diſtinguiſh this electricity from the other. This is merely that we may, on many occaſions, conſiderably abbreviate language.

The different electrical ſtates of the different portions of the conductor may be ſeen in another way, which is perhaps more ſimple and unexceptionable than that already narrated. While the globe remains at D, take the two extreme pieces A and C aſide; or, if only two pieces have been uſed, draw the remote piece farther away. Now remove the excited globe. When we examine A ſeparately, we ſhall find it wholly negative, or undercharged, ſtrongly repelling a ball electrified by ſealing-wax, and attracting a ball electrified by glaſs. The other piece C exhibits poſitive electricity, attracting and repelling what A repelled and attracted. If only three pieces of the conductor have been employed, the middle piece B is generally poſitive; but this in a very faint degree.

If all the pieces be again joined, they are void of electricity. If, inſtead of ſuch conductors, a row of metal balls, ſuſpended by ſilk lines, are employed, one of them may generally be found without any ſenſible electricity, when ſeparated from the reſt, having been the neutral part of the row while united.

Theſe very ſimple facts ſhew, as completely as can be wiſhed, that if the electric phenomena depend on a fluid moveable in the pores of the body, the conſtitution given it by Mr Æpinus is adequate to the explanation. We may now venture to aſſert, that every other phenomenon of attraction and repulſion will be found in exact conformity with the legitimate conſequences of this conſtitution of the electric fluid.

65 In the induction of electricity nothing is communicated. Inherent powers are excited.

That nothing is communicated from the electric will appear ſtill more forcibly by the following experiment: Let a conductor be rendered electrical in the way now deſcribed, and touch either extremity of it with the little electrometer, and obſerve attentively the divergency of its threads. Now approach its remote extremity with another conducting body, ſuch as a ſingle piece of thoſe conductors, it will be rendered electrical; as may be diſcovered by a delicate electrometer. Obſerve carefully whether the electrometer in contact with the firſt conductor be affected:—it will generally be found to ſpread its threads wider. It will *certainly* be thus affected if the other conductor be very long and bulky, or touched by the hand; or if, inſtead of this ſecond conductor, we approach the firſt with the extended palm of the hand. As the ſecond conductor was rendered electrical, ſo, undoubtedly, is the hand alſo: and its electrification has not deprived the firſt conductor of any of its electric power, but, on the contrary, has increaſed it. And this augmentation of its power is equally ſenſible at both ends: For an electrometer at the other end will alſo diverge more when the hand is brought near the remote end. This theroy explains this in the moſt ſatisfactory manner. The firſt conductor renders the ſecond electric, by propelling its fluid to a greater diſtance. The ſecond conductor now acts on the fluid that is moveable in the firſt, and cauſes a greater accumulation in its end which is fartheſt from the electric; that is, renders it more electric.

66 The forced diſpoſition of fluid is affected by other electrified bodies.

Suppoſe that, inſtead of employing an excited globe of glaſs, we had made uſe of a conducting body, ſlightly overcharged. Thus if we employ the conductor A, overcharged, to induce electricity on C; this will produce the ſame general effect on our ſet of conductors. But if we have previouſly examined the force of the redundant body, by ſuſpending a pith-ball near it, and obſerving its deviation from the perpendicular, we may ſometimes

ſometimes be led to think, that it has imparted ſomething to the other body. For if the other body and the pith-ball be on oppoſite ſides of the redundant body, the pith-ball will fall a little; indicating a diminution of electric force. But this *ſhould happen* according to the theory; for it was ſhewn, in n° 52. that the conſtipation in the remote end of the overcharged body will be diminiſhed, and along with this, its action on the pith-ball. We ſhould find the electricity of the other end, next the conductor, increaſed, could we find an eaſy way of examining it; but an electrometer applied there will be too much affected by the conductor.

The ſame concluſions may be drawn from the following facts: Hang up a ruſh-pith electrometer. Approach it below with a body ſlightly electrified. The legs of the electrometer immediately diverge, though attracted by the electrified body. Hold the hand above the electrometer, and they will diverge ſtill more; touch the top of it, and they ſpread yet farther. Hold the electrified body (very weakly electrified) above the electrometer, ſo that its legs may diverge a little. Hold the hand above the electrified body; the legs of the electrometer will come nearer each other.

Theſe appearances are obſerved whether the electric be poſitive or negative. We need not take up time in explaining this by the theory, its agreement is ſo obvious.

Electric needles polarity and verticity.

Laſtly, on this head, if, in place of a fixed conductor, we uſe one of the needles of gilt card, ſet on its pivot, and if we then approach it with another conducting body, in the manner repreſented by E and C of fig. 6. we ſhall obſerve that end of the needle to avoid the other body; but if we bring them together, in the manner repreſented by F and B, they will attract each other. The attraction will be greater when the body F is long; and moſt of all when it communicates with the ground. Theſe phenomena are therefore in perfect conformity with the theory; but it may ſometimes happen that E will attract the end of C that is neareſt to A, and E will be electrified poſitively if A be poſitive. This ſeems inconſiſtent with the theory; and, accordingly, it has been adduced by Volta againſt Lord Mahon's account of the electrical ſtate of a conductor in a ſituation ſimilar to that of C. But the theory of Æpinus ſhews the poſſibility of this caſe. When E is very long, or when it is held in the hand, it is rendered *much more* undercharged than the adjacent part of C; and the fluid in the remoter, but not much remoter, part of C is ſtrongly attracted by the copious redundant matter in the near end of E, and is brought back again, and paſſes over into E, in the way to be deſcribed immediately. The caſe is rare, and it will not happen at any conſiderable diſtance from the neutral point of C. If, indeed, E touch the near end of C before A is brought near, the approach of A will cauſe fluid to paſs into E immediately, and C will be left undercharged on the whole.

The reader, who is at all converſant with electrical experiments, will be ſenſible, that theſe experiments are delicate, requiring the greateſt dryneſs of air, and every attention to prevent the diſſipation of electricity during the performance. This, by changing the ſtate of the conductors and electrometers, will frequently occaſion irregularities. The electrometers are moſt apt to change in this reſpect, it being ſcarcely poſſible to make them perfectly ſmooth and free from ſharp angles. It may therefore happen, that when the conductors have affected them *for ſome time*, by the action of the diſturbing electric, the removal of this electric will not cauſe the electrometers to hang perpendicular; they will often be attracted by the conductors, and often repelled; but the intelligent experimenter, aware of theſe circumſtances, will know what allowances to make. 67

Phenomena of imperfect conductors greatly corroborate the theory.

The theory obtains a ſtill more complete ſupport from a compariſon with ſimilar experiments made with imperfect conductors. If, in place of the ſeries A, B, C, of metalline conductors, we employ cylinders of glaſs or ſealing-wax, or even dry wood or marble, and electrometers with ſilk threads in place of the ruſh-pith electrometers, we ſhall find all the appearances to be ſuch as the theory enables us to predict. If, for example, we uſe a ſingle cylinder A of glaſs, we ſhall find that the neighbourhood of the electric D ſcarcely induces any electricity on A. The electrometer will hardly exhibit the ſmalleſt attraction, and its motions will be almoſt entirely ſuch as ariſe from the immediate influence of the electric body D. A cylinder of very dry wood will be more affected by the electric D; and a circumſtance of theoretical importance is very diſtinctly obſerved, namely, the gradual ſhifting of the neutral point. It will be found to advance along the cylinder for a very long while, when every circumſtance is very favourable, the air very dry, and the wood almoſt a nonconductor; and its final ſituation will be found much nearer to the electric than in the braſs conductor. Several inſtructive experiments of this kind may be found in a treatiſe publiſhed in 1783 by Dr Thomas Milner at Maidſtone in Kent, entitled, "Experiments and Obſervations on Electricity." The author does not profeſs to advance any new doctrines, but only to exhibit experiments ſcientifically arranged for forming a ſyſtem. He ſupports the Franklinian ſyſtem as it was generally underſtood at that time; but is much embarraſſed for the explanation of the repulſion of negative electrics. The Æpinian correction of this theory did not offer itſelf to his mind. 68

Irregularities.

We need not go over the ſame ground again with imperfect conductors. It is well known that ſuch bodies are more weakly attracted and repelled; that the balls of an electrometer with linen threads diverge vaſtly more when an electrified body is held below it, than if the threads are ſilken: that ſuch electrometers frequently exhibit very capricious appearances from the ſlow but real progreſs of the electricity along the threads. Theſe anomalies will be better underſtood when we explain the diſſipation of electricity along imperfect conductors. 69

Induced electricity of imperfect conductors is really permanent.

A very eſſential deduction from the theory is, that the electricity induced on an imperfect conductor muſt have ſome permanency. This is fully confirmed by experiment. But the remarkable inſtances of this particular cannot be produced till we be better acquainted with the methods of producing great accumulations of fluid. It is enough to obſerve at preſent, that a permanent electricity may always be obſerved at the junction of the conductors with their inſulating ſtalks. The braſs conductor A ceaſes to be electric as ſoon as the excited globe is removed; but the very top of the glaſs ſtalk on which it is ſupported will ſenſibly affect a delicate electrometer for a long while after. The following

ing pretty experiment ſhews this permanency very diſtinctly. Set one of the ſealing-wax needles on its pivot, and place it between two inſulated metal ſpheres of conſiderable ſize, at ſuch a diſtance from both as not to receive a ſpark. Electrify theſe balls moderately, one of them poſitively, and the other negatively, and keep them thus electrified for ſome hours by renewing their electrification. The needle quickly arranges itſelf in the line adjoining the two ſpheres, juſt as a magnetic needle will do when placed between two magnets whoſe diſſimilar poles front each other. Any gentle force will derange the needle; but it will vibrate like a magnetic needle, and finally ſettle in its former poſition. When this has been continued ſome time, that end of the needle which pointed to the poſitive globe will be found negative, and the other will be found poſitive, if examined with an electroſcope. And now, if the two globes be removed, this little needle will remain electrical for entire days in dry froſty weather, and its ends will approach any body that is brought near it (taking care not to come too cloſe); and the end which pointed to the poſitive globe will avoid a piece of rubbed ſealing-wax, but will approach a piece of rubbed glaſs; but the other end will be affected in the oppoſite way. In ſhort, it proves an electric needle with a poſitive and negative pole.

If two ſmall inſulated balls are moderately electrified, and placed about ſix inches aſunder, this needle, when carried round them, will arrange itſelf exactly as a magnetic needle does when carried round a magnet of the ſame length. If the ſame trial be made with the needle of gilt card, it will arrange itſelf in the ſame manner that a ſoft iron needle arranges itſelf near a magnet, but either end will turn indifferently to either globe.

Electrical meridians. If a thin glaſs plate, coated with red ſealing-wax, be ſet on the poſitive and negative globes, and we ſprinkle (from a conſiderable height) a fine powder of black ſealing-wax, and then pat the plate gently with a glaſs rod ſo as to agitate it a little, the particles of wax powder will gradually arrange themſelves into curve lines, diverging from the point over one of the globes, and converging to the point over the other, preciſely like the curves formed by iron-filings ſprinkled on a paper held over a magnet. Each little rag of wax becomes electrical by poſition, acquires two poles, and the poſitive pole of one attracts the negative pole of another; and they adhere in a certain determinate poſition, nearly a tangent to the curve, which was mentioned in nº 50, and indicates the law of magnetic action. When in this ſtate, if a hot brick be held over the plate till the wax ſoften a little, the particles of black wax will adhere to the red coating, and give us a permanent ſpecimen of the action.

70 It is well known that liquid ſealing-wax is a conductor. The writer of this article filled a glaſs tube with powdered ſealing-wax, and melted it, and then expoſed it, in its melted ſtate, to the influence of a poſitive and a negative globe, hoping to make a powerful and permanent electric needle, which ſhould have two poles, and exhibit a ſet of phenomena reſembling thoſe of magnetiſm. Accordingly he, in ſome meaſure, ſucceeded, by keeping the globes continually electrified for ſeveral hours, till the wax was quite cold. It had two diſtinct poles, and preſerved this property, *even though plunged in water, and while immerſed in the water*; but he was greatly diſappointed as to the degree of its electricity. It juſt affected a ſenſible electrometer at the diſtance of ſix inches from either pole. It was conſiderably ſtronger than if it had not been melted during the impregnation, but by no means in the degree that he expected. It retained ſome electricity for about ſix weeks, although lying neglected among conducting bodies. After its power ſeemed quite extinct, he was melting it again in order to renew it. Some light fibrous things chanced to be near it. While it was ſoftening, it became very ſenſibly electrical, cauſing theſe fibres to bend towards it, and even to cling to the tube. We ſhall ſee by and bye, that he was miſtaken in expecting more remarkable appearances, and that the theory, when properly applied, does not promiſe them. Having thus eſtabliſhed (as we think) this theory on ſufficient foundations for making it a very perſpicuous way of explaining the phenomena of induced electricity, we proceed to compare it with the ſecond general fact in electricity.

71 Electricity by communication. Prop. II. When an inſulated body B is brought very near an electrified body A, a ſpark is obſerved to paſs between them, accompanied with a noiſe (which we ſhall call the electric Snap), and B is now electrified permanently, and the electricity of A is diminiſhed.

Although this be one of the moſt familiar facts in electricity, it will be proper to conſider its attending circumſtances in a way that connects it with what we have now learned concerning electricity by poſition.

Let the inſulated body A (fig. 14.) be furniſhed with a cork-ball, hanging by a ſilk thread from a glaſs ſtalk connected with A; let B be fitted up in the ſame manner; let A be electrified weakly, and its degree of electricity be eſtimated by the inclination of the ball *towards* A: ſince B is not electrified, its electrometer will hang perpendicular; but when it approaches A (keeping the electrometers on the remote ſides of both), its electrometer will approach it, and the electrometer of A will gradually approach the perpendicular. When the bodies are brought very near, a ſpark is ſeen between them; and, at that inſtant, the electrometer of B comes much nearer to it, and that of A drops farther from it. If they be now ſeparated, their electrometers will retain their new poſitions with very little change, and B will now manifeſt the ſame kind of electricity with A.

Such is the appearance when A has been but weakly electrified. Bringing B near A, the fluid in B is drawn to the remote ſide, if A be overcharged, or drawn to the ſide neareſt to A, if A has been undercharged. B acts on its electrometer in conſequence of the change made in the diſpoſition of its fluid. The electrometer is attracted. In the mean time, the change made in the diſpoſition of the fluid in B affects the moveable fluid in A. If A was overcharged, the ajacent ſide of B becomes undercharged, and its redundant matter, attracting the fluid in A, condenſes it in the adjacent ſide, abſtracting part of the redundant fluid from that ſide which is next to the pith-ball. Then the joint action of the whole redundant fluid in A on the pith-ball is diminiſhed.

Muſt happen abruptly. As there is now an attraction in the redundant fluid in A for the redundant matter on the adjacent ſide of B, B, it is reaſonable to ſuppoſe, that when this attraction, joined to the repulſion of the redundant fluid behind it, is able to overcome the attraction which connects it with the ſuperficial particles of the matter, it will then eſcape and fly into B: but this will not happen gradually, but at once, as ſoon as the expelling force has ariſen to a very conſiderable intenſity. We cannot ſay what is the preciſe augmentation that is neceſſary; but we can clearly ſee, that however great the attraction for the adjoining particles may be, while the particle is ſurrounded by them on *all* ſides, it will yield to the ſmalleſt inequality of force, becauſe the particles before it attract as much as thoſe behind it; but when it is juſt about to quit the laſt or ſuperficial particles of A, a much greater force is now neceſſary. It can be ſtrictly demonſtrated, that when the mutual tendency is inverſely as the ſquare of the diſtance, the action of a particle placed immediately without a ſphere of ſuch matter is double of its action when ſituated in the very ſurface*. A *ſaltus* of this kind muſt obtain whatever be the law of electric attraction. We ſhall ſee other cauſes alſo which ſhould prevent the eſcape of redundant fluid, and alſo its admiſſion, till the impelling force is encreaſed in a certain abrupt degree.

* *Opuſ. les de d'Alembert*, T. I. 257.

72 Theſe obſervations muſt ſuffice at preſent to explain the deſultory nature of this transference, if there be really a transference. That this has happened, may be confidently inferred from the ſudden diminution of the electricity of A, indicated by the ſudden fall of its electrometer; but it is more expreſsly eſtabliſhed, that there has been a transference by the change produced on B. It is now permanently electrified, and its electricity is of the ſame kind with that of A, poſitive or negative according as A is poſitive or negative. And now we are enabled to explain the third general fact in electricity.

73 Imparted electricity produces mutual repulſion.

Prop. III. When a body has imparted electricity to another, it conſtantly repels it, unleſs that other has afterwards imparted all its electricity to other bodies. This fact, from which there is no exception, is an immediate conſequence of the theory. Before the transference ſuppoſed by it, B was in its natural ſtate; after the transference, both bodies contain redundant fluid, or redundant matter; therefore they muſt mutually repel.

We may now take another form of the experiment, which will be much more convincing and inſtructive. Let A be electrified poſitively, or by redundancy, and let its electrometer be attached to it by a conducting ſtalk, and have a flaxen thread; let this be the caſe alſo with the electrometer of B; then the appearances ſhould happen in the following order: When A is made to approach B, the electrometer of B muſt gradually riſe, diverging *from* B; becauſe the fluid condenſed on the ſide remote from A, and in the electrometer, will act more ſtrongly on it than the deſerted matter on the other ſide of B; and when the ſudden transference is made, and B is wholly overcharged, its electrometer will immediately riſe much higher, and muſt remain at that height, nearly, when A is removed. On the other hand, the electrometer attached to the remote ſide of A muſt deſcend, by reaſon of the change made in the diſpoſition of the fluid in A by the induced electrical ſtate of B: and when a conſiderable portion of the redundant fluid in A paſſes into B, the electrometer of A muſt ſuddenly ſink much lower, and remain in that ſtate when B is removed.

Transference of a peculiar ſubſtance highly probable.

Many circumſtances of this phenomenon corroborate our belief of a real transference of matter. The cauſe of electric action reſided formerly in A alone; it now reſides alſo in B. The larger that B is, the greater is the diminution of A's electric power, and the ſmaller is the power acquired by B. It perfectly reſembles, in this reſpect, the communication of ſaltneſs, ſweetneſs, &c. by mixing a ſolution of ſalt or ſugar with different quantities of water; and the evidence of a transference of a ſubſtance, the cauſe of electric attractions and repulſions, is at leaſt as cogent as the evidence of the transference of heat, when we mix hot water with a quantity of cold, or when a hot ſolid body is applied to the ſide of a cold one. We alſo ſee ſo many chemical and other changes produced by this communication of electricity, that we can hardly refuſe admitting that *ſome material ſubſtance* paſſes from one body to another, and, in its new ſituation, exerts its attractions and repulſions, and produces all their effects.

We may deduce the following corollaries; all of which are exactly conformable to the phenomena, ſerving ſtill more to confirm the juſtneſs of the theory. 74

Degrees of vivacity proportioned to the quantity imparted.

1. A certain quantity of what poſſeſſes theſe powers of attraction and repulſion is neceſſary for giving a determined vivacity to the appearances. Another ſpark muſt paſs between the bodies, *only if they be brought ſtill nearer*, and their electrometers muſt riſe and fall ſtill farther. For by the firſt transference of electric fluid into B, the expelling power of A is diminiſhed, and the ſuperior attraction of the redundant matter in the adjacent ſide of B is alſo counteracted by the repulſion of the fluid which has entered into it; therefore no more will follow unleſs theſe forces be encreaſed, at leaſt to their former degree. When this addition has been made to B, and this abſtraction from A, their reſpective electrometers muſt be affected. All this is in perfect conformity to experience. 75

Communication moſt remarkable in conductors.

2. All the phenomena of communicated electricity muſt be more remarkable in proportion to the conducting power of the bodies. A very imperfect conductor, ſuch as glaſs or ſealing-wax, will impart or receive fluid only between the very neareſt parts; whereas a metalline body is inſtantly affected through its whole extent. This deduction is perfectly agreeable to the whole train of electric experiments. The finger receives a ſtrong ſpark from a large metalline electrified body, which diſcharges *every part of it* of a portion of its electricity. But an excited globe, which ſhews, by its action on a diſtant body, as great a degree of electricity, will give only a very ſmall ſpark; and it is found not to be affected at any conſiderable diſtance from the point of its ſurface from which the transference was made. The whole electricity of a perfect conductor is diſcharged by touching it; but a nonconductor will ſucceſſively give ſparks, if touched in many different parts; and it may be ſeen by a nice electrometer, that each contact takes away the electricity only from a very ſmall ſpace round it: and it is further highly deſerving of notice, that ſome time after a ſpark has been obtained from a particular ſpot of the electric, a ſecond ſpark may be obtained from it, the electricity of the neighbouring parts having been gradually diffuſed through it.

3. If

76 Insulation necessary for electric appearances.

3. If an electrified conducting body touch any thing communicating with the ground by perfect conductors, all its electricity must disappear, and none can appear in the body touched by it; for the mass of the earth bears such an unmeasurable proportion to that of the greatest body that we can electrify, that when the redundancy or deficiency is divided between them, it must be imperceptible in both.

77 Hence the necessity of *insulation*, as it is called, or the surrounding by non conductors every body which we would have exhibit electric appearances. We must refer the reader to the article ELECTRICITY in the *Encycl.* for all the observations on this head, and the reasons of preference given to certain substances to be employed for insulating supports. But we must consider, in its proper place, the manner in which the electric fluid is dissipated by imperfectly insulating substances; a subject intimately connected with the theory.

78 An electrified body attracts and then repels any unelectrified body.

4. Any unelectrified body will be first attracted by an electrified body, will touch it, and will then be repelled. The neutral body is rendered electrical by induction. It is, *in consequence of this*, attracted, comes near enough to receive a spark, or even touches it, and is then electrified by communication; and, *in consequence of this*, it is repelled. This is confirmed by an endless train of experiments. It was first taken notice of (we think) by Sir Isaac Newton. Otho Guericke, a gentleman of Magdeburgh, to whom we owe the air pump, mentions many instances of the repulsion, but did not observe that it was an universal law. Newton was so struck with it as to engage in a considerable train of experiments in the early part of his life, while meditating on the power of gravity; but even his sagacious mind did not observe the whole process of nature in his experiments. He observed, that the light bodies which rose and adhered to the rubbed plate of glass were soon after repelled by it; but did not observe, that the same piece would again rise to the glass after it had touched the table. This fact is now the foundation of many experiments, which the itinerant electricians vie with each other in rendering very amusing. We may render them instructive. Take away the middle conductor B (fig. 11.), and hang in its place a cork ball by a long silk thread. As soon as the electric body D is brought near to A, the ball is attracted by its remote end, comes into contact, is repelled by it, and attracted by the adjacent end of C, touches it, is faintly repelled by it, and again attracted by A; and the operation is repeated several times. When all has ceased, remove C, and also the electric D. C is found to have the same electricity with D, and A has the opposite electricity. The process is too obvious to need any detailed application of the theory. The cork ball was the carrier of fluid from A to C if D was electric by redundancy, or from C to A if D was undercharged. If instead of removing C when the vibrations of the ball have ceased, we bring D a little nearer, they will be renewed, and, after some time, will again cease. The reason is plain. The carrier ball had brought the conductor A into a state of equilibrium with the action of D. But this action is now increased, and the effects are renewed. If we now remove D, the ball will vibrate between A and C with great rapidity for a considerable time before the vibrations come to an end; and we shall find their number to be the same as before. The cause of this is also obvious from the theory. We may suppose A to be negative, and C positive. One of them will attract the ball into contact, and will repel it, having put it into an electric state opposite to that of the other conductor. It now becomes a carrier of fluid from the positive to the negative conductor, till it nearly restore both to their primitive state of neutrality.

79 Irregularities frequent—Why.

There is frequently a seeming capriciousness in those attractions and repulsions. A pith ball, or a down feather, hung by silk, will cling to the conductor, or otherwise electrified body, and will not fly off again, at least for a long while. This only happens when those bodies are so dry as to be almost non-conductors. They acquire a positive and negative pole, like an iron nail adhering to a magnet, and are not repelled till they become almost wholly positive or negative. It never happens with conducting light bodies.

80 Electric action, like gravitation, is not hindered by the interposition of non-conductors.

5. It should follow from the theory, that the electric attractions and repulsions will not be prevented by the intervention of non-conducting substances in their neutral state. Accordingly, it is a fact, that the interposition of a thin pane of glass, let it be ever so extensive, does not hinder the electrometer from being affected. Also, if an insulated electric be covered with a glass bell, an electrometer on the outside will be affected. Nay, a metal ball, covered to any thickness with sealing-wax, when electrified, will affect an electrometer in the same way as when naked. We cannot see how these facts can be explained by the action of electric atmospheres. It is indeed said, that the atmosphere on one side of the glass produces an atmosphere on the other; but we have no explanation of this production. If the interposed plate be a non-conductor, how does the one atmosphere produce the other? It must produce this effect by acting at a distance on the particles which are to form this atmosphere. Of what use, then, is the atmosphere, even if those atmospheres could effect the observed motions of the electrometer in consistency with the laws of mechanics? The atmospheres only substitute millions of attractions or repulsions in place of one. We must observe, however, that the motions of the electrometer are modified, and sometimes greatly changed, by the interposed non-conducting plate; but this is owing to the electricity induced on the plate. If the electric is positive, the adjacent surface of the plate becomes faintly negative, and the side next the electrometer slightly positive. This affects the electrometer even more than the more remote electric does. That this is the cause of the difference between the state of the electrometer when the plate is there and when it is removed, will appear plainly by breathing gently on the glass plate to damp it, and give it a small conducting power. This will make some change in the position of the electrometer. Continue this more and more, till the plate will no longer insulate. The changes produced on the electrometer's position will form a regular series, till it is seen to assume the very position which it would have taken had the plate been brass. Then, considering those changes in a contrary order, and supposing the series continued a little farther, we shall always find that it leads to the position which it would have taken when no plate whatever is interposed. We consider this as an important fact, shewing that the electric action is similar to gravitation, and that there is

is no more occaſion for the intervention of an atmoſphere for explaining the phenomena of electricity than for explaining thoſe of gravitation.

81
Strong electricity may be excited without appearing.

6. Since non-electrics are conductors, and ſince electrics may be excited by friction with a non-electric, it follows, that if this non-electric be inſulated, and ſeparated from the electric, it will exhibit ſigns of electricity; but when they are together, there muſt not appear any marks of it, however ſtrong the excitation may be. We do not pretend to comprehend diſtinctly the manner in which friction, or the other modes of excitation, operate in changing the connection between the particles of the fluid and thoſe of the tangible matter; nor is this explained in any electric theory that we know; but if we are ſatiſfied with the evidences which we have for the exiſtence of a ſubſtance, whoſe preſence or abſence is the cauſe of the electric phenomena, we muſt grant that its uſual connection with the tangible matter of bodies is changed in the act of excitation, by friction, or by any other means. In the caſe of friction producing poſitive electricity on the ſurface of the electric, we muſt ſuppoſe that the act of friction cauſes one body to emit or abſorb the fluid more copiouſly than the other, or perhaps the one to emit, and the other to abſorb. Which ever is the caſe, the adjoining ſurfaces muſt be in oppoſite ſtates, and the one muſt be as much overcharged as the other is undercharged. When the bodies (which we may ſuppoſe to have the form of plates) are joined, and the one exactly covers the other, the aſſemblage muſt be inactive; for a particle of moveable fluid, ſituated anywhere on the ſide of the overcharged plate, will be as much attracted by the undercharged ſurface of the remote plate as it is repelled by the overcharged ſurface of the near plate. The ſurfaces are equal, and equally electric, and act on either ſide with equal intenſity; and they are coincident. Therefore their actions balance. The action is expreſſed by the formula of n° 43; namely, $F' m' \times \overline{z - z'}$; and $z - z'$ is $= 0$, by reaſon of the equal diſtances of theſe ſurfaces from the particle of exterior fluid.

But let the plates be ſeparated. Part, and probably the greateſt part, of the redundant fluid on one of the rubbed ſurfaces will fly back to the other, being urged both by the attraction of the redundant matter and the repulſion of its own particles. But the electric, being electric becauſe, and only becauſe, it is a non-conductor, muſt retain ſome, or will remain deprived of ſome, in a ſtratum a little within the ſurface. The two plates muſt therefore be left in oppoſite ſtates, and the conducting, or non electric plate, if inſulated before ſeparation, muſt now exhibit electric action.

All this is exactly agreeable to fact. We alſo know, that electrics may be excited by rubbing on each other; and if of equal extent, and equally rubbed, they exhibit no electric powers while joined together; but when parted, they are always in oppoſite ſtates. The ſame thing happens when ſulphur is melted in a metal diſh, or when Newton's metal is melted in a glaſs diſh. While joined, they are moſt perfectly neutral; but manifeſt very ſtrong oppoſite electricities when they are ſeparated. This completely diſappears when they are joined again, and reappears on their ſeparation, even after being kept for months or years in favourable circumſtances. We have obſerved the plates of talc, and other laminated foſſils, exhibit very vivid electricity when ſplit aſunder.

82
Principles of the conſtruction of electric machines.

Attention to theſe particulars enables us to conſtruct machines for quickly exciting vivid electricity on the ſurface of bodies, and for afterwards exhibiting it with continued diſpatch. The whirling globe, cylinder, or plate, firſt employed by Mr Haukſbee, for the ſolitary purpoſe of examining the electricity of the globe, was moſt ingeniouſly converted by Hauſen, a German profeſſor, into a rapid collector and diſpenſer of electricity to other bodies, by placing an inſulated prime conductor cloſe to that part of the ſurface of the globe which had been excited by friction. Did our limits give us room, we ſhould gladly enlarge on this ſubject, which is full of moſt curious particulars, highly meriting the attention of the philoſopher. But it might eaſily occupy a whole volume; and we have ſtill before us the moſt intereſting parts of the mechanical department of electricity, and ſhall hardly find room for what is eſſentially requiſite for a clear and uſeful comprehenſion of it. We muſt, therefore, requeſt our readers to have recourſe to the original authors, who have conſidered the excitation by friction minutely. And we particularly recommend the very careful peruſal of Beccaria's Diſſertations on it, comparing the phenomena, in every ſtep, with this theory of Æpinus. Much valuable information is alſo obtained from Mr Nicholſon's Obſervations, of which an abſtract is given in the article Electricity *Encycl.* The Æpinian theory will be found to connect many things, which, to an ordinary reader, muſt appear ſolitary and accidental.

83
Evidences of the materiality of the electric fluid.

Seeing that this very ſimple hypotheſis of Æpinus ſo perfectly coincides in its legitimate conſequences with all the general phenomena of attraction and repulſion, and not only with thoſe that are ſimple, but even ſuch as are compounded of many others—we may liſten, without the imputation of levity, to the other evidences which may be offered for the materiality and mobility of the cauſe of thoſe mechanical phenomena. Such evidences are very numerous, and very perſuaſive. We have ſaid, that the transference of electricity is deſultory, and that the change made in the electric ſtate of the communicating bodies is always conſiderable. It appears to keep ſome ſettled ratio to the whole electric power of the body. When the form of the parts where the communication takes place, and other circumſtances, remain the ſame, the transference increaſes with the ſize of the bodies; and all the phenomena are more vivid in proportion. When the conductor is very large, the ſpark is very bright, and the ſnap very loud.

Snap.

1. This ſnap alone indicates ſome material agent. It is occaſioned by a ſonorous undulation of the air, or of ſome elaſtic fluid, which ſuddenly expands, and as ſuddenly collapſes again. But ſuch is the rapidity of the undulation, that when it is made in cloſe veſſels it does not exiſt long enough, in a very expanded ſtate, to affect the column of water, ſupported in a tube by the elaſticity of the air, for the purpoſe of a delicate thermometer or barometer; juſt as a muſket ball will paſs through a looſe hanging ſheet of paper without cauſing any ſenſible agitation.

Spark, and heat.

2. The ſpark is accompanied by intenſe heat, which will kindle inflammable bodies, will melt, explode, and calcine metals.

3. The

Chemical effects.

3. The fpark produces fome very remarkable chemical effects. It calcines metals even under water or oil; it renders Bolognian phofphorus luminous: It decompofes water, and makes new compofitions and decompofitions of many gaziform fluids; it affects vegetable colours; it blackens the calces of bifmuth, lead, tin, luna cornea; it communicates a very peculiar fmell to the air of a room, which is diftinct from all others; and in the calcination of metals, it changes remarkably the fmells with which this operation is ufually accompanied: it affects the tongue with an acidulous tafte; it agitates the nervous fyftem.—When we compare thefe appearances with fimilar chemical and phyfiological phenomena, which naturalifts never hefitate in afcribing to the action of material fubftances, transferable from one body, or one ftate of combination, to another, we can fee no greater reafon for hefitating in afcribing the electric phenomena to the action of a material fubftance: which we may call *a fluid*, on account of its connected mobility, and *the electric fluid*, on account of its diftinguifhing effects. We are well aware, that thefe evidences do not amount to demonftration; and that it is poffible that the electric phenomena, as well as many chemical changes, may refult from the mere difference of arrangement, or pofition, of the ultimate particles of bodies, and may be confidered as the refult of a change of modes, and not of things. But in the inftances we have mentioned, this is extremely improbable.

This is therefore affumed.

We therefore venture to affume the exiftence of this fubftance, which philofophers have called *the electric fluid*, as a propofition abundantly demonftrated; and to affirm, on the authority of all the above-mentioned facts, that its mechanical character is fuch as is expreffed in Mr Æpinus's hypothefis.

We proceed, therefore, to explain the moft interefting phenomena of electricity from thefe principles.

84
Diftribution of it depends on its law of action.

We have feen that, in a perfect conductor, in its natural ftate, the electric fluid is uniformly diftributed, and cannot remain in any other condition. We are particularly interefted to know how it is diftributed in an overcharged or undercharged body, and how this is affected by the circumambient non-conducting air. It is evident that much depends on this. The tendency to efcape, and, particularly, the tendency to transference from one body to another, muft be greateft where the fluid is moft conftipated. We know that it tends remarkably to diffipate from all protuberances, edges, and long bodies, and that it is impoffible to confine it in a body having very acute far-projecting points; and, what is more paradoxical, it is hardly poffible to prevent its entering into a body furnifhed with a fharp point. The fmalleft reflection muft fuggeft to our imagination, that a perfectly moveable fluid, whofe particles mutually repel, even at confiderable diftances, and which is confined in a veffel from which it cannot efcape, muft be compreffed againft the fides of the veffel, and be denfer there than in the middle of the veffel. But in what proportion its denfity will diminifh as we recede from the walls of the veffel, muft depend on the change of electric repulfion by an increafe of diftance. The intenfity varies in the proportion of fome function of the diftance, and may be expreffed by the ordinates of a curve, on whofe axis the diftances are meafured. But we are ignorant of this function. We muft therefore endeavour to difcover it, by obferving a proper folution of phenomena. Having made fome approximation to this difcovery, fuch as fhall give rife to a *probable conjecture* concerning the function which expreffes the intenfity of electric repulfion, mathematics will then enable us to fay how the fluid muft be diftributed (at leaft in fome fimple and inftructive cafes) in a perfectly conducting body furrounded by the air, and what will be its action on another body. Thus we fhall obtain oftenfible refults, which we can compare with experiments. The writer of this article made many experiments with this view above 30 years ago, and flatters himfelf that he has not been unfuccefsful in his attempts. Thefe were conducted in the moft obvious and fimple manner, fuggefted by the reafonings of Mr Æpinus; and it was with fingular pleafure that, fome years after, he perufed the excellent differtation of Mr Cavendifh in the Philofophical Tranfactions, vol. 61. where he obtained a much fuller conviction of the truth of the conclufion which he had drawn, in a ruder way, from more familiar appearances. Mr Cavendifh has, with fingular fagacity and addrefs, employed his mathematical knowledge in a way that opened the road to a much farther and more fcientific profecution of the difcovery, if it can be called by that name. After this, Mr Coulomb, a diftinguifhed member of the French academy of fciences, engaged in the fame refearch in a way ftill more refined; and fupported his conclufions by fome of the moft valuble experiments that have been offered to the public. We fhall now give a very brief account of this argument: and have premifed thefe hiftorical remarks; becaufe the writer, although he had eftablifhed the general conclufion, and had read an account of his inveftigation in a public fociety in 1769, in which it was applied to the moft remarkable facts then known in electricity, has no claim to the more elaborate proofs of the fame doctrine, which is given in fome of the following paragraphs. Thefe are but an application of Mr Cavendifh's more cautious and general mathematical procedure, to the function which the writer apprehends to be fufficiently eftablifhed by obfervation.

Procefs for difcovering this law.

The moft unexceptionable experiments with which we can begin, feem to be the repulfions obfervable between two *fmall* fpheres. Whatever be the law of diftribution of the particles in a fphere, the general action of its particles on the particles of another fphere will follow a law which will not differ much from the law of action between two particles, if the diameters of the fpheres be fmall in proportion to their diftance from each other. The inveftigation was therefore begun with them. But the fubject required an electrometer fufceptible of comparifon with others, and that could exhibit abfolute meafures. The one employed was made in the following manner; and we give it to the public as a valuable philofophical inftrument.

Comparable electrometer.

Fig. 15. reprefents the electrometer in front. A is a polifhed brafs ball, $\frac{1}{4}$th of an inch in diameter. It is fixed on the point of a needle three inches long, as flender as can be had of that length. The other end of the needle paffes through a ball of amber or glafs, or other firm non conducting fubftance, about half or three-fourths of an inch in diameter; but the end muft not reach quite to the furface, although the ball is completely perforated. From this ball rifes a flender glafs rod FEL, three inches long from F to E, where it 85

 bends

bends at right angles, and is continued on to L, immediately over the centre of the ball A. At L is fixed a piece of amber C, formed into two parallel cheeks, between which hangs the ſtalk DCB of the electrometer. This is formed by dipping a ſtrong and dry ſilk thread, or fine cord, in melted ſealing-wax, and holding it perpendicular till it remain covered with a thin coating, and be fully penetrated by it. It muſt be kept extended, that it may be very ſtraight; and it muſt be rendered ſmooth, by holding it before a clear fire. This ſtalk is faſtened into a ſmall cube of amber, perforated on purpoſe, and having fine holes drilled in two of its oppoſite ſides. The cheeks of the piece C are wide enough to allow this cube to move freely between them, round two fine pins, which are thruſt thro' the holes in the cheeks, and reach about half way to the ſtalk. The lower part of the ſtalk is about three inches long, and terminates in a gilt and burniſhed cork-ball (or made of thin metal), a quarter of an inch in diameter. The upper part CD is of the ſame length, and paſſes through (with ſome friction) a ſmall cork-ball. This part of the inſtrument is ſo proportioned, that when FE is perpendicular to the horizon, and DCB hangs freely, the balls B and A juſt touch each other. Fig. 16. gives a ſide perſpective view of the inſtrument. The ball F is fixed on the end of the glaſs rod FI, which paſſes perpendicularly through the centre of a graduated circle GHO, and has a knob handle of boxwood on the farther end I. This glaſs rod turns ſtiffly, but ſmoothly, in the head of the pillar HK, &c. and has an index NH, which turns round it. This index is ſet parallel to the line LA, drawn through the centre of the fixed ball of the electrometer. The circle is divided into 360 degrees, and 0 is placed uppermoſt, and 90 on the right hand. Thus the index will point out the angle which LA makes with the vertical. It will be convenient to have another index, turning ſtiffly on the ſame axis, and extending a good way beyond the circle.

This inſtrument is uſed in the following manner: A connection is made with the body whoſe electricity is to be examined, by ſticking the point of the connecting wire into the hole at F, till it touch the end of the needle; or, if we would merely electrify the balls A and B, and then leave them inſulated, we have only to touch one of them with an electrified body. Now, take hold of the handle I, and turn it to the right till the index reach 90. In this poſition, the line LA is horizontal, and ſo is CB; and the moveable ball B is reſting on A, and is carried by it. Now electrify the balls, and gently turn the handle backwards, bringing the index back toward 0, &c. noticing carefully the two balls. It will happen that, in ſome particular poſition of the index, they will be obſerved to ſeparate. Bring them together again, and again cauſe them to ſeparate, till the exact poſition at ſeparation is aſcertained. This will ſhew their repulſive force in contact, or at the diſtance of their centres, equal to the ſum of their radii. Having determined this point, turn the inſtrument ſtill more toward the vertical poſition. The balls will now ſeparate more and more. Let an aſſiſtant turn the long index ſo as to make it parallel to the ſtalk of the electrometer, by making the one hide the other from his view. The mathematical reader will ſee that this electrometer has the properties aſcribed to it. It will give abſolute meaſures: for by poiſing the ſtalk, by laying ſome grains weight on the cork-ball D, till it becomes horizontal and perfectly balanced, and computing for the proportional lengths of BC and DC, we know exactly the number of grains with which the balls muſt repel each other (when the ſtalk is in a horizontal poſition), in order *merely to ſeparate*. Then a very ſimple computation will tell us the grains of repulſion when they ſeparate in any oblique poſition of the ſtalk; and another computation, by the reſolution of forces, will ſhew us the repulſion exerted between them when AL is oblique, and BC makes any given angle with it. All this is too obvious to need any farther explanation. The reaſon for giving the connection between A and C ſuch a circuitous form, was to avoid all action between the fixed and the moveable part of the electrometer, except what is exerted between the two balls A and B. The needle AF, indeed, may act a little, and might have been avoided, by making the horizontal axis FI to join with A: but as it was wanted to make the inſtrument of more general uſe, and frequently to connect it with an electrical machine, a battery, or a large body, no mode of connection offered itſelf which would not have been more faulty in this reſpect. The neateſt and moſt compendious form would have been to attach the axis FI to C, and to make CA and CB ſtiff metalline wires, in the ſame manner as Mr Brookes's electrometer is made. But as the whole of their lengths would have acted, this conſtruction would have been very improper in the inveſtigation of the law of electric repulſion. As it now ſtands, we imagine that it has conſiderable advantages over Mr Brookes's conſtruction; and alſo over Mr De Luc's incomparable electrometer, deſcribed in his Eſſays on Meteorology. It has even advantages over Mr Coulomb's comparably more delicate electrometer, which is ſenſible, and *can meaſure* repulſions which do not exceed the 50,000 of a grain; for the inſtrument which we have deſcribed will meaſure the *attractions* of the oppoſitely electrified bodies; a thing which Mr Coulomb could not do without a great circuit of experiments. For inſtead of making the ball B *above* A, by inclining the inſtrument to the right hand, we may incline it to the left; and then, by electrifying one of the balls poſitively, and the other negatively, when at a great diſtance from each other, their mutual attraction will cauſe them to approach; CB will deviate from the vertical toward A; and we can compute the force by means of this deviation.

We muſt remind the perſon who would make obſervations with this inſtrument, that every part of it muſt be ſecured againſt diſſipation as much as poſſible, by varniſhing all its parts, by having all angles, points, and roughneſſes removed, and by chooſing a dry ſtate of the air, and a warm room; and, becauſe it is impoſſible to prevent diſſipation altogether, we muſt make a previous courſe of experiments, in a variety of circumſtances, in order to determine the diminution per minute correſponding to the circumſtances of the experiments that are to be made with further views.

We truſt that the reader will accept of this particular account of an inſtrument which promiſes to be of conſiderable ſervice to the curious naturaliſt; and we now proceed with an account of the concluſions which have been drawn from obſervations made with it.

Here we could give a particular narration of ſome of the experiments, and the computations made from them; but we omit this, becauſe it is really unneceſſary. It ſuffices to ſay, that the writer has made many hundreds, with different inſtruments, of different ſizes, ſome of them with balls of an inch diameter, and radii of 18 inches. Their coincidence with each other was far beyond his expectation, and he has not one in his notes which deviate from the medium $\frac{1}{8}$ of the whole force, and but few that have deviated $\frac{1}{12}$. The deviations were as frequently in exceſs as in defect. His cuſtom was to meaſure all the forces by a linear ſcale, and expreſs them by ſtraight lines erected as ordinates to a baſe, on which he ſet off the diſtances from a fixed point; he then drew the moſt regular curve that he could through the ſummits of theſe ordinates. This method ſhews, in the moſt palpable manner, the coincidence or irregularity of the experiments.

86 Spheres, when electrified, repel with a force proportional to $\frac{1}{x^2}$;

The reſult of the whole was, that the mutual repulſion of two ſpheres, electrified poſitively or negatively, was very nearly in the inverſe proportion of the ſquares of the diſtances of their centres, or rather in a proportion ſomewhat greater, approaching to $\frac{1}{x^{2,06}}$. No difference was obſerved, although one of the ſpheres was much larger than the other; and this circumſtance enables us to make a conſiderable improvement on the electrometer. Let the ball A be made an inch in diameter, while B is but $\frac{1}{4}$ of an inch. This greatly diminiſhes the proportion of the irregular actions of the reſt of the apparatus to the whole force, and alſo diminiſhes the diſſipation when the general intenſity is the ſame.

87 And attract according to the ſame law.

When the experiments were repeated with balls having oppoſite electricities, and which therefore attracted each other, the reſults were not altogether ſo regular, and a few irregularities amounted to $\frac{1}{6}$ of the whole; but theſe anomalies were as often on one ſide of the medium as on the other. This ſeries of experiments gave a reſult which deviated as little as the former (or rather leſs) from the inverſe duplicate ratio of the diſtances; but the deviation was in defect as the other was in exceſs.

We therefore think that it may be concluded, that the action between two ſpheres is exactly in the inverſe duplicate ratio of the diſtance of their centres, and that this difference between the obſerved attractions and repulſions is owing to ſome unperceived cauſe in the form of the experiment.

88 Attractions and repulſions are equal at equal diſtances.

It muſt be obſerved alſo, that the attractions and repulſions, with the ſame denſity and the ſame diſtances, were, to all ſenſe, equal, except in the forementioned anomalous experiments. The mathematical reader will ſee, that the above-mentioned irregularities are imperfections of experiment, and that the gradations of this function of the diſtances are too great to be much affected by ſuch ſmall anomalies. The indication of the law is preciſe enough to make it worth while to adopt it, in the mean time, *as a hypotheſis*, and then to ſelect, with judgment, ſome legitimate conſequences which will admit of an exact compariſon with experiment, on ſo large a ſcale, that the unavoidable errors of obſervation ſhall bear but an inſignificant proportion to the whole quantity. We ſhall attempt this: and it is peculiarly fortunate, that this obſerved law of action between two ſpheres gives the moſt eaſy acceſs to the law of action between the particles which compoſe them; for Sir Iſaac Newton has demonſtrated (and it is one of his moſt precious theorems), that if the particles of matter act on each other with a force which varies in the inverſe duplicate ratio of the diſtances, then ſpheres, conſiſting of ſuch particles, and of equal denſity at equal diſtances from the centre, alſo act on each other with forces varying in the ſame proportion of the diſtances of their centres. He demonſtrates the ſame thing of hollow ſpherical ſhells. He demonſtrates that they act on each other with the ſame force as if all their matter were collected in their centres. And, laſtly, he demonſtrates that if the law of action between the particles be different from this, the ſenſible action of ſpheres, or of hollow ſpherical ſhells, will alſo be different (ſee *Principia*, I. Prop. 74, &c. alſo Astronomy, *Encycl.* 307.).

89 Electric action is inverſely as the ſquare of the diſtance.

Therefore we may conclude, that the law of electric attraction and repulſion is ſimilar to that of gravitation, and that each of thoſe forces diminiſhes in the ſame proportion that the ſquare of the diſtance between the particles increaſe. We have obtained much uſeful information from this diſcovery. We have now full confirmation of the propoſitions concerning the mutual action of two bodies, each overcharged at one end and undercharged at the other. Their evidence before given amounted only to a reaſonable probability; but we now ſee, that the curve line, whoſe ordinates repreſent the forces, is really convex to the abſciſſa, and that $Z + z'$ is always greater than $Z' + z$; from which circumſtance all the reſt follows of courſe.

90 Diſpoſition of ſuch fluid when redundant or deficient.

Let us now enquire into the manner in which the redundant fluid, or redundant matter, is diſtributed in bodies; the proportion in which it ſubſiſts in bodies communicating with each other; the tendencies to eſcape; the forces which produce a transference, &c. &c.

In the courſe of this enquiry, a continual reference will be made to the following elementary propoſition: 91 Lemma.

Let ABD (fig. 17.) be the baſe of a cone or pyramid, whoſe vertex is P, and axis PC; and let *a b d* be another ſection of it by a plane parallel to the baſe; let theſe two circles, or ſimilar polygons, conſiſt of matter or fluid of equal and uniform denſity; and let P be a particle of fluid or matter; the attraction or repulſion of this particle for the whole matter or fluid in the figure ABD is equal to its attraction or repulſion for the whole matter or fluid in *a b d*. For the attraction for a particle in ABD is to the attraction for a particle ſimilarly placed in *a b d* as Pc^2 to PC^2; and the number of particles in ABD is to that of thoſe in *a b d* as PC^2 to Pc^2; therefore the whole attraction for ABD is to that for *a b d* as $Pc^2 \times PC^2$ to $PC^2 \times Pc^2$, or in the ratio of equality.

Cor. 1. The ſame will be true of the action of plates of equal thickneſs and equal denſity; or, in general, having ſuch thickneſs and denſity as to contain quantities of matter or fluid proportional to their areas.

2. The action of all ſuch ſections made by parallel planes, or by planes equally inclined to their axis, are equal.

3. The tendency of a particle P to a plane, or plate of uniform thickneſs and denſity, and infinitely extended, or to a portion of it bounded by the ſame pyramid, is the ſame, at whatever diſtance it be placed from the plate, and it is always perpendicular to it.

4. This

4. This tendency is proportional to the denſity and thickneſs of the plate or plates jointly.

It is only in two or three ſimple caſes that we can propoſe to ſtate with preciſion what will be the diſpoſition and action of the electric fluid in bodies; but we ſhall ſelect thoſe that are moſt inſtructive, and connected with the moſt remarkable and important phenomena.

92 Diſpoſition in parallel plates.

Let A $a\,d$ D (fig. 18.) and E $e\,h$ H repreſent the ſections of a part of two infinitely extended parallel plates (which we ſhall call A and E), conſiſting of ſolid conducting matter, in which the electric fluid can move without any obſtruction, but from which it cannot eſcape.

When both are overcharged,

Firſt, Let them be both overcharged, A containing the quantity r of redundant fluid, and E containing the quantity s, and let r be greater than s.

The fluid will be diſpoſed in the following manner:

1. There will be two ſtrata, A $a\,b$ B and G $g\,h$ H, adjoining to the remote ſurfaces, in each of which the quantity $\frac{r+s}{2}$ will be crowded together as cloſe as poſſible.

2. Adjoining to the interior ſurface (that is, the ſurface neareſt to E) of the plate A, there will be a ſtratum C $c\,d$ D, containing the quantity $\frac{r-s}{2}$ crowded together.

3. The adjacent ſide of E will have a ſtratum E $e\,f$ F, juſt ſufficient for containing the quantity $\frac{r-s}{2}$ at its natural denſity. This ſtratum will be entirely exhauſted of fluid.

4. The ſpaces B $b\,c$ C and F $f\,g$ G will be in their natural ſtate.

For a particle of fluid in the ſpace B $b\,c$ C is urged in the direction $a\,d$ by the force $\frac{r+s}{2}$ (n° 91, 3.), and in the direction $d\,a$ by the force $\frac{r-s}{2}$, therefore it is, on the whole, urged in the direction $a\,d$ with the force s, which will balance the repulſion of the redundant fluid in the other plate. A particle of fluid in the ſpace F $f\,g$ G is repelled in the direction $h\,e$ by a force $\frac{r+s}{2}$ by the fluid in G $g\,h$ H, and it is attracted in the ſame direction by the redundant matter in E $e\,f$ F, with the force $\frac{r-s}{2}$. Theſe make a force r which balances the repulſion r of the other plate. No other diſpoſition will be permanent; for if a particle be taken out from either ſtratum A $a\,b$ B or C $c\,d$ D into the ſpace between them, the repulſion from that ſtratum which it quitted is leſſened, and the repulſion of the oppoſite ſtratum, joined to that of the other plate, will drive it back again. The ſame thing holds with reſpect to the fluid in the other plate.

93 *Cor.* 1. If the two plates be equally overcharged, all the redundant fluid will be crowded on the remote ſurfaces, and the adjacent ſurfaces will be in the natural ſtate.

94 When they are undercharged,

In the *ſecond* place, let the plates be undercharged, and let r be the fluid wanting in A, and s the fluid wanting in E, and let s be greater than r; then,

1. The ſtrata adjoining to A a and H h will be completely exhauſted of fluid, and the redundant matter in each will be ſuch as would be ſaturated by $\frac{r+s}{2}$.

2. The ſtratum C $c\,d$ D will contain redundant fluid $\frac{s-r}{2}$, crowded cloſe.

3. The ſtratum E $e\,f$ F will be deprived of fluid, and the quantity abſtracted is $\frac{s-r}{2}$.

4. The ſpaces B $b\,c$ C and F $f\,g$ G are in the natural ſtate.

The demonſtration is the ſame as in the former caſe.

95 When they are in oppoſite ſtates

Thirdly, Let A be overcharged, and E undercharged, A containing the redundant fluid r, and E wanting the fluid s; and let r be greater than s. Then,

1. The ſtrata A $a\,b$ B and G $g\,h$ H contain the redundant fluid $\frac{r-s}{2}$, crowded cloſe.

2. The ſtratum C $c\,d$ D contains the quantity $\frac{r+s}{2}$, crowded cloſe.

3. The ſtratum E $e\,f$ F is exhauſted, and wants the quantity $\frac{r+s}{2}$.

4. The reſt is in the natural ſtate.

Cor. 2. If the redundant fluid in A be juſt ſufficient to ſaturate the redundant matter in E, the two remote ſurfaces will be in their natural ſtate, all the redundant fluid in A being crowded into the ſtratum C $c\,d$ D, and all the redundant matter being in E $e\,f$ F. 96

This diſpoſition will be the ſame, whatever is the diſtance or thickneſs of the plates, unleſs the redundant fluid in A be more than can be contained in the whole of E when crowded cloſe.

97 Preſſure and tendency to eſcape.

When the two plates are overcharged, the fluid preſſes their remote ſurfaces with the force $\frac{\overline{r+s}^2}{4}$, and would eſcape with that force if a paſſage were opened. It would enter the remote ſurfaces of two undercharged plates with the ſame force; and, in either caſe, it would run from the inner ſurface of one to the adjacent ſurface of the other, with the force $\frac{\overline{r-s}^2}{4}$.

If one be overcharged and the other undercharged, fluid would eſcape from the remote ſurface with the force $\frac{\overline{r-s}^2}{4}$, and would run through a canal between them with the force $\frac{\overline{r+s}^2}{4}$.

Mutual actions.

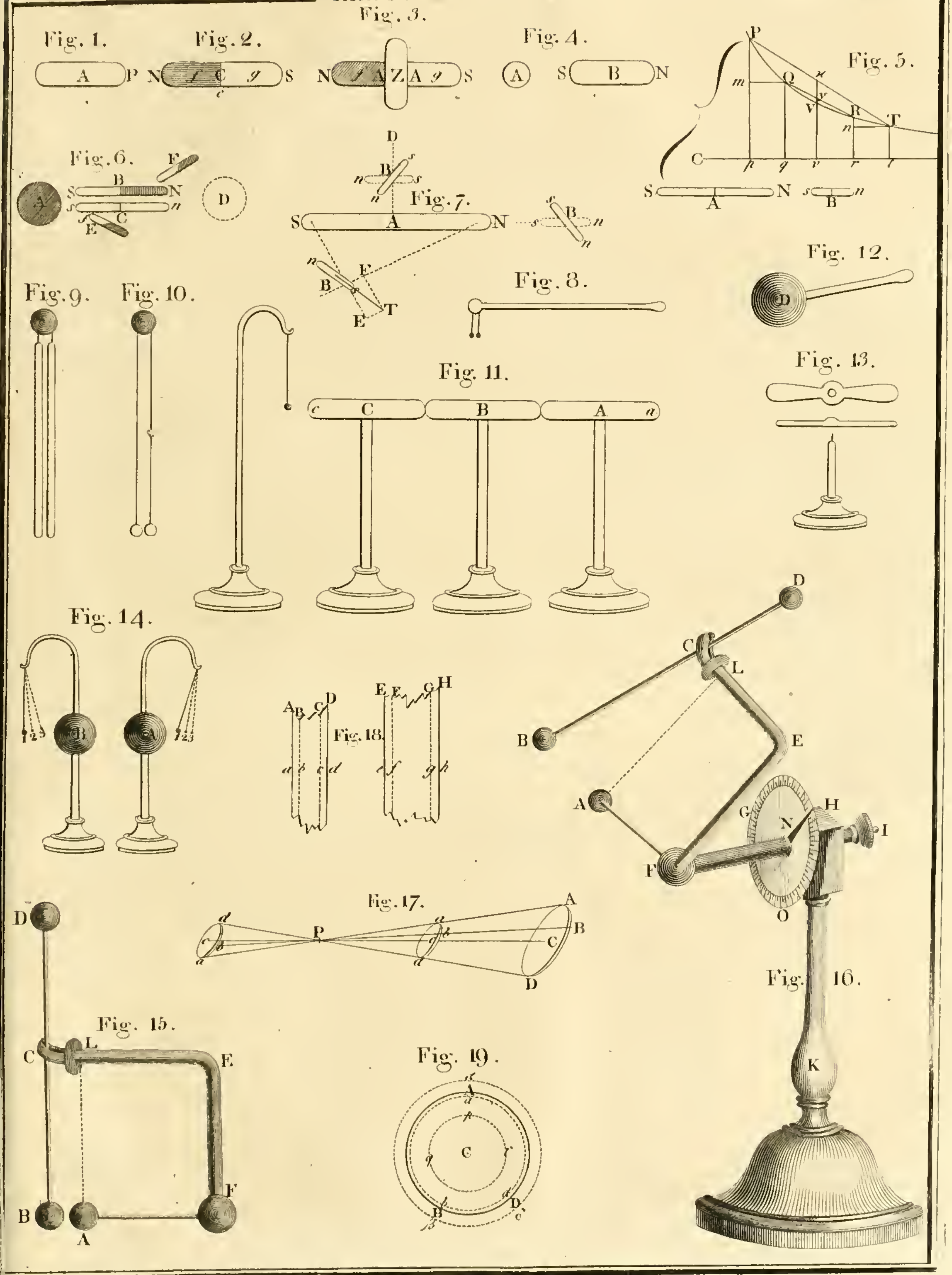
They repel or attract each other with the force $\overline{r+s}^2$, according as they are both over or undercharged, or as one is overcharged and the other undercharged.

This example of parallel plates, infinitely extended, is the ſimpleſt that can be ſuppoſed. But it cannot obtain under our obſervation; and in all caſes which we can obſerve, the fluid cannot be uniformly ſpread in any ſtratum, but muſt be denſer near the edges, or near the centre, as they are overcharged or undercharged.

98 Diſpoſition in a ſphere.

Let ABD (fig. 19) repreſent a ſphere of perfectly conducting matter, overcharged with electric fluid, which is perfectly moveable in its pores, but cannot eſcape from the ſphere. Let it be ſurrounded by conducting

ELECTRICITY PLATE XXIV



ducting matter faturated with moveable fluid. It is required to determine the difpofition of the fluid within and without this fphere.

Sir Ifaac Newton has demonftrated (*Princ.* I. 70.) that a particle *p*, placed anywhere within this fphere, is not affected by any matter that is without the concentric fpherical furface *p q r* in which itfelf is fituated, therefore not affected by what is between the furfaces ABD and *p q r*. He alfo demonftrates, that the matter within the furface *p q r* acts on the particle *p* in the fame manner as if the whole of it were collected in the centre C.

Hence it follows, that the redundant fluid will be all conftipated as clofe as poffible within the external furface of the fphere, forming a fhell of a certain minute thicknefs, between the fpherical furfaces ABD and *a b d*; and all that is within this (that is, nearer the centre C) will be in its natural ftate.

With refpect to the diftribution of the fluid in the furrounding matter, which we fuppofe to be infinitely extended, we muft recollect that this fhell of conftipated redundant fluid repels any external particle of fluid in the fame manner as if all were collected at C. Hence it is evident, that the fluid in the furrounding matter will be repelled, and, being moveable, it will recede from this centre; and there will be a fpace all round the fphere ABD which is undercharged, forming a fhell between the concentric furfaces ABD and $\alpha\ \beta\ \delta$. This fhell will contain fuch a quantity of redundant matter, that its attraction for a particle of fluid is equal to the repulfion of the fhell of fluid crowded internally on the furface ABD. All beyond this furface $\alpha\ \beta\ \delta$ will be in its natural ftate; for this redundant matter acts on a particle of fluid, fituated farther from the centre, in the fame manner as if all this redundant matter were collected in the centre C. So does the redundant fluid in the conftipated fhell. Therefore their actions balance each other, and there is no force exerted on any particle of fluid beyond this deficient fhell. This deficient fhell will not affect the fluid in the fphere *a b d* by Newton's demonftration. No other difpofition will be permanent. But farther: This undercharged fhell muft be completely exhaufted; for a particle of fluid placed between ABD and $\alpha\ \beta\ \delta$ will be more repelled by the fluid in the crowded fhell within the furface ABD, than it is attracted by the redundant matter of its own fhell that is lefs remote from the centre; and it is not affected by what is more remote from the centre. Therefore the fluid without the fphere ABD cannot be in equilibrio, unlefs the fhell between ABD and $\alpha\ \beta\ \delta$ be not only rarefied, but altogether exhaufted of fluid.

If the fphere be undercharged, the fpace between ABD and *a b d* will be entirely exhaufted of fluid, and there will be a fhell $\alpha\ \beta\ \delta$ of redundant matter furrounding the fphere. All within *a b d*, and all without $\alpha\ \beta\ \delta$, will be in its natural ftate. It is unneceffary to repeat the fteps of the fame demonftration.

This valuable propofition is by the Hon. Mr Cavendifh.

99 Confequences of this difpofition.

This would be the difpofition in and about a glafs globe filled and furrounded with an ocean of water, and having redundant fluid within it, on the fuppofition that glafs is impervious to the electric fluid. But it would not affect an electrometer, even fuppofing that the movements of the electrometer could be affected under water. Suppofe the globe of water to be furrounded with air, and that the fluid is difpofed in both in the manner here defcribed; it will be perfectly neutral in its action on any electrometer fituated in the air. But, by reafon of the almoft total immobility of the fluid in pure dry air, this ftate cannot foon obtain; and, till it obtain, the conftipated fhell within the glafs muft repel the fluid in an electrometer more than the partially rarefied fhell of air, which furrounds the glafs, attracts it. By the gradual retiring of the fluid in the furrounding air from the globe, the attraction of the deferted matter will come nearer to equality with the repulfion of the conftipated fhell within the glafs, and the globe will appear to have loft fluid. Yet it may retain all the redundant fluid which it had at the firft. Therefore we are not to imagine that a body fimilar to this globe has no redundant electric fluid, or only a fmall quantity, becaufe we obferve it inactive, or nearly fo.

100 Verified by the phenomena. Electric Well explained.

Thus we fee, as we proceed, that the Æpinian theory is adequate to the explanation of the phenomena. But we fee it much more remarkably in a very familiar and amufing experiment, ufually called the ELECTRIC WELL. See ELECTRICITY, *Encycl.* Sect. x. 4.

To fee it in perfection, make a glafs veffel of globular fhape, with a narrow mouth, fufficiently wide, however, to admit an electrometer fufpended to the end of a glafs rod of a crooked form, fo that the electrometer can be prefented to any part of the infide. Smear the outfide of the globe with fome tranfparent clammy fluid, fuch as fyrup. Set it on an infulating ftand (a wine glafs), and electrify it pofitively. Hold the electrometer near it, anywhere without, and it will be ftrongly affected. Its deviations from the perpendicular (if the ball of the electrometer has alfo been electrified) will indicate a force inverfely as the fquare of the diftance from the centre of the globe, pretty exactly, if the thread of the electrometer is of filk. Now let down the electrometer into the infide of the globe. It will not be affected in any fenfible degree, nor approach or avoid any body that is lying within the globe. The electrometer may be held in all parts of the globe, and when brought out again, is perfectly inactive and neutral. But if the balls of the electrometer be touched with a wire, while hanging free within the globe, they will, on withdrawing the wire, repel each other; and when taken out, they will be found negatively electrified. The experiment fucceeds as well with a metal globe; nay, even although the mouth be pretty wide; in which cafe, there is not a perfect balance of action in every direction. The electrometer may be made to touch the bottom of the globe, or anywhere not too near the mouth, without acquiring any fenfible electricity; but if we touch the outfide with the electrometer, it will inftantly be electrified and ftrongly repelled. Deep cylinders, and all round veffels with narrow mouths, exhibit the fame faintnefs of electricity within, except near the brims, although ftrongly electric without; and even open metal cups have the interior electricity much diminifhed.

101 Electric bodies are only fuperficially fo.

Reflecting on this valuable propofition of Mr Cavendifh, we fee clearly why an overcharged electric is only fuperficially fo; and that this will be the cafe even although we attempt to accumulate a great quantity of electricity in it, by melting it in a thin glafs globe, and electrifying

electrifying it while liquid, and keeping up the accumulating force till it becomes quite cold. The preſent writer, not having conſidered the ſubject with that judicious accuracy that Mr Cavendiſh exerted, had hopes of producing a powerful and permanent electric in this way, and was mortified and puzzled by the diſappointment, till he ſaw his miſtake on reading Mr Cavendiſh's diſſertation.

Cautions in certain experiments.

Theſe obſervations alſo point out a thing which ſhould be attended to in our experiments for diſcovering the electricity excited in the ſpontaneous operations of nature, as in chemical compoſition and decompoſition, congelation, fuſion, evaporation, &c. It has been uſual to put the ſubſtances into glaſs, or other non-conducting veſſels, or into veſſels which conduct very imperfectly. In this laſt caſe eſpecially, the very faint electricity which is produced, inſtantly forms a compenſation to itſelf in the ſubſtance of the veſſel, and the apparatus becomes almoſt neutral, although there may have been a great deal of electricity excited. It will be proper to conſider, whether the nature of the experiment will admit of metalline veſſels. In the experiments on metalline ſolutions, the beſt method ſeems to be, to make the veſſel itſelf the ſubſtance that is to be diſſolved.

102 Electricity more nearly proportional to the ſurface than to the quantity of matter.

For ſimilar reaſons we may collect, without a more minute examination, that bodies of all ſhapes, when overcharged, will have the redundant fluid much denſer near the ſurface than in the interior parts; and denſer in all elevations, bumps, projections, angles, and near the ends of oblong bodies; and that, in general, the quantity of redundant fluid, or redundant matter, will be much more nearly proportional to the ſurfaces of bodies than to their quantities of matter. All this is fully proved by experience. The experiment of the electrified chain is a very beautiful one. Lay a long metal chain in an inſulated metal diſh furniſhed with an electrometer. Let one end be held an inch or two above the coil by a ſilk thread. Electrify the whole, and obſerve the divergency of the electrometer; then, gradually drawing up the chain from the coil, the electrometer will gradually fall lower, and lowering the chain again will gradually raiſe it.

103 We now ſee with how little reaſon Lord Mahon concluded that the point of his conductor, obſerved to be neutral, correſponded with his theory; namely, one of the media of a harmonic diviſion. We ſee no reaſon for beginning the computation at the extremity of the prime conductor. It certainly ſhould not have been from the extremity. Had the prime conductor been a ſingle globe, it ſhould have begun from the centre of this globe. If it was of the uſual form, with an outſtanding wire, terminated by a large ball, the action of the body of the conductor ſhould certainly have been taken into the account. In ſhort, almoſt any point of the long conductor might have been accommodated to his Lordſhip's theory.

104 We might now proceed to inveſtigate the diſtribution of the electric fluid in bodies expoſed to the action of others, and particularly in the oblong conductors made uſe of in our preparatory propoſitions. The problem is determinate, when the length and diameter of cylindric conductors are given; but even when the electric employed for inducing the electricity is in the form of a globe, we muſt employ functions of the diſtances that are pretty complex, and oblige us to have recourſe to ſecond fluxions. The mutual actions of two oblong conductors, of conſiderable diameters, give a problem that will occupy the firſt mathematicians; but which is quite improper for this ſcanty abſtract. Nor is a minute knowledge of the diſpoſition of the fluid of very important ſervice. We may therefore content ourſelves with a general repreſentation of the ſtate of the fluid in the following manner, which will give us a pretty diſtinct notion how it will act in moſt caſes:

General repreſentation of the diſpoſition of the fluid.

Let A (fig. 20.) be an overcharged ſphere, and BC a conducting cylindric or priſmatic body: draw *b c* parallel to BC, and erect perpendiculars B *b*, C *c*, P *p*, &c. to repreſent the equable denſity of the fluid, when the conductor is in its natural ſtate; but let B *d*, C *r*, P *s*, &c. repreſent the unequal denſities in its different points, while in the vicinity of the overcharged ſphere. Theſe ordinates muſt be bounded by a line *d n r*, which will cut the line *b c* in the point *n* of the perpendicular, drawn from the neutral point N of the conductor. The whole quantity of fluid in the conductor is repreſented by the parallelogram BC*c b*; which muſt therefore be equal to the ſpace BC *r n d*: the redundant fluid in any portion CP or PN is repreſented by the ſpaces *c r t p*, or *t p n*; and the redundant matter, or deficient fluid, in any portion BQ, is repreſented by *b d v q*. The action of this body on any body placed near it, depends entirely on the area contained between this curve line and its axis *b c*. The only circumſtance that we can aſcertain with reſpect to this curve is, that *the variations of curvature* in every point are proportional to the forces exerted by the ſphere A; and are therefore inverſely as the ſquares of the diſtances from A. This property will be demonſtrated by and bye. The place of *n*, and the magnitude of the ordinates, will vary as the diameter of the conductor varies. We ſhall conſider this a little more particularly in ſome caſes which will occur afterwards. We may conſider the ſimpleſt caſe that can occur; namely, when the conductor is, like a wire, of no ſenſible diameter, nay, as containing only one row of particles.

In a very ſlender canal the fluid muſt be almoſt equally diſtributed.

Let AE (fig. 21.) be ſuch a ſlender conducting canal; and let B *b*, C *c*, E *e*, &c. repreſent the denſity of the fluid which occupies it, being kept in this ſtate of inequable denſity by the repulſion for ſome overcharged body. A particle in C is impelled in the direction CE by all the fluid on the ſide of A, and in the direction CA by all the fluid on the ſide of E. The moving force, therefore, ariſes from the difference of theſe repulſions. When the diameter of the canal is conſtant, this ariſes only from the difference of denſity. The force of the element adjacent to E may therefore be expreſſed by the exceſs of D *d* above C *c*, and the action at the diſtance CD jointly. Therefore, drawing $\beta c \varepsilon$ parallel to AE, this force of the element E will be expreſſed by $\frac{d\delta}{c\delta^2}\dot{x}$, repelling the particle in the direction CA. If CF be taken equal to CD, the force of the element at F will be expreſſed by $\frac{f\varphi}{c\varphi^2}\dot{x}$, or $\frac{f\varphi}{c\delta^2}\dot{x}$, alſo impelling the particle in the direction CA. The joint action of theſe two elements therefore is $\frac{d\delta+f\varphi}{c\delta^2}\dot{x}$. If *b c e* were a ſtraight line, we ſhould have $d\delta+f\varphi$ always

ways proportional to $c\delta$; and it might be expreſſed by $m \times c\delta$; m being a number expreſſing what part of $c\delta$ the ſum of $d\delta$ and $f\varphi$ amounts to (perhaps $\frac{1}{10}$th, or $\frac{1}{20}$th, or $\frac{1}{30}$th, &c.). But in the caſe expreſſed in the figure, $d\delta$ does not increaſe ſo faſt as $c\delta$, and $f\varphi$ increaſes faſter than $c\delta$. However, in the immediate neighbourhood of any point C, we may expreſs the accelerating force tending towards A by $\frac{m\,c\,\dot{\delta}}{c\,\delta^2}x$, without any ſenſible error; that is, by $m\frac{\dot{x}}{x}$; that is, by the fluxion of the area of a hyperbola HD′G, having CC′ and CK for its aſſymptotes; and the whole action of the fluid between F and D, on the particle C, will be expreſſed by the area C′CDD′H. Hence it follows, that the action of the ſmalleſt conceivable portion of the canal immediately adjoining to C on both ſides, or the difference of the actions of the two adjoining elements, is equal to the action of all beyond it. This ſhews, that the ſtate of compreſſion is hardly affected by any thing that is at a ſenſible diſtance from C; and that the denſity of the fluid, in an indefinitely ſlender canal, is, to all ſenſe, uniform. The geometer will alſo ſee, that the ſecond fluxion of D d is proportional to the force of the diſtant body. We learn, therefore, ſo much of the nature of the curve $b\,c\,e$.—(*Coulomb*).

We are now in a condition to examine the communication of electricity by means of conducting canals (which is one of the moſt important articles of the ſtudy), having found that the fluid, in a very ſlender canal, is very nearly of uniform denſity throughout.

106 Communication and transference by canals.

There can be no doubt but that, if a body B (fig. 22.) be overcharged or undercharged, any other body C, which communicates with it by a conducting canal, will alſo be overcharged or undercharged. It is as evident, that if a body, in any ſtate of electricity, be in the neighbourhood of an overcharged or undercharged body A, while it communicates with C by a canal leading from the ſide moſt remote from A, fluid will be driven from B into C, or abſtracted from C into B.

107 By crooked canals.

It is not, however, ſo clear, that when the canal leads from the ſide neareſt to A (as in fig. 23.), fluid will be driven from B into C. We conceive the fluid to be moveable in the body and in this canal, but not to eſcape from it. Its motion, therefore, in this caſe, ſhould, in the opinion of Mr Cavendiſh, reſemble the running of water in a ſyphon by the preſſure of the air. While the repulſion of the redundant fluid in A allows the bend of the ſyphon neareſt to A to retain fluid, a current ſhould take place from B along the ſhort leg, in conſequence of the ſuperior action on the fluid in the long leg. But if the repulſion of A can drive the fluid out of the bend between E and F, Mr Cavendiſh thinks, that it does not appear that fluid will come up from B in oppoſition to the repulſion of A, and then run along to D. But fluid does not move, in either of theſe caſes, on the principle of a ſyphon; becauſe there is nothing to hinder the fluid from expanding in the part EDF. And we are rather diſpoſed to think, that it will always move from B, over the bend, to C: For even if the fluid can be completely driven out of the bend EF, it muſt be done by degrees, and the fluid in the long leg will, from the very beginning of the action of A, be more moved from its place than that in the ſhort leg; and therefore will yield to the compreſſion, which acts tranſverſely, and, by thus yielding more toward F than toward E, the fluid will ruſh through the contracted part, and go into C. We do not ſay this with full confidence; but are thus particular, on account of an important uſe that may be made of the experiment. For if the body A be undercharged, fluid will certainly be attracted from C, and paſs over the bend into B, however great the action of A may be. Perhaps this may be ſo contrived, therefore, as to decide the long agitated queſtion, *Whether the electricity of excited glaſs be plus or minus?* If it be found that this apparatus, being preſented to the rubber of an electrical machine, diminiſhes the poſitive electricity of C, and increaſes that of B; but that, preſenting the ſame apparatus to the prime conductor, makes little change—we may conclude, that the electricity of the prime conductor is poſitive. We have tried the experiment, paying attention to every circumſtance that ſeemed likely to inſure ſucceſs; but we have always found hitherto, that the apparatus was equally affected by both electricities.

Propoſal for diſcovering redundancy of fluid.

We muſt now conſider the action of electrified bodies on the canals of communication; becauſe this will give us the eaſieſt method of aſcertaining the proportion in which the expelling fluid is diſtributed between them. For when two bodies communicate by a canal, and have attained a permanent ſtate, we muſt conceive that their oppoſite actions on the fluid moveable along this canal are in equilibrio, or are equal. This will generally be a much eaſier problem than their action on each other, ſince we have ſeen a little a ago, that the fluid in a ſlender canal is of uniform denſity very nearly. A very few examples of the moſt important of the ſimple caſes muſt ſuffice.

108 Action of a plate on a rectilineal canal.

Therefore let AC a (fig. 24.) repreſent the edge of a thin conducting circular plate, to which the ſlender canal CP is perpendicular in the centre. It is required to determine the action of the matter or fluid, uniformly ſpread over this plate, on the fluid moveable in the canal PC?

1. Required the action of a particle in A on the fluid in the whole canal? Join AP; and call CP x, AP y, and AC r; and let f expreſs the intenſity of action at the diſtance 1, or the unit of the ſcale on which the lines are meaſured. 109

The action of A on P, in the direction AP, is $\frac{f}{y^2}$. This, when eſtimated in the direction CD, is reduced to $\frac{f}{y^2} \times \frac{x}{y}$; and is therefore $= f\frac{x}{y^3}$. Therefore the fluxion of the action, in the direction CP, on the whole canal, is $f\frac{x}{y^3}\dot{x} = f\frac{y\dot{y}}{y^3}$ (becauſe $x : y = \dot{y} : \dot{x}) = f \times \frac{\dot{y}}{y^2}$. The variable part of the fluent is $= f\frac{-1}{y}$, and the complete fluent is $= f\left(C - \frac{1}{y}\right)$, where C is a conſtant quantity, accommodated to the nature of the caſe. Now, the action muſt vaniſh when the canal vaniſhes, or when $x = 0$, and $y = r$. Therefore $C - \frac{1}{r} = 0$, and $C = \frac{1}{r}$; and the general expreſſion

preſſion of the action is $f\left(\frac{1}{r}-\frac{1}{y}\right), = f\frac{y-r}{ry}$, expreſſing the action of a particle in the circumference of the plate on the fluid in the whole canal CP.

2. Required the action of the plate, whoſe diameter is A a, on the particle P?

110 1. On a ſingle particle in the canal.

Let a repreſent the area of a circle, whoſe diameter is = 1. Then ar^2 is the area of the plate, and $2a\dot{r}r$ is the fluxion of this area; becauſe $\dot{r}:\dot{y}=y:r$, $2a\dot{r}r$ is $=2ay\dot{y}$. Therefore the fluxion of the action of the plate on the particle P is $f\times 2ay\dot{y}\times\frac{x}{y^3}, = 2fax\times\frac{\dot{y}}{y^2}$. The fluent of this has for its variable part $2fax\times\frac{-1}{y}$ (for when the particle P is given, x does not vary). This is $=2fa\times\frac{-x}{y}$. To complete this fluent, we muſt add a conſtant quantity, which ſhall make the fluent = 0 when the particle P is at an infinite diſtance; and therefore when $x=y$. Therefore $\frac{y}{y}-\frac{x}{y}=0$, or $1-\frac{x}{y}=0$, or C = 1; and the complete fluent for the whole plate is $2fa\left(1-\frac{x}{y}\right)$.

111 The meaning of this expreſſion may not occur to the reader: For $1-\frac{x}{y}$ is evidently an abſtract number; ſo is a. Therefore the expreſſion appears to have no reference to the ſize of the plate. But this agrees with the obſervation in n° 91. where it was ſhewn, that provided the angle of the cone or pyramid remained the ſame, the magnitude of the baſe made no change in its attraction or repulſion for a particle in the vertex.

It will appear by and bye, that $1-\frac{x}{y}$ is a meaſure or function of a certain angle of a cone.

Cor. If PC be very ſmall in proportion to AC, the action is nearly the ſame as if the plate were infinite: For when the plate is infinite, $\frac{x}{y}$ is = 0, and the action is = 1, whatever is the diſtance (ſee n° 91—93). Therefore, when x is very ſmall in compariſon of r, and conſequently of y, $1-\frac{x}{y}$ is very nearly = 1.

112 2. On the whole canal.

3. To find the action of the plate on the whole column?

The fluxion of this muſt be $=2fa\times\left(1-\frac{x}{y}\right)\dot{x}$, or $2fa\left(\dot{x}-\frac{x\dot{x}}{y}\right)$, or $2fa\times(\dot{x}-\dot{y})$; becauſe $\dot{y}=\frac{x\dot{x}}{y}$. The fluent of this has for its variable part $2fa\times(x-y)$. A conſtant quantity muſt be added, which ſhall make it = 0 when the column = 0; that is, when $y=r$, and $x=0$; that is, $C-r=0$, and $C=r$. Therefore the complete fluent is $=2fa(x+r-y)$.

113 Geometrical expreſſion of theſe actions.

Thus have we arrived at a moſt ſimple expreſſion of the attraction or repulſion of a plate for ſuch a column, or for portions of ſuch a column. And it is moſt eaſily conſtructed geometrically, ſo as to give us a ſenſible image of this action of eaſy conception and remembrance. It is as follows: Produce PC till CK = CA, and about the centre P deſcribe the arch AI, cutting CK in I. Then $2fa\times$ IK is evidently the geometrical expreſſion of the attraction or repulſion. This is plainly a cylinder, whoſe radius is a unit of the ſcale, and whoſe height is twice IK.

In like manner, by deſcribing the arch A i round the centre p, we have $2fa\times i$K for the action of the plate on the ſmall column Cp; and $2fa\times$ Ii is the action of the plate on the portion Pp.

The general meaning of the expreſſion $2fa\times$ IK is, that the action of the whole plate on the column PC is the ſame as if all the fluid in the cylinder $a\times 2$ IK, were placed at the diſtance 1 from the acting particle.

From this propoſition may be eaſily deduced ſome very uſeful corollaries by the help of the geometrical conſtruction.

1. If PC be very great in compariſon with AC, the action is nearly the ſame as if the column were infinitely extended; for in this caſe IK is very nearly = CK, the difference being to the whole nearly as AC to twice AP. 114

115 Important corollary.

2. If, in addition to this laſt condition, another column p C be very ſmall in compariſon of AC, then the action on PC is to that on p C very nearly as p C to AC. For it will appear that i K : IK = p C : AC very nearly. It is exactly ſo when CP : CA = CA : C p; and it will always be in a greater proportion than that of p C to IK.

This will be found to be a very important obſervation.

The redundant fluid has hitherto been ſuppoſed to be uniformly ſpread over the plate: but this cannot be; becauſe its mutual repulſion will cauſe it to be denſer near the circumference. We have not determined, by a formula of eaſy application, what will be the variation of denſity. Therefore let us conſider the reſult of the extreme caſe, and ſuppoſe the whole redundant fluid to be crowded into the circumference of the plate, as we ſaw that it muſt be on the ſurface of a globe.

116 Action of a circumference on a canal.

In this caſe the action on the fluid in the canal will be $fa\left(r-\frac{r^2}{y}\right)$. For the area of the plate is ar^2, and the action of a particle in the circumference on the whole canal was ſhewn (n° 109) to be $f\left(\frac{y-r}{ry}\right)$. Therefore the action of the whole fluid crowded into the circumference is $far^2\times\frac{y-r}{ry}, = far\frac{y-r}{y}$. It may be repreſented as follows: Deſcribe the quadrant C b BE, cutting AP and Ap in B and b. Draw BD and b d parallel to PC. Then PB $=y-r$, and DC $=r\frac{y-r}{y}$. Therefore the action is repreſented by f multiplying a cylinder, whoſe radius is 1 and height is DC. In like manner, d C is the height of the cylinder correſponding to the column p C, and D d the height correſponding to P p.

Cor. 1 When CP is very great in compariſon with CA, the point D is very near to A, and I is very near to C, and CD is to IK nearly in the ratio of equality. 117

In

In this caſe the action of the fluid, uniformly ſpread over the plate, is nearly double of the action of the ſame fluid crowded round the circumference; for they are as cylinders, having the ſame baſes and heights in the ratio of 2 IK to DC, which is nearly the ratio of 2 to 1.

118 2. On the other hand, when the column pC is very ſhort, the action of the fluid ſpread uniformly over the plate is to its action, when crowded round the circumference, nearly in the ratio of 4 AC to pC. For theſe actions are in the ratio of $2\,fa \times i$K to $1\,fa \times d$C, or as $2\,i$K to dC, or nearly as $2\,p$C to dC, or more nearly as $2\,bd$ to dC. But C$d : bd = bd : b$A + Ad, or nearly $= bd : 2$CA. Therefore C$d : 2\,bd = p$C : 4 CA nearly.

119 Hence we ſee that the action on ſhort columns is much more diminiſhed by the receſs of the redundant fluid toward the circumference than that on long columns. Therefore, any external electric force which tends to ſend fluid along this canal, and from thence to ſpread it over the plate, will ſend into the place a greater quantity of fluid than if the fluid remained ultimately in a ſtate of uniform diſtribution over its ſurface; and that the odds will be greater when the canal is ſhort.

120
Equivalent centre of action.

Laſtly, on this ſubject, If KL be taken equal to AP, or PL be equal to KI, the repulſion which all the fluid in the plate, collected in K, would exert on the fluid in the canal CL, is equal to the repulſion which the ſame fluid, conſtipated in the circumference, would exert on the column CP. For we have ſeen that the action of a particle in A on the whole column PC, when eſtimated in the direction PC, is $\frac{y-r}{yr}$; and it is well known that the the action of a particle in K for the column CL is $\frac{1}{KC} - \frac{1}{KL}$, or $\frac{1}{r} - \frac{1}{y}$, $= \frac{y-r}{yr}$. Therefore the action of the whole fluid, collected in the circumference, on the column CP is equal to that of the ſame fluid, collected in K, on the columns CL.

121 *Cor.* 1. If the column CP is very long in proportion to AC or KC, the actions of the fluids in theſe two different ſituations are very nearly the ſame. The action of the fluid collected in K exceeds its action when collected in A only by its action on the ſmall and remote column LP. The action of all the fluid collected at K on the column CP, is eaſily had by taking Cl = KP. It is equal to the action of the ſame fluid placed in A on the column Cl.

122 *Cor.* 2. The action of all the fluid uniformly ſpread, exerted on the column CP, is to the action of the ſame fluid collected in K, exerted on the column CL, as 2 IK to CD.

123 If the column CP is very great in proportion to AC, the half breadth of the plate, the action in the firſt caſe is very nearly double of the action in the other caſe, and is exactly in this proportion if CP is of infinite extent.

124
Action of a ſpherical ſurface, or ſhell, or ſolid, on the ſame canal.

Cor. 3. If CNO be a ſpherical ſurface or ſhell of the ſame thickneſs and diameter as the plate Aa, and containing redundant fluid of the ſame uniform denſity, the action of this fluid on the column CL is double of the action of the fluid uniformly ſpread over the plate on the column CP, and quadruple of the action of the fluid collected in the circumference: for the action is the ſame as if all were collected in the centre K, and the ſurface of the ſphere is four times that of the plate, and therefore they are as IK to 2 CD.

Let us now conſider the comparative actions of different plates or ſpheres on the canals.

125
Actions of two plates, or two ſpheres, are as their diameters, when the canals are infinitely long.

If two circular plates, DE, de (fig. 25.), or two ſpherical ſhells, ABO, abo, of equal diameters and thickneſs with the plates, and containing redundant fluid of equal denſity, communicate with infinitely extended ſtraight canals OP, op, paſſing through their centres perpendicular to their ſurfaces, alſo containing fluid uniformly diſtributed and of equal denſity—the repulſions will be as the diameters. For the repulſion of the ſpherical ſurfaces is the ſame as if all the fluid were collected at their centres; and the repulſion of the fluid uniformly ſpread over the ſurfaces of the plates is double of its repulſion if collected at the centres of theſe ſpheres; it follows, that the repulſions of the plates are proportional to thoſe of the ſphere. But becauſe the repulſion of a plate whoſe radius is r was ſhewn to be $= 2a \times \overline{r+x-y}$, and when the column is infinitely extended, x is equal to y, and $\overline{r+x-y} = r$, it follows, that the repulſions of the plates are as $2a \times R$ and $2a \times r$, or proportional to their diameters. Therefore the repulſions of the ſpheres are in the ſame proportion.

Cor. 1. If the canals are very long in proportion to the diameters of the plates or ſpheres, the repulſions are nearly in the ſame proportion. 126

127
The proportion of the greateſt action is diminiſhed if the canals are ſhort.

Cor. 2. But as the lengths of the canals diminiſh, the repulſions approach to equality; for it was ſhewn, that when the canal was very ſmall, the repulſion was to that for an infinite column as the length of the canal to the radius of the plate. Therefore if the radius of the greater plate be (for example) double of that of the ſmaller, and the little columns be $\frac{1}{20}$th of the radius, it will be $\frac{1}{10}$th of the radius of the ſmaller plate. Now $\frac{1}{10}$th of half the repulſion is equal to $\frac{1}{20}$th of the double repulſion. Alſo, in the caſe of the ſpheres, the repulſion of a particle at the ſurface is as the quantity of fluid directly, and as the ſquare of the radius inverſely; but when the denſity is the ſame in both ſhells, the quantity is as the ſurface, or as the ſquare of the radius. Therefore the repulſions are equal.

128
Actions of two ſpheres are equal if the denſity be inverſely as the diameters;

Cor. 3. If the denſity of the fluid in two ſpherical ſhells be inverſely as the diameters, the repulſions for an infinitely extended column of fluid are equal; for each repels as if all the fluid was collected in the centre. Therefore, if the denſity, and conſequently the quantity, be varied in any proportion, the repulſion will vary in the ſame proportion. The repulſions will now be as $CO \times \frac{1}{CO}$ to $co \times \frac{1}{co}$, or in the ratio of equality.

129
Or if the quantity of redundant fluid be as the diameters.

Cor. 4. When the quantities of redundant fluid in two ſpheres are proportional to their diameters, their repulſions for an infinitely extended canal are equal: for if this redundant fluid is conſtipated in the ſurfaces of the ſpheres, as it always will be when they conſiſt of conducting matter, the denſities are as the diameters inverſely, becauſe the ſurfaces are as the ſquares of the diameters. Therefore, by the laſt corollary, their actions on an infinitely extended canal are equal. But in ſpheres of non-conducting matter it may be differently, diſpoſed, in concentric ſhells of uniform denſity.

This makes no change in the action on the fluid that is without the ſphere, becauſe each ſhell acts on it as if it were all collected in the centre. Therefore the repulſions are ſtill equal.

130 Two ſpheres overcharged in this proportion are in equilibrio if communicating by a very long canal.

Cor. 5. Two overcharged ſpheres, or ſpherical ſhells, OAB, *o a b* (fig. 26.), communicating by an infinitely extended canal of conducting matter, contain quantities of redundant fluid proportional to their diameters; for their actions on the fluid in the interjacent canal muſt be in equilibrio, and therefore equal. This will be the caſe only when the quantities of fluid are in the proportion of their diameters.

When the canals are very long in proportion to the diameters of the ſpheres, the proportion of the quantities of redundant fluid will not greatly differ from that of the diameters.

131 *Cor.* 6. When the ſpheres of conducting matter are thus in equilibrio, the preſſures of the fluid on their ſurfaces are inverſely as their diameters; for the repulſion of a particle at the ſurface is the ſame with the tendency of that particle from the centre of the ſphere, the actions being mutual. Now this is proportional to the quantity of redundant fluid directly, and to the ſquare of the diſtance from the centre inverſely, that is, to the diameter directly, and to the ſquare of the diameter inverſely, that is, to the diameter inverſely.

Tendency of the fluid to eſcape is inverſely as the diameter.

Hence it follows, that the tendency to eſcape from the ſpheres is inverſely as the diameter, all other circumſtances being the ſame: for in as far the eſcape proceeds from mere electric repulſion, it muſt follow this proportion. But there are evident proofs of the co-operation of other phyſical cauſes. We obſerve chemical compoſitions and decompoſitions accompanying the eſcape of electric fluid, and its influx into bodies: we are ignorant how far, and in what manner, theſe operations are affected by diſtance. Boſcovich ſhews moſt convincingly, that the action of a particle (of whatever order of compoſition), on external atoms and particles, is ſurpriſingly changed by a change in the diſtance and arrangement of its component atoms. A conſtipation, therefore, to a certain determined degree and lineal magnitude, may be neceſſary for giving occaſion to ſome of thoſe chemical operations that accompany, and perhaps occaſion, the eſcape of the electric fluid. If this be the caſe (and it is *demonſtrable* to be poſſible, if the operations of Nature be owing to attractions and repulſions), the eſcape *muſt* be deſultory. It is actually ſo; and this confirms the opinion.

The public is indebted to Mr Cavendiſh for the preceding theorems on the action of ſpheres and circular plates. He has given them in a more abſtract and general form, applicable to any law of electric action which experience may warrant. We have accommodated them to the inverſe duplicate ratio of the diſtances, as a point ſufficiently eſtabliſhed; and we hope that we have rendered them more ſimple and perſpicuous. We have availed ourſelves of Mr Coulomb's demonſtration of the uniform denſity in the canal, without which the theorems could not have been demonſtrated. The minute quantity of the fluid in the canal can have no ſenſible effect on the diſpoſition or proportion of the fluid in the plates or ſpheres.

It may be thought that the laſt corollary, reſpecting the equilibrium of two ſpheres, is not agreeable to hydroſtatical principles, which require the equality of the two forces which balance each other at the orifices of the ſlender cylindric canal; whereas, in that corollary the forces at the extremities of the canal are inverſely as the diameters of the ſpheres or plates. This would be a valid objection, if the compreſſing forces acted only on the extremities of the canals; but they act on every particle through their whole length. It is not, therefore, the preſſure at one end of the canal that is in equilibrio with the preſſure at the other end, by the interpoſition of the fluid. It is the preſſure at one end, together with the ſum of all the intermediate preſſures in that direction, that is in equilibrio with all the preſſure in the oppoſite direction. The preſſures at the ends are only parts of the whole oppoſite preſſures; they are the firſt in each account. In this manner a ſlender pipe, having a ball at each end, may be kept filled with mercury, while lying horizontal, if the air in each ball is of equal denſity. But if it be raiſed perpendicular to the horizon, it cannot remain filled from end to end, unleſs the air of the ball below be made ſo elaſtic by condenſation, that its preſſure on the lower orifice of the pipe exceed the preſſure of the air in the upper ball on the other orifice by a force equal to the weight of the mercury, that is, to the aggregate of the action of gravity on each particle of mercury in the pipe. Therefore the repulſions of the ſpheres that we are ſpeaking of are in equilibrio by the intervention of the fluid in the canal, in perfect conſiſtency with the laws of hydroſtatical preſſure.

This propoſition agrees with hydroſtatical laws.

Mr Cavendiſh has purſued this ſubject much farther, and has conſidered the mutual action of more than two bodies, communicating with each other by canals of moveable fluid uniformly denſe. But as we have not room for the whole of his valuable propoſitions, we ſelected thoſe which were elementary and leading theorems, or ſuch as will enable us to explain the moſt important phenomena. They are alſo ſuch, as that the attentive reader will find no difficulty in the inveſtigation of thoſe which we have omitted.

Mr Cavendiſh's moſt general propoſition is as follows: 132

General propoſition with reſpect to the ſtate of communicating bodies.

When an overcharged body communicates, by a canal of *very great* length, ſtraight or crooked, with two or more ſimilar bodies, alſo at a very great diſtance from each other, and all are in electric equilibrium, and conſequently each body overcharged in a certain determined proportion, depending on its magnitude, if any two of theſe bodies are made to communicate in the ſame manner, their degrees of electricity are ſuch, that no fluid will paſs from one to the other, their mutual actions on the fluid in this canal being alſo in equilibrio. He brings out this by induction and combination of the ſingle caſes, each of which he demonſtrates by means of the following theorem:

The action of an overcharged ſphere ACB (fig. 25.) on the fluid in the whole of a canal *d f* P that is oblique tending to impel the fluids in the direction of that canal, is equal to its action on the fluid in the whole of the rectilineal canal CP. Let *h i* be a minute portion of the ſtraight canal, and *f d* the portion of the crooked canal which is equidiſtant from the centre C of the ſphere; draw the radii C *f* C *d*, and the concentric arches *h f*, *i d*, cutting *f* C in *g*; and draw *g e* perpendicular to *f d*; the force acting on *i h*, impelling it toward P, may be repreſented by *h i*. The 133

It is indifferent whether the canal be ſtraight or crooked.

ſame

ſame force acting on df, in the direction cf, muſt therefore be expreſſed by gf. This, when eſtimated in the direction of the canal df, is reduced to ef; but it is exerted on each particle of df. Now $df : gf = gf : ef$, and $df \times ef = gf^2, = gf \times hi$; therefore the whole force on df, in the direction df, is equal to the force on ih, in the direction ih. Hence the truth of the propoſition is manifeſt.

We beg the curious reader to apply this to the caſe in hand, and he will find, that the moſt complicated caſes may all be reduced to the ſimple ones which we have demonſtrated to be ſtrictly true when the bodies are ſpheres or plates, and the canals infinitely long and which are very nearly true when the canals are *very long*, and the bodies ſimilar: And we now proceed to one compound caſe more, which includes all the moſt remarkable phenomena of electricity.

134 Curious and very important caſe of four plates.

Let HK, AB, DF, and LM (fig. 27,.) be four parallel and equal circular plates, two of which, HK and AB communicate by a canal GC of indefinite extent, joining their centres, and perpendicular to their planes; let DF and LM be connected in the ſame manner, and let the two canals be in one ſtraight line: let the plate HK be overcharged, and the plate LM juſt ſaturated. It is required to determine the diſpoſition and proportion of the electric fluid in the plates which will make this condition of HK and LM poſſible and permanent, every thing being in equilibrio?

The plate HK being overcharged, and communicating with AB, AB, muſt be overcharged in the ſame manner, and being alſo equal to HK, it muſt be overcharged in the ſame degree containing an equal quantity of redundant fluid diſpoſed in the ſame manner. To ſimplify the inveſtigation, we ſhall firſt ſuppoſe that the redundant fluid is uniformly ſpread over the ſurfaces of both.

When the plates HK and AB are in this ſtate, let the plates DF and LM be brought near them, as is repreſented in the figure, CE being the diſtance of the centres of AB and DF. It is evident, that the redundant fluid in AB will act on the natural moveable fluid in DF, and drive ſome of it along the canal EN, and render LM overcharged. Take off this redundant fluid in LM. This will diminiſh or annihilate the repulſion which it was beginning to exert on the canal EN; therefore more fluid will come out of DF, and again render LM overcharged. The redundant fluid in LM may again be taken off, in leſs quantity than before, as is plain. Do this repeatedly till no more can be taken off. But this will undoubtedly render DF undercharged, and it will now contain redundant matter. This will act on the fluid in the canal GC, and abſtract it from G; therefore fluid will come out of HK into AB. HK will be leſs overcharged than before, and AB will be more overcharged. But the now increaſed quantity of redundant fluid in AB will act more ſtrongly on the moveable fluid in DF, and drive more out of it. This will leave more redundant matter in it than before, and this will act as before on the fluid in the canal GC. This will go on, by repeatedly touching LM, till at laſt all is in equilibrio. Or this ultimate ſtate may be produced at once by allowing LM to communicate with the ground. And now, in this permanent ſtate of things, HK contains a certain quantity of redundant fluid; AB contains a greater quantity; DF contains redundant matter; and LM contains its natural quantity. The demand of the problem therefore is to determine the proportion of the redundant fluid in HK to that in AB, and the proportion of the redundant fluid in AB to the deficiency of fluid in DF. The dynamical conſiderations which determine theſe proportions are, *1ſt*, The repulſion of the redundant fluid in AB, for the fluid in the canal EN, muſt be preciſely equal to the attraction of the redundant matter in DF for the ſame fluid in the canal; for LM being ſaturated, is neutral. *2d*, The repulſion of the redundant fluid in HK, for the whole fluid in the canal GC, muſt balance the exceſs of the repulſion of the redundant fluid in AB above the attraction of the redundant matter in DF for the ſame.

Let the redundant fluid in AB be $= f$.
the redundant matter in DF $= m$.
the redundant fluid in HK $= F$.

Becauſe HK and AB are equal, there can be no doubt but that the fluid in thoſe plates would be ſimilarly diſpoſed; and it is highly probable, that if AB be very near DF, the redundant fluid in AB, and the redundant matter in DF will alſo be diſpoſed nearly in the ſame manner. This will appear plainly when we conſider with attention the forces acting between a very ſmall portion of AB and the correſponding portion of DF. The probability that this is the caſe is ſo evident, that we apprehend it unneceſſary to detail the proofs. We ſhall afterwards conſider ſome circumſtances which ſhew that the diſpoſition in the three plates will (though nearly ſimilar) be nearer to a ſtate of uniform diſtribution than if only AB and HK had been in action. Aſſuming therefore this ſimilarity of diſtribution, it follows, that their actions on the fluid in the canals will be ſimilar, and nearly proportional to their quantities.

Therefore let 1 be to n as the repulſion of the fluid in AB, for the fluid that would occupy CE, is to its repulſion for the fluid in EN or CG.

Then the action of AB on EN is $f \times \overline{n-1}$, and the action of DF on EN is mn; therefore, becauſe the plate LM is inactive, the actions of AB and DF on EN muſt balance each other, and $f \times \overline{n-1} = mn$, and $m = f \times \frac{n-1}{n}$.

The repulſion of f for the fluid in CG is fn. The attraction of m for it is $m \times \overline{n-1}$; and becauſe $m = f \times \frac{n-1}{n}$, the attraction of m for the fluid in CG is $f \times \frac{\overline{n-1}}{n} \times \overline{n-1}$. Therefore the repulſion of f is to the attraction of m as fn to $f \times \frac{\overline{n-1}^2}{n}$, or as fn^2 to $f \times \overline{n-1}^2$, or as n^2 to $\overline{n-1}^2$. Call the repulſion of f r, and the attraction of m a.

We have $r : a = n^2 : \overline{n-1}^2$
and $r : r-a = n^2 : n^2 - (n-1)^2 = n^2 : 2n-1$.

Therefore, becauſe the repulſion of F is equal to this exceſs of r above a, we have $n^2 : 2n-1 = f : F$, and $F = f\frac{2n-1}{n^2}$, or $f = F\frac{n^2}{2n-1}$. Therefore, if n^2 is much greater than $2n-1$, the quantity of redundant fluid

fluid in AB will be much greater than the quantity in HK.

135 Prodigious accumulation of redundant fluid;

Now, when the electric action is inversely as the square of the distance, and EC is very small in comparison with AC, we have seen (nº 115.) that 1 : n nearly = CE : CA, or that n is nearly $\frac{AC}{EC}$. When this is the case, and consequently n is a considerable number, we may take the number $\frac{n^2}{2n}$ for $\frac{n^2}{2n-1}$ without any great error. In this case f is equal to $F\times\frac{n}{2}$ very nearly. Suppose CA to be six inches, and CE to be $\frac{1}{20}$th of an inch; this will give $n = 120$, and $f = 60$ F; or, more exactly, $F = \frac{n^2}{2n-1} = \frac{14,400}{239}$; $= 60\frac{1}{4}$. If, instead of the plate HK, we employ a globe of the same diameter, f will be but half of this quantity, or $f = F\times\frac{n}{4}$ (nº 123 124.).

136 And evacuation:

It also appears, that when the plates AB and DF are very near to each other, and consequently n a large number, the deficiency in DF is very nearly equal to the redundancy in AB. In the example now given, m is $\frac{59}{60}$ of f, being $= f\times\overline{n-1}$.

137 Yet no very sensible appearance.

Yet this great deficiency in DF does not make it electrical on the side toward LM. It is just so much evacuated, that a particle of fluid at its surface has no tendency to enter or to quit it.

Lastly, this great quantity of fluid collected in AB does not render it more electrical than HK.

In general, things are in the condition treated of in nº 22, 23, &c.

The attentive reader will readily see, that this account of the apparatus of four plates is only an approximation to the condition that really obtains under our observation. Our canals are not of indefinite length, nor occupied by fluid that is distributed with perfect uniformity; nor is the fluid uniformly spread over the surface of the plates. He will also see, that the real state of things, as they occur in our experiments, tends to diminish the great disproportion which this imaginary statement determines. But when the canals are very long, in comparison with the diameters of the plates, and AB is very near to DF, the difference from this determination is inconsiderable. We shall note these differences when we consider the remarkable phenomena that are explained by them.

In the mean time, we shall just mention some simple consequences of the present combination of plates.

138 Method of destroying this great accumulation: 1. By degrees;

Suppose AB touched by a body. Electric fluid will be communicated. But by no means all the redundant fluid contained in AB: only as much will quit it as will reduce it to a neutral state, if the body which touches it communicates with the ground; that is, till the attraction of the redundant matter in DF attracts fluid on the remote side of AB as much as the redundant fluid left in AB repels it. When this has been done DF is no longer neutral; for the repulsion of AB for the fluid in EN is now diminished, and therefore the attraction of DF will prevail. If we now touch DF, it may again become neutral with respect to EN; but AB will now repel again the fluid in CG, and again be electric on that side by redundancy. Touching AB a second time takes more fluid from it, and DF again becomes electric by deficiency, and attracts fluid on that side.—And thus, by repeatedly touching AB and DF alternately, the great accumulation of fluid in AB may be exhausted, and the nearly equal deficiency in DF may be made up.

139 2. All at once.

But this may be done in a much more expeditious way. Suppose a slender conducting canal $a\ b\ d$ brought very near to the outsides of the plates, the end a being near to A, and the end d to D. The vicinity of a to A causes the fluid in $a\ b$ to recede a little from a by the repulsion of the redundant fluid in AB. This will leave redundant matter in a, which will strongly attract the redundant fluid from A, and a may receive a spark. But the consequence, even of a nearer approach of the fluid to the outward surface of A, will render the corresponding part of DF more attractive, and the retiring of fluid from a along $a\ b$ will push some of its natural fluid toward d; and thus A becomes more disposed to give out, and a to take it in, while d is disposed to emit, and D to attract. Thus, every circumstance favours the passage of the whole, or almost the whole, redundant fluid to quit AB at A, to go along $a\ b\ d$, and to enter into DF at D.

140 The plates strongly attract each other.

It is plain, that there must be a strong tendency in the fluid in AB to go into DF, and that the plates must strongly attract each other. A particle of fluid situated between them tends toward DF with a force, which is to the sole repulsion of AB nearly as twice the redundant fluid in it to what it would contain if electrified to the same degree while standing alone.

With this particular and remarkable case of induced electricity, we shall conclude our explanation of Mr Æpinus's Theory of Electric Attraction and Repulsion. The reader will recollect, that we began the consideration of the disposition of the electric fluid in bodies, in order to deduce such legitimate consequences of the hypothetical law of action as we could compare with the phenomena.

141 Method of examining the validity of this theory.

These comparisons are abundantly supplied by the preceding paragraphs, particularly by nº 74, 75, 76; by nº 130, and by nº 134.

Let a smooth metal sphere be electrified positively in any manner whatever, and then touch it with a small one in its natural state. The redundant fluid is divided between them in a proportion which the theory determines with accuracy. By the theory also the redundant fluid in both acts as if collected in the centre. Therefore the proportion of the repulsions is determined. These can be examined by our electrometer. But, as this mensuration may be said to depend on the truth of the theory, we may examine this independent of it. Let the balls be equal. Then the redundant fluid is divided equally between the bodies, whatever be the law of action. Therefore observe the electrometer, as it is affected by the electrified body, both before and after the communication. This will give the positions of the electrometer which correspond to the quantities 2 and 1.

142 Graduation of electrometer.

Take off the electricity of one of the balls by touching it, and then touch the other ball with it. This will

will reduce to $\frac{1}{2}$ the original quantity $\frac{1}{4}$, and therefore to $\frac{1}{8}$th of the original quantity. This will determine the value of another position of the electrometer. In like manner, we obtain $\frac{1}{8}$th, $\frac{1}{16}$th, &c. &c. Then, by touching a ball containing 1 with a ball containing $\frac{1}{2}$, we get a position for $\frac{3}{4}$, $\frac{3}{8}$, $\frac{3}{8}$, &c. Proceeding in this way, we graduate our electrometer independently of all theory, and can now examine the electricity of bodies with confidence. The writer of this article took this method of examining his electrometer, not having then seen Mr Cavendish's dissertation, which gives another mode of measurement. He had the satisfaction of observing, in the first place, that the positions of the instrument which unquestionably indicated 1, $\frac{1}{2}$, $\frac{1}{4}$, &c. were precisely those which should indicate them if electric repulsion be inversely as the squares of the distances. Having thus examined the electrometer, it was easy to give to balls any proposed degree of electricity, and then make a communication between balls of very different diameters. The electrometer informed us when the repeated abstractions by a small ball reduced the electricity of a large ball to $\frac{1}{2}$, $\frac{1}{4}$, &c. This shewed the proportion of electricity contained in balls of different diameters. This was also found to be such as resulted from an action in the inverse duplicate ratio of the distances.

143 Long after this, Mr Cavendish's investigation pointed out the proportion of the redundant electric fluid in balls of different sizes joined by long wires; in n° 130, &c. these were examined—and found to be such as were so indicated by the electrometer.

144 And, lastly, the mode of accumulating great quantities of fluid by means of parallel plates, gave a third way of confronting the hypothetical law with experiment. The argument was no less satisfactory in this case; but the examination required attention to particulars not yet mentioned, which made the proportions between the fluid in HK and AB (fig. 27.) widely different from those mentioned in the preceding paragraphs. These circumstances are among the most curious and important in the whole study, and will be considered in their place.

145 The law of electric action is well determined.

We rest therefore with confidence on the truth of the law of electric action, assumed by us as a principle of explanation, and investigation. It is quite needless and unprofitable to give any detail of the numerous experiments in which we confronted it with the phenomena. The scrupulous reader will get ample satisfaction from the excellent experiments of Mr Coulomb with his delicate electrometer. He will find them in the Memoirs of the Academy of Sciences of Paris for 1784, 1785, 1786, and 1787. Some of them are of the same kind with those employed by the writer of this article; others are of a different kind; and many are directed to another object, extremely curious and important in this study, namely, to discover how the electric fluid is disposed in bodies; and a third set are directed to an examination of the manner in which the electric fluid is dissipated along imperfect conductors.

But we have already drawn this article to a great length, and must bring it to an end, by explaining some very remarkable phenomena, namely, the operation of the Leyden phial, the operation of the electrophorus, and the dissipation of electricity by sharp points and by imperfect conductors.

146 Of the Leyden phial.

The observations of Mr Watson on the necessity of connecting the rubber of an electrical machine with the ground, might have suggested to philosophers the doctrine of *plus* and *minus* electricity, especially after the valuable discoveries of Mr Symmer and Cigna. A serious consideration of these general facts would have led to the theory of coated glass almost at its first appearance. But the historical fact was otherwise; and a considerable time elapsed between the first experiments with charged glass by Kleist, and the clear and satisfactory account given by Dr Franklin, of all the essential parts of the apparatus, and the probable procedure of nature in the phenomenon. The impermeability of glass by the electric fluid, and the consequent abstraction of it from the one side while it was accumulated on the other, suggested to his acute mind the leading principle of electrical philosophy; namely, that all the phenomena arise from the redundancy or deficiency of electric fluid, and that a certain quantity of it resides naturally in all bodies in a state of uniform distribution, and, in this state, produces no sensible effect. This was, in his hands, the inlet to the whole science; and the greatest part of what has been since added is a more distinct explanation how the redundancy or deficiency of electric fluid produces the observed phenomena. Dr Franklin deduced this leading principle from observing, that as fast as one side of a glass plate was electrified positively, the other side appeared negative, and that, unless the electricity of that side was communicated to other bodies, the other side could be no farther electrified. Having formed this opinion, the old observations of Watson, Symmer, and Cigna, were explained at once, and the explanation of the Leyden phial would have come in course. It is for these reasons, as much as for the important discovery of the sameness of electricity and of thunder, that Dr Franklin stands so high in the rank of philosophers, and is justly considered as the author of this department of natural science. Whatever credit may be due to the chemical speculations of De Luc, Wilcke, Winkler, and many others, who have attempted to associate electricity with other operations of nature, by resolving the electric fluid into its constituent parts, all their explanations presuppose a mathematical and mechanical doctrine concerning the mode of action of the ingredients, which will either account for the total inactivity of the compound, or which will explain, in the very same manner, the action of the compound itself: yet all seem to content themselves with a vague and indistinct notion of this preliminary step, and have allowed themselves to speak of electrical atmospheres, and spheres of activity, and such other creatures of the mind, without once taking the trouble of considering whether those assumptions afforded any real explanation. How different was Newton's conduct. When he discovered that the planets attracted each other in the inverse duplicate ratio of the distances, and that terrestrial gravity was an instance of the same force, and that *therefore* the deflection of the earth was the effect of the accumulated weight of all its parts; he did not rashly affirm this of the planets, till he examined what would be the effect of the accumulated attraction in the abovementioned proportion.

Mr Æpinus has the honour of first treading in the steps of our illustrious countryman; and he has done it 147 it with singular success in the explanation of the phenomena of attraction and repulsion, as we have already seen. In no part of the study has his success been so conspicuous as in the explanation of the curious and important phenomena of the Leyden phial. It only remained for him to account for the accumulation of such a prodigious quantity of this agent as was competent to the production of effects which seemed to exceed the similar effects in other cases, out of all proportion. Indeed, the disproportion is so great, as to make them appear to be of a different and incomparable nature. Dr Wilson's experiments in the pantheon are therefore precious, by shewing that nothing was wanted for the production of all the effects of the Leyden phial but a surface sufficiently extensive for containing a vast quantity of fluid, and so perfectly conducting as to admit of its simultaneous and rapid transference. Therefore we assert, that one of the chief merits of Mr Æpinus's theory is the satisfactory explanation of the accumulation of this vast quantity of fluid in a small space. We trust, therefore, that our readers will peruse it with pleasure. But we must here observe, that Mr Æpinus has not expressly done this in the work which we have already made so much use of, nor in any other that we know of. He has gone no farther than to point out to the mathematicians, that his hypothesis is adequate to the accounting for any degree of accumulation whatever. This he does in that part of his work which contains the formulæ of n° 38, 39, 40, 41, &c. And he afterwards shews, that all the phenomena of attraction and repulsion which are observed in the charged jar are precisely such as are necessary consequences of his theory.

148 Theory of charged glass completed by Mr Cavendish.

It is to the Hon. Mr Cavendish that we are indebted for the satisfactory, the complete (and we may call it *the proper*), explanation of all the phenomena. Forming to himself the same notion of the mechanical properties of the electric fluid with Mr Æpinus, he examined, with the patience, and much of the address, of a Newton, the action of such a fluid on the fluid around it, and the sensible effects on the bodies in which it resided; the disposition of it in a considerable variety of cases; and particularly its action on the fluid contained in slender canals and in parallel plates;—till he arrived at a situation of things similar to the Leyden phial. And he then pointed out the precise degree of accumulation that was attainable, on different suppositions concerning the law of electric action in general. We have given an abstract of this investigation accommodated to the inverse duplicate ratio of the distances.

149 From this it appears (n° 135), that whatever quantity of electric fluid we can put into a circular plate 12 inches in diameter, by simple communication with the prime conductor of an electrical machine, we can accumulate 60 times as much in it by bringing the plate within $\frac{1}{10}$th of an inch of another equal plate which communicates with the ground; and it appears in n° 139, that all this accumulated fluid may be transferred in an instant to the other plate (which is shewn to be almost equally deprived of fluid), by connecting the two plates by a small wire.

But as it was also shewn in that paragraph, that the force with which the accumulated fluid was attracted by the redundant matter in the other plate was exceedingly great, and consequently its tendency to escape was proportionably increased; this accumulation cannot be obtained unless we can prevent this spontaneous transference.

150 Inexplicable by material atmospheres.

Here the non-conducting power of idio-electrics, without any diminution, the action of the electric fluid on fluid or matter on the other side of them, comes to our aid, and we at once think of interposing a plate of glass, or wax, or rosin, or any other electric, between our conducting plates. Such is the immediate suggestion of a person's mind who entertains the Æpinian notion of the electric fluid; and such, we are convinced, is the thought of all who imagine that they understand the phenomena of the Leyden phial. But those who attempt to explain electric action by means of what they call electric atmospheres of variable density or intensity, are not intitled to make any such inference, nor to expect any such phenomena as the Leyden phial exhibits. Electricity, they say, acts by the intervention of atmospheres: Therefore, whatever allows the propagation of this action (conceive it in any manner whatever), allows the propagation of these agents; and whatever does not conduct electric action, does not conduct the agents. Interposed glass should therefore prevent all action on the other plate. This is true, even although it were possible (which we think it is not) to form a clear notion of the free passage of this material atmosphere in an instant, and this without any diminution of its quantity, and consequently of its action, by the displacement of so much of it by the solid matter of the body which it penetrates. Yet without this undiminished action of the electrified plate on the fluid, and on the matter, beyond the glass, and on the canal by which its fluid may be driven off into the general mass—no such accumulation can take place; and if the phenomena of the Leyden phial are agreeable to the results of the Æpinian hypothesis, all explanation by atmospheres must be abandoned. Indeed when the partisans of the atmospheres attempt to explain their conceptions of them, they do not appear to differ from what are called *spheres of activity* a phrase first used by Dr Gilbert of Colchester, in his celebrated work *De Magnete et Corporibus Magneticis*): and spheres of activity will be found nothing more than a figurative expression of some indistinct conception of *action in every direction*. When we use the words *attraction* and *repulsion*, we do not speak a whit more figuratively than when we use the general word *action*. These terms are all figurative, only *attraction* and *repulsion* have the advantage of specifying the *direction* in which we conceive the *action* to be exerted.

It therefore becomes still more interesting to the philosopher to compare the phenomena of CHARGED GLASS with the Æpinian theory. They afford an *experimentum crucis* in the question about electric atmospheres.

151 Phenomena of charged glass explained.

Let G (fig. 28.) represent the end of a prime conductor, furnished with Henley's electrometer. Let AB represent a round plate of tinfoil, pasted on a pane of glass which exceeds the tinfoil about two inches all round. The pane is fixed in a wooden foot, that it may stand upright and be shifted to any distance from the conductor. DF represents another plate of the same dimensions as AB, in the centre of which is a wire EN, having a small ball on the end N, to which is attached a Canton's electrometer. This wire passes through the wooden ball O, fastened to the insulating stand

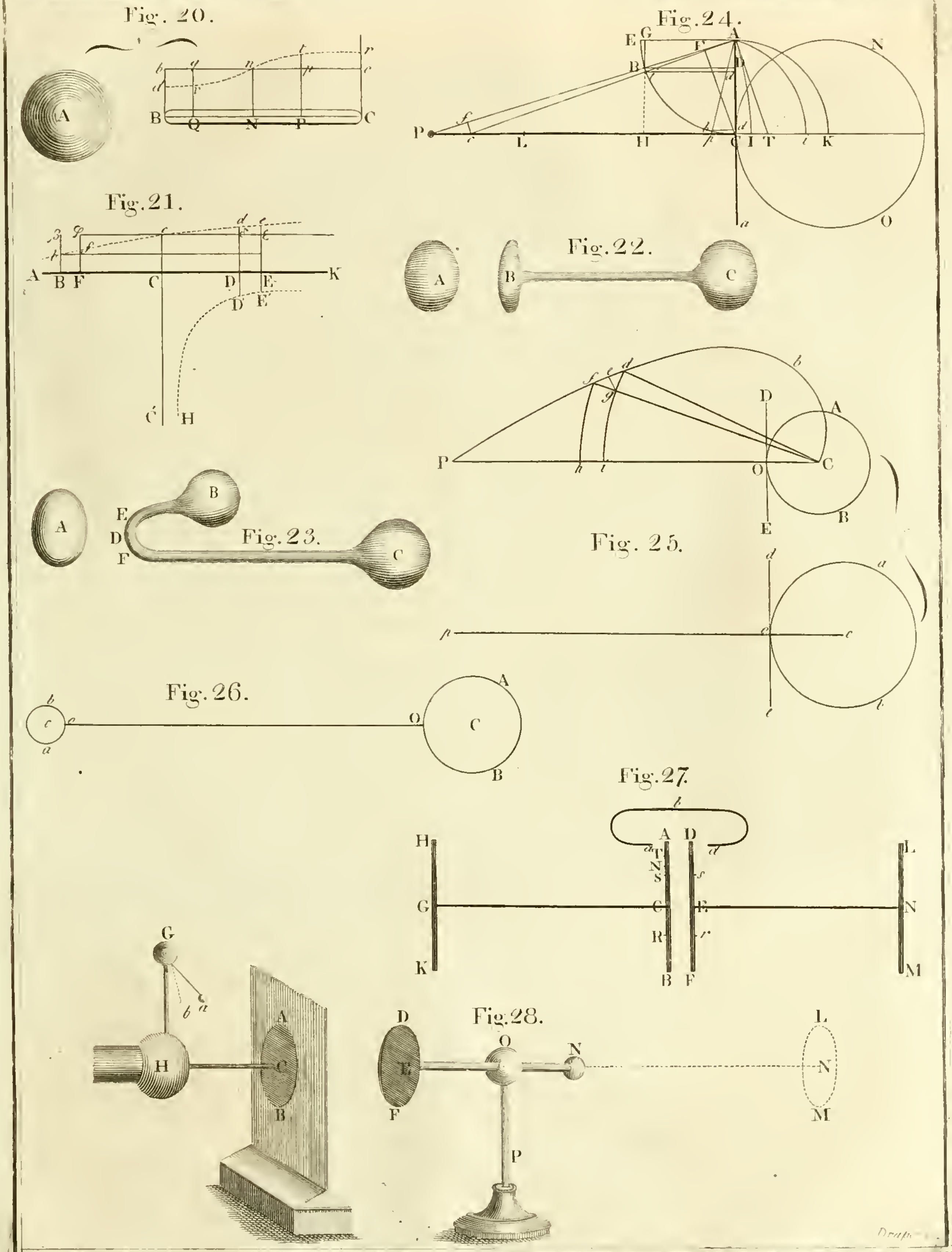


Fig. 20.
Fig. 21.
Fig. 22.
Fig. 23.
Fig. 24.
Fig. 25.
Fig. 26.
Fig. 27.
Fig. 28.

ſtand P. The glaſs pane muſt be very clean, dry, and warm. Connect the conductor G with AB by a wire reaching to the centre C. Turn the cylinder of the electrical machine ſlowly, till the electrometer riſe to 30° or 40°, and note the number of turns. Take off the electricity, and having taken away the connecting wire GC, turn the machine again till the electrometer riſe to the ſame height. The difference in the number of turns will give ſome notion of the expenditure of fluid neceſſary for electrifying the plate of tinfoil alone. This will be found to be very trifling when the electricity is in ſo moderate a degree. It is proper, however, to keep to this moderate degree of electrification, becauſe when it is much higher, the diſſipation from the edges of the plate is very great. Replace the wire, and again raiſe the electrometer to 30°. Now bring forward the plate DF, keeping it duly oppoſite and parallel to AB, and taking care not to touch it. It will produce no ſenſible change on the poſition of the electrometer till it come within four or three inches of the glaſs pane; and even when we bring it much nearer (if a ſpark do not fly from the glaſs pane to DF), the electrometer HG will ſink but two or three degrees, and the electrometer at N will be little affected. Now remove the plate DF again to the diſtance of two or three feet, and attach to its ball N a bit of chain, or ſilver or gold thread, which will trail on the table. Again, raiſe the electrometer, to 30°, and bring DF gradually forward to AB. The electrometer HG will gradually fall down, but will riſe to its former height, if DF be withdrawn to its firſt ſituation. It is ſcarcely neceſſary to ſhew the conformity of this to the theory contained in nº 134, 135, &c. As the plate DF approaches, the redundant fluid in AB acts on the fluid in DF, and drives it to the remote end of the wire EN, as was ſhewn by the divergency of the balls at N; and then an accumulation begins in AB, and the electrometer HG falls, in the ſame manner as if part of the fluid in the prime conductor were communicated to AB. When DF communicates with the ground, the electrometer at N cannot ſhew any electricity, but much more fluid is now driven out of DF, in proportion as it is brought nearer to AB. Inſtead of connecting AB immediately with the prime conductor, let the wire GC have a plate at the end G, of the ſame dimenſions as AB, having an electrometer attached to the ſide next to AB. Let this apparatus of two plates be electrified any how, and note the divergency of the electrometer at H, before DF, communicating with the ground, is brought near it, and then attend to the changes. We ſhall find the divergency of this electrometer correſpond with the diſtance of DF very nearly as the theory requires.

152 State of the coatings.

While the plates AB and DF are near each other, eſpecially when DF communicates with the ground, if we hang a pith-ball between them by a ſilk thread, it will be ſtrongly attracted by the plate which is neareſt to it, whether DF or AB; and having touched it, it will be briſkly repelled, and attracted by the glaſs pane, which will repel it after contact, to be again attracted and repelled by DF; and thus bandied between the plates till all electricity diſappear in both, the electrometer attached to H deſcending gradually all the while.

153 As all theſe phenomena are more remarkable in proportion as the plates are brought nearer, they are moſt of all when DF is applied cloſe to the glaſs pane. And if, in this ſituation, we take any accurate method for meaſuring the intenſity of the electricity in the plate HG, before the approach of DF, we ſhall find the diminution, occaſioned by its coming into full contact with the pane, conſiderably greater than what is pointed out in nº 135. When we employed plates of 12 inches diameter, paſted on a pane one-fortieth of an inch in thickneſs, we found the diminution not leſs than 199 parts of 200; and we found that it required at leaſt 200 times the revolution of the cylinder to raiſe the electrometer to the ſame height as before. This compariſon is not ſuſceptible of great accuracy, by reaſon of many circumſtances, which will occur to an electrician. But in all the trials we have made, we are certain that the accumulation greatly exceeded that pointed out by the Æpinian theory as improved by Mr Cavendiſh. And we muſt here obſerve, that we found this ſuperiority more remarkable in ſome kinds of glaſs than others, and more remarkable in ſome other idioelectrics. We think that in general it was moſt remarkable in the coarſe kinds of glaſs, provided they were uniformly tranſparent. We found it moſt remarkable in ſome common glaſs which had exfoliated greatly by the weather: but we alſo found that ſuch glaſſes were very apt to be burſt by the charge. The hardeſt and beſt London crown-glaſs ſeemed to accumulate leſs than any other; and a coloured glaſs, which when viewed by reflection ſeemed quite opake, but appeared brown by tranſmitted light, admitted, an accumulation *greatly* exceeding all that we have tried; but it could not be charged much higher without the certainty of being burſt. This diverſity in the accumulation, which may be made in different kinds of glaſs, hinders us from comparing the *abſolute* accumulations aſſigned by the theory with thoſe which experiment gives us. But though we cannot make this compariſon, we can make others which are equally ſatisfactory. We can diſcover what proportion there is between the accumulation in glaſs of the ſame kind, as it may differ in thickneſs and in extent of ſurface. Uſing mirror glaſs, which is of uniform and meaſurable thickneſs, and very flat plates, which come into accurate or equable contact—we found that the accumulation is inverſely as the thickneſs of the plates; but with this exception, that when two plates were uſed inſtead of a plate of double thickneſs, the diminution by the increaſe of thickneſs was not nearly in the proportion of this increaſe. Inſtead of being reduced to one-half, it was more than two-thirds; and in the kind called Dutch plate, the diminution was inconſiderable.

154 Strong attraction between them.

The experiments with the Dutch and other double plates, ſuggeſted another inſtructive and pretty experiment. Obſerving theſe plates to cohere with conſiderable force, it was thought worth while to meaſure it; which was attempted in this manner: Two very flat braſs plates AB, DF (fig. 29.), furniſhed with wires and balls, were ſuſpended, about three inches aſunder, by ſilk threads, as repreſented in the figure. At G was attached a very fine ſilver wire, which hung very looſe between it and the prime conductor, without coming near the table. Another was attached to N, which touched the table. A plate of mirror glaſs was ſet between them, as ſhewn by QR. When this apparatus was electrified, the threads of ſuſpenſion immediately began to deviate from the perpendicular, and the plates to approach the glaſs pane and each other. The pane was carefully ſhifted, ſo as to be kept in the exact middle between them. This reſult ſhewed very plainly the preſſure of the fluid on one of the plates, and the mutual attraction of the redundant matter and redundant fluid. This increaſed as the accumulation increaſed; and it was attempted to compare the attraction with the accumulation, by comparing the deviation of the ſuſpending threads with that of the electrometer attached to the prime conductor; but we could not reconcile the ſeries (which, however, was extremely regular) with the law of electric action. This harmony was probably diſturbed by the force employed in raiſing the ſilver wires. When more flexible ſilver threads were uſed, much was loſt by diſſipation from the roughneſs of the thread. We did not think of employing a fine flaxen thread moiſtened: but, indeed, an agreement was hardly to be expected; becauſe theory teaches us, that the diſtribution of the redundant fluid in AB will be extremely different from the diſtribution of the redundant matter in DF, till the plates come very near each other. The accumulation in AB depends greatly on the law of diſtribution, being leſs (with any degree of redundancy) when the fluid is denſer near the centre of the plate. Other circumſtances concurred to diſturb this trial; but the theory was abundantly confirmed by the experiment, which ſhewed the ſtrong attraction ariſing from the accumulation. This was ſo great, that although the plates were only three inches in diameter, and the glaſs pane was $\frac{1}{12}$ of an inch thick, and the threads deviated about 18 degrees from the perpendicular—it required above an ounce weight, hung on the wire EN, to ſeparate the plates from the glaſs.

155 Diſcharge; how it is effected.

The experienced electrician need not be told, that by bringing the two ends of a bent wire in contact with the two plates (firſt touching DF with it) diſcharges the apparatus, and cauſes the plates to drop off from the pane. But he may farther obſerve, that if there be attached to each end of the diſcharging wire a downy feather, and if he firſt bring the end near the plate DF, and obſerve the feather to be not at all, or but a very little, affected, and if he then bend round the other end toward the plate AB, *both feathers* will immediately ſtretch out their fibres to the plates, and cling faſt to them, long before the diſcharging ſpark is ſeen. This is a fine proof of the proceſs of diſcharge, which begins by the induction of electricity on the ends of the diſcharing wire; firſt, negative electricity on the end that approaches A, and, in the ſame inſtant, oppoſite electricities at D and the adjoining end of the wire.

156 Beautiful and inſtructive experiment by Profeſſor Richmann.

The following obſervation of Profeſſor Richmann of St Peterſburgh (the gentleman who fell a ſacrifice to electrical ſtudies by a thunder ſtroke from his apparatus) is extremely inſtructive and amuſing. Let a glaſs pane be coated on both ſides, and furniſhed with a ſmall electrometer attached to the coatings. It is repreſented as if ſeen edgewiſe in fig. 30. Let it be charged poſitively (that is, by redundancy) by the coating AB, while DF communicates with the ground. The electrometer A *a* will ſtand out from the plate, and D *d* will hang down cloſe by its coating, as long as DF communicates with the ground. But as the electricity gradually diſſipates by communication to the contiguous air, the ball *a* will gradually, but very ſlowly, fall down. We may judge of the intenſity of the remaining electricity by the deviation of the electrometer, and we may conceive this deviation divided into degrees, indicating, not angles, but intenſities, which we conceive as proportional to the redundancy or deficiency which occaſion them.

If we take away the communication with the ground, we ſhall obſerve the ball *a* fall down very ſpeedily, and then more ſlowly, till it reach about half of its firſt elevation. The ball *d* will at the ſame time riſe to nearly the ſame height; the angle between the two electrometers continuing nearly the ſame as at firſt. When *d* has ceaſed to riſe, both balls will very ſlowly deſcend, till the charge is loſt by diſſipation. If we touch DF during this deſcent, *d* will immediately fall down, and *a* will as ſuddenly riſe nearly as much; the angle between the electrometers continuing nearly the ſame. Remove the finger from DF, and *a* will fall, and *d* will riſe, to nearly their former places; and the ſlow deſcent of both will again continue. The ſame thing will happen if we touch AB; *a* will fall down cloſe to the plate, and *d* will riſe, &c. And this alternate touching of the coatings may be repeated ſome hundreds of times before the plate be diſcharged. If we ſuſpend a crooked wire *v m u*, having two pith-balls *v* and *u* from an inſulated point *m* above the plate, it will vibrate with great rapidity, the balls ſtriking the coatings alternately; and thus reſtoring the equilibrium by ſteps. Each ſtroke is accompanied by a ſpark.

All theſe phenomena are not only conſequences of the theory, but their meaſures agree preciſely with the computations deduced from the formulæ in n° 22, 23, 24, accommodated to the caſe by means of n° 135 and 136, as we have verified by repeated trials. But it would occupy much room to trace the agreement here, and would fatigue ſuch readers as are not familiarly converſant with fluxionary calculations. The inquiſitive reader will get full conviction by peruſing Æpinus's Eſſay, Appendix i. A very diſtinct notion may be conceived of the whole proceſs, by ſuppoſing that in a minute AB loſes $\frac{1}{10}$th of the unbalanced redundancy actually in it, and conſequently diminiſhes as much in its action. It will be proved afterwards, that the diſſipations in equal times are really in proportion to the ſuperficial repulſions then exerted. We may alſo ſuppoſe, that the action of the redundant fluid, or redundant matter, in either coating, on the external fluid contiguous to it, is to its action on the fluid contiguous to the other coating in the conſtant proportion of 10 to 9. We ſelect this proportion for the ſimplicity of the computation. Then the difference of theſe actions is always $\frac{1}{10}$th of the full action on the fluid contiguous to it. This is alſo an exact ſuppoſition in ſome particular caſe, depending on the breadth of the coating and the thickneſs of the pane.

Theory of it.

Now, let the primitive unbalanced repulſion between AB and the contiguous fluid of the electrometer be 100, while DF communicates with the ground. The ball *a* will ſtand at 100; the ball *d* will hang touching DF. Then *a*, by loſing $\frac{1}{10}$th, retains only 90, and would ſink to 90°: But as this deſtroys the equilibrium on the other ſide, fluid will enter into DF, ſo as to reduce the deficiency $\frac{9}{10}$th. Therefore nine degrees of fluid will

will enter; and its action on *a* will be the same as if $\frac{9}{10}$ths of 9, or 8,1 had been restored to AB. Therefore *a* will rise from 90 to 98,1; or it will sink in one minute from 100 to 98,1.

But if we have cut off the communication of DF with the ground, this quantity of fluid cannot come into DF; and the quantity which really comes into it from the air will be to that which escapes from A as the attraction on the side of DF to the repulsion on the side of AB. By the diminution of the repulsion $\frac{1}{10}$th, and the want of 9 degrees of fluid in DF to balance it, DF acquires an attraction for fluid, which may be called 9. Therefore, since $\frac{1}{10}$th of the primitive repulsion of AB has dissipated 10 measures of fluid in the minute, the attraction of DF will cause it to acquire $\frac{1}{10}$th of 9, or 0,9 from the air in the same minute. At the end of the minute, therefore, there remains an unbalanced attraction for fluid = 8,1; and consequently an unbalanced repulsion between the redundant matter in DF, and that in the ball *d*. Therefore *d* will rise to 8,1. But *a* cannot now be at 98,1; because DF has not acquired 9 measures of fluid, but only $\frac{9}{10}$ths of one measure. Therefore *a*, instead of rising from 90 to 98,1, will only rise to 90 + $\frac{9}{10}$ths × $\frac{9}{10}$ths; that is, to 90,81.

At the close of the minute, therefore, *a* is at 90,81, and *d* is at 8,1, and their distance is 98,91. In the next minute, AB will lose $\frac{1}{10}$th of the remaining unbalanced electricity of that side, and DF will now acquire a greater proportion than before; because its former unbalanced attraction gets an addition equal to $\frac{9}{10}$ths of the loss of AB. This will make a larger compensation in the action on *a*, and *a* will not fall so much as before. And because in the succeeding minutes the attraction of DF for fluid is increasing, and the repulsion of AB is diminishing, the compensation in the action on *a*, by the increased attraction of DF, continues to increase, and the descent of *a* grows continually slower; consequently a time must come, when the repulsion of AB for fluid is to the attraction of DF for it, nearly in the proportion of 10 to 9. When this state obtains, *d* will rise no more; because the receipt of fluid by DF, being now $\frac{9}{10}$ths of the loss by AB, it will exactly compensate the additional attraction of DF for fluid, occasioned by that loss. The next loss by AB not being so great, and the next receipt by DF continuing the same, by reason of its undiminished attraction, there will be a greater compensation in the action on *a*, which will prevent its descending so fast; and there will be more than a compensation for the additional attraction of DF for fluid: that is, the fluid which has now come into DF will render it, and also the ball *d*, less negative than before; and therefore they will not repel so strongly. Therefore *d* must now descend. It is evident, that similar reasons will still subsist for the slow descent of *a*, and the slower descent of *d*, till all redundancy and deficiency are at an end.

This maximum of the elevation of *d* happens when *a* has descended about one-half of its elevation; that is, when the unbalanced repulsion of AB is reduced to about one half. For if one half of the unbalanced fluid be really taken out of AB, and if DF can get no supply whatever, it must acquire an attraction corresponding to $\frac{9}{10}$ths of this; and if the supply by the air be now opened to it, things will go on in the way already described, till all is discharged.

This account of the process is only an approximation; because we have supposed the changes to happen in a desultory manner, as in the popular way of explaining the acceleration of gravity. The rise of *d* is not at an end till the attraction of DF for fluid is to the repulsion of AB as 19 to 20.

But if we interrupt this progress in any period of it, by touching DF, we immediately render it neutral, and *d* falls quite down, in consequence of receiving a complete supply of fluid. But this must change the state of AB, and cause it to rise $\frac{9}{10}$ths of the descent of *d*. As *a* and *d* were nearly at an equal height before DF was touched, it is plain that *a* will rise to nearly twice its present height; after which, the same series of phenomena will be repeated as soon as the finger is removed from DF.

If, instead of touching DF, we touch AB, the same things must happen; *a* must fall down, and *d* must rise to nearly twice its present height, and all will go on as before, after removing the finger. Lastly, if instead of allowing either side to touch the *ground* alternately, we only touch it with a *small insulated body*, such as the wire with the balls *v* and *u*, the ball attached to the side touched sinks, till the electricity is shared between the coating and the wire with balls. The ball attached to the other coating rises $\frac{9}{10}$ths of the sinking of the first ball. The crooked wire ball is now repelled by the coating which it touched, and the other ball is brought near to the other coating, and must be attracted by it, because the electricities are opposite. This operation evidently tends to transfer the redundant fluid *by degrees* to the side where it is deficient. It needs no explanation. We shall only mention a thing which we have always observed, without being able to account for it. The vibration of the wire acquires a certain rapidity, which continues for a long while, and suddenly accelerates greatly, and immediately afterwards ceases altogether.

This pretty experiment of Professor Richmann will be found very instructive; and will enable us to understand the operation of the electrophorus, and to see the great mistake of those who say that it is perfectly similar to a discharged glass plate.

157 Electric action *e distanti* demonstrated.

Thus, then, we see, that all the classes of phenomena, connected with attraction and repulsion, are precisely such as would result from the action of a fluid so constituted. The complete undiminished action of the cause of those phenomena on the other side of the interposed non-conductor of that cause is demonstrated, and all explanation by the mechanical action of material elastic atmospheres of variable density must be abandoned, and the infinitely simpler explanation by the attractive and repulsive forces of the fluid itself must be preferred.

So happily does the Franklinian theory of positive and negative electricity explain the phenomena, when a suitable notion is formed of the manner of action of this fluid. We cannot but think that this is attained, when, to the general doctrine of Æpinus, we add the specification of the law of action, so fully verified by the experiments of Mr Coulomb, which are in the hands of the public; and are of that simple nature, that any

any careful experimentor can convince himſelf of their accuracy (See n° 144.). We may therefore proceed with ſome confidence, and apply this doctrine even to caſes where experiment does not offer itſelf for proof.

158
Franklin miſtaken in ſuppoſing that a charged plate contains its natural quantity of fluid.

Dr Franklin affirms that electric fluid cannot be thrown into one ſide of the coated pane unleſs it be abſtracted from the other; and that therefore the charged glaſs contains no more than it did before charging. We indeed find, that we cannot *charge* the inſide, if the outſide do not communicate with the ground. He proves it alſo by ſaying, that if a perſon, when inſulated, diſcharges a glaſs through his own body, he is not found electrified: And he infers, as a neceſſary conſequence of this, that a ſeries of any number of jars may be charged by the ſame turns of a machine, if we make the outſide of the firſt communicate with the inſide of the ſecond, and the outſide of the ſecond with the inſide of the third; and ſo on; and the outſide of the laſt communicate with the ground. Having made the trial, and having found that more turns of the machine were neceſſary, he attributes this to diſſipation into the air by the communication. But our theory teaches us otherwiſe. We learn from it, that the redundant matter in the plate DF is leſs than the redundant fluid in AB, in the proportion of $n-1$ to n; and therefore the redundant fluid in the overcharged ſide of the next plate is no greater. The charge or redundancy in the mth jar of the ſeries will therefore be $\overline{\frac{n-1}{n}}\Big|^{m}$. Thus, if n, or the charge of the 1ſt jar, be 60, the charge of the 10th jar will be nearly 51. Although a coated plate cannot be *charged*, unleſs one of the coatings communicate with the ground, it may be *electrified* as much as one of the coatings can be alone. And this is ſeen in our attempt to charge it: For as ſoon as we attempt to electrify one ſide, the other is electrified alſo; for it gives a ſpark, which no unelectrified body will do. Alſo, when we diſcharge a jar by an inſulated diſcharger, we always leave it electrical in the ſame way with the body from which it was charged. If a man is not found electrified after having diſcharged a jar through his own body, it is owing to the great ſurface of his body, which reduces the ſimple electrification of a ſide of the jar to a very inſignificant and inſenſible quantity.

159
Miſtake of Wilcke's.

Wilcke (and we believe Franklin before him) maintains, that when the jar has been charged, by connecting one ſide with the prime conductor and the other with the rubber, it is neutral and inactive on both ſides. But this is not ſo; and a ſlight reflection might have convinced them that it cannot be ſo: if it were, the jar could not be diſcharged. Each ſide, while connected with the machine, muſt be in the condition of the part with which it is connected, and in a diſpoſition to take or give. If the trial be carefully made, it will be found to be *equally active* on both ſides; and the diſcharging rod, having down on its ends, will ſhew this in an unequivocal manner, and ſhew that its condition differs in this reſpect from that of a jar charged in the ordinary way. It is in the maximum ſtate of Richmann's plate, deſcribed in n° 156. when d riſes no more.

160
Charge one jar by the diſcharge of another.

In diſcharging a jar A, if inſtead of the outſide communicating with the inſide by a wire, we make it communicate with the inſide of a ſecond jar B, while the outſide of B is made to communicate with the inſide of A, we ſhall find B charged by the diſcharge of A; and that the diſcharge of A is not complete, the charge 2^2 always remaining, whatever may have been the magnitude of n.

161
Important inference.

We may infer from this experiment, that when a ſhock is given to a number of perſons, a, b, c, &c. we are not to conclude, that the fluid which comes into the deficient ſide of the jar is the ſame which came out of the redundant ſide. The whole, or perhaps only a part, of the moveable fluid in the perſon a goes into b, replacing as much as has paſſed from b into c, &c. Indeed, where the canal is a ſlender wire, we may grant that great part of the individual particles of fluid which were accumulated on the inſide of the jar have gone into the outſide. Perhaps the quantity transferred, even in what we call *a very great diſcharge*, may be but a ſmall proportion of what naturally belongs to a body. This may be the reaſon why a charge will not melt more than a certain length of wire. Mr Cavendiſh aſcribes this to the greater obſtruction in a longer wire; but this does not appear ſo probable. A greater obſtruction would occaſion a longer delay of the transference; and therefore the action of the ſame quantity would be longer continued. He proves, that a metal wire conducts many hundred times faſter than water; yet, when water is diſſipated by a diſcharge, it is found to have actually conducted a *much greater* proportion of the whole charge. We aſcribe it chiefly to this, that, in a ſhort wire, the quantity transferred exceeds the whole quantity belonging to the wire.

162
Leyden phial like a coated pane.

It is ſurely needleſs to prove that the theory of the Leyden phial is the ſame with that of the coated pane. The only difference is, that we are not ſo able to tell the diſpoſition of the accumulated fluid, and the evacuated matter, in every figure. When the phial is of a globular form, and of uniform thickneſs, with an exceedingly ſmall neck, we then know the diſpoſition more accurately than in a plate. The redundant fluid is then uniformly diſtributed. If we could inſure the uniformity of thickneſs, ſuch a phial would be an excellent UNIT for meaſuring all other charges by; but we can neither inſure this (by the manner of working glaſs,) nor meaſure its want of uniformity: whereas we can have mirror plate made of preciſely equal thickneſs, and meaſure it. This, therefore, muſt be taken as our unit.

163
Excellent method for verifying the theory.

And here we remark, that this gives us the moſt perfect of all methods for comparing our theory with experiment. We muſt take two plates, of the ſame glaſs and the ſame thickneſs, but of different dimenſions of coated ſurface. We muſt charge both by very long conducting wires on both ſides, and then meaſure how often the charge of the one is contained in the other. Mr Cavendiſh has given an unexceptionable method of doing this independent of all theory. As it applies equally to jars, however irregular, we ſhall take it altogether.

Meaſure of a charge.

When a jar is charged, obſerve the electrometer connected with it, and immediately communicate the charge to another equal jar (the perfect equality being previouſly aſcertained by the methods, which will appear immediately. Again note the electrometer. This will give the elevation, which indicates one-half, independent

pendent of all theory. Now electrify a jar, or a row of equal jars, to the same degree with the first, and communicate the charge to a coated mirror plate, discharging the plate after each communication, till the electrometer reaches the degree which indicates one-half. This shews how often the charge of the plate is contained in that of the jar or row of jars.

Let the charge of the plate be to that of the jars as x to 1. Then, by each communication, the electricity is diminished in the proportion of $\overline{1+x}$ to 1. If m communications have been made, it will be reduced in the proportion of $\overline{1+x}^m$ to 1. Therefore $\overline{1+x}^m = 2$, and $1+x = \sqrt[m]{2}$, and $x = \sqrt[m]{2} - 1$.

When x is small in proportion to 1, we shall be very near the truth, by multiplying the number of communications by 1,444, and subtracting 0,5 from the product. The remainder shews how often the charge of the plate is contained in that of the jars, or $\frac{1}{x}$.

Thus may the perfect equality of two jars be ascertained; and the one which exceeds, on trial, may be reduced to equality by cutting off a little of the coating. An electrician should have a pair of small jars or phials so adjusted. It will serve to discover in a minute or two the mark of one-half electricity for any electrometer, and for any degree; as also for measuring jars, batteries, shocks, &c. much more accurately than any other method: because such phials, constructed as we shall describe immediately, may be made so neutral, and so retentive, that the quantity which dissipates during the handling becomes quite insignificant in proportion to the quantity remaining; whereas, in all experiments with electrometers, constructed with the most curious attention, the dissipations are great in proportion to the whole, and are capricious.

164 It was chiefly by this method that the writer of this article, having read Mr Cavendish's paper, compared the measures given by experiment with those which result from an action in the inverse duplicate ratio of the distance. When the charges were moderate, the coincidence was perfect; when the charges were great, the large plates contained a little more. This is plainly owing to their being less disposed to dissipate from the edges.

165 Maxims for constructing jars, batteries, &c.

We may now follow with some confidence the practical maxims deducible from the theory for the construction of this accumulating apparatus. The theory prescribes a very conducting coating, in close and uninterrupted contact; It prescribes an extensive surface, and a thin plate of idio-electric substance. Accordingly all these are in fact attended by a more powerful effect. Metal is found to be far preferable to water, which was first employed, having been suggested by the original experiments of Gray, Kleist, and Cunæus. A continuous plating is prescribed, in preference to some methods commonly practised; such as filling the jar with brass dust, or gold leaf, or covering its surface with filings stuck on with gum water, or coating the inside with an amalgam of mercury and tin. This last appears, by reflection from the outside, to give a very continuous coating; but if we hold the jar between the eye and the light, we may perceive that it is only like the covering with a cobweb. Yet there are cases where these imperfect coatings only are practicable, and some rare ones where they are preferable. In the medical exhibition of electricity, where the purpose intended is supposed to require the transfusion of a great quantity of the electric fluid, any thing that can diminish the irritating smartness of the spark is desirable. This is greatly effected by those imperfect coatings. Small shocks, which convey the same quantity of fluid with the sharp pungent and alarming spark from a large surface, are quite soft and inoffensive, greatly resembling the spasmodic quivering, sometimes felt in the lip or eye-lid, and will not alarm the most fearful patient.

Hint for medical exhibition of electricity.

166 How to preven. the bursting of jars by high charges.

Close contact of the metallic coating is observed to increase the effect of the charge. But it is also found, that it greatly increases the risk of bursting the glass by spontaneous discharge through its substance. An experienced electrician (we think it is Mr Brookes of Norwich) says, that since he has employed paper covered with tinfoil, with the paper next the glass, instead of the foil itself, he has never had a jar burst; whereas the accident had been very frequent before. The theory justifies this observation. Paper is an imperfect conductor, even when soaked with flour paste; and the transfusion, though rapid, is not instantaneous nor desultory, but begins faintly, and swells to a maximum. It operates on the glass, like gradual warming instead of the sudden application of great heat.

167 Very curious observation by Mr Cuthbertson.

Mr Cuthbertson, an excellent artist in all electrical apparatus, and inventor of the best air-pump, has made a curious observation on this subject. He says that he has uniformly observed, that jars take a much greater charge (nearly one third), if the inside be considerably damped, by blowing into it with a tube reaching to the bottom (*Nicholson's Journal, March* 1799).—We must acknowledge, that we can form no distinct conception of what Mr Cuthbertson calls *an undulation of the elastic atmosphere*. We do not know whether he means that the atmosphere is actually undulating as water, or as air in the production of sound, its parts being in a reciprocating motion; or whether he only means that this atmosphere consists of quiescent strata, alternately denser and rarer. Nor can we form any notion how either of these undulations contributes to the explosion, or prevents it. We are really but very imperfectly acquainted with that part of the science which should determine the precise accumulation that produces the desultory transference. We mentioned one necessary consequence of the action inversely as the square of the distance, which has some relation to this question, *viz.* that a particle, making part of a spherical surface, is twice as much repelled when it has just quitted the surface as when it made part of it, provided its place be immediately supplied. And another circumstance has been frequently mentioned, *viz.* that a greater, and perhaps much greater, force is necessary for enabling a particle of fluid to quit the last series of particles of the solid matter than for producing almost any constipation. But we are not certain that these circumstances are of sufficient influence to explain the whole of the event. *Valeant quantum valere possint.* Yet we are of opinion that Mr Cuthbertson has assigned the true cause, namely, the imperfect coating of the inside of the glass. When we come to the explanation of the escape of electricity along imperfect conductors, we hope that it will appear, that the disposition to escape must be greatly diminished by a charge, which disposes the

the fluid fo, that in no place the conftipation is remarkably greater than in another part very near it, and the denfity changes every where flowly.

163 Beft forms for jars, &c. With refpect to the form of the coated glafs, the theory prefcribes that which will occafion fuch a diftribution of the electric fluid as fhall make its repulfion for the fluid in the canal which connects it with the prime conductor as little as poffible. In this refpect, it would feem that a plate is the beft, and a globe the worft: but if both are very thin, the difference cannot be confiderable. Our experience, however, feems to indicate the oppofite maxim as the moft proper. We have uniformly found a globe to be far preferable to a plate of the fame thicknefs, and that a plate was generally the weakeft form. It muft be owned, that we have not yet been able to afcertain by the theory what is the exact diftribution of the redundant fluid in a plate. In a fphere, it muft be uniformly fpread over the furface. We muft alfo afcribe part of the inferiority of the plate to its greater tendency to diffipation from the edges. If a plate be coated in a ftar-like form, with flender projecting points, we fhall obferve them luminous in the dark, almoft at the beginning of the accumulation; and the plate will difcharge itfelf by thefe points, over the uncoated part, before it has attained any confiderable ftrength. Thofe forms are leaft expofed to this deterioration which have the leaft circumference to the fame quantity of furface. We have always found, that a fquare coating will not receive a more powerful charge without exploding than a circular one of the fame breadth, although it contains a fourth more furface; and this although any vifible efcape from the angles be prevented by covering the outline with fealing-wax. Of all forms, therefore, a globe, with a very narrow, but long neck, is the moft retentive. But it is very difficult to coat the infide of fuch a veffel. The balloons ufed in chemical diftillations make excellent jars, and can be eafily coated internally when the neck will admit the hand. The thinneft of tinfoil may be ufed, by firft pafting it on paper, and then applying it either with the foil or the paper next the glafs. It fhould be cut into guffets, as in the covering of terreftrial globes; and they fhould be put on overlapping about half an inch. The middle of the bottom is then coated with a circular piece. The great bottles for holding the mineral acids are alfo good jars, but inferior to the balloons, becaufe they are very thick in the bottom, and for fome diftance from it. A box of balloons contains more effective furface than an equal box of jars of the fame diameter and height of coating.

169 Compendious battery. The moft compendious battery may be made in the following manner: Choofe fome very flat and thin panes of the beft crown glafs, coat a circle (*a b c d*), (fig. 31.) in the middle of both furfaces, fo as to leave a fufficient border uncoated for preventing a fpontaneous difcharge; let each of them have a narrow flip of tinfoil *a* reaching from the coating to the edge on one fide, and a fimilar flip *c* leading to the oppofite edge on the other fide. Lay them on each other, fo that the flips of two adjoining plates may coincide. Connect all the ends of thefe flips on one fide together by a flip of the fame foil, or a wire which touches them all. Then, connecting one of thefe collecting flips with the prime conductor, and the other with the ground, we may charge and difcharge the whole together. If the panes be round, or exact fquares, we may employ as few of them together as we pleafe, by fetting the whole in an open frame, like an old-fafhioned plate-warmer; and then turning the fet which we would employ together at right angles to the reft. This evidently detaches the two parcels from each other. This battery may be varied in many ways; and if the whole is always to be employed together, we may make it extremely retentive, by covering the uncoated border of the plate with melted pitch, and, while it is foft, preffing down its neighbour on it till the metallic coatings touch. For greater variability this may be done in parcels of the whole.

170 Another. On the fame principle, a moft compendious battery may be made by alternate layers of tinfoil and hard varnifh, or by coating plates of very clear and dry Mufcovy glafs. But thefe muft be ufed with caution, left they be burft by a fpontaneous difcharge; in which cafe we cannot difcover where the flaw has happened. They make a furprifing accumulation, without fhewing any vivid electricity.

171 Portable jar. We have made a very fine electric phial for carrying about, by forming tin-plate (iron plate tinned) into fomewhat of a phial fhape, with a long neck. We then covered this with a coating of fine fealing-wax, about $\frac{1}{10}$th of an inch thick, quite to the end of the neck, and coated the fealing-wax, all but the neck, with tinfoil. It is plain that the fealing-wax is the coated idio-electric, and that the tin plate phial ferves for an inner coating and wire. The diffipation is almoft nothing if the neck be very fmall; and it only requires a little caution to avoid burfting by too high a charge. Even this may be prevented by coating the fealing-wax fo near to the end of the neck, that a fpontaneous difcharge muft happen before the accumulation is too great.

172 Importance of a clofe difcharge. It is well known that the difcharge happens when the difcharging balls are at a confiderable diftance from each other; therefore only as much is difcharged as correfponds to that diftance. This is one caufe of the refiduum of a difcharge which fometimes is pretty confiderable. Some experiments require the very utmoft force of the charge. It is therefore proper to make the difcharge as clofe and abrupt as poffible. But the moft rapid approach that we can make of the difcharger is nothing in comparifon with the velocity with which the fluid feems to fly off, and will therefore have but fmall influence in making a more inftantaneous and complete difcharge. Theory points out the following method: Let a very thick plate of glafs (half an inch), of feveral inches diameter, be put between the difcharging balls, which fhould, in this cafe, be fmall, and let thefe balls be ftrongly preffed againft it by a fpring. While the charge is going on, a very fmall part of the glafs plate, round the points of contact, will receive a weak and ufelefs charge; but this will not hinder the battery from acquiring the fame intenfity of charge. When this is completed, let the intervening glafs plate be brifkly withdrawn. The difcharge will begin with an intenfity which is unattainable in the ordinary manner of proceeding.

173 Lateral explofion. Much has been faid of the lateral explofion. It appears, that in fome of the prodigious transferences of electricity that have taken place in the difcharge of great furfaces through wires barely fufficient to conduct them, flafhes

flafhes of light are thrown off laterally; but the moft delicate electrometer, it is faid, is not affected. The fact is not accurately narrated; we have always obferved a very delicate electrometer to be affected. The paffage of fuch a quantity of fluid is almoft equivalent to the co-exiftence of it in any given fection of the wire; but it remains there for fo fhort a time, that, acting as an accelerating force, it cannot produce a very fenfible motion. It is like the difcharging a piftol ball through a fheet of paper hanging loofely. It goes through it without very fenfibly agitating it.

174
Propofal for difcovering which is redundant electricity.

It has fometimes appeared to us probable, that, by means of this lateral explofion, the direction of the current may be difcovered. Let the jar *a b* (fig. 32.) be difcharged by a wire *a c d e b*, interrupted at *c d* by the coating of a very thin plate of talc; let the coating alfo be very thin. There muft be *fome* obftruction to the motion, which muft caufe the fluid to prefs on the fides or furfaces of the coating, juft as the obftruction to the motion of water in a pipe (arifing from friction, or even from material obftacles in the pipe) caufes the water to prefs on the fides of the pipe. Therefore if a wire *x ε* connect the other coating with the ground, we fhould expect that fluid will be expelled along this wire, and a charge be given to the plate of talc. Now whether the courfe in this apparatus be from *b* to *a*, or from *a* to *b*, if any charge be acquired by *c d*, it will *probably* be pofitive in *c d*, and negative in *x ε*; for it is electric fluid that is fuppofed to pafs: therefore we fhould always have one fpecies of electricity, whether *a* has been charged by glafs or by fealing-wax: and this fpecies will indicate which is pofitive. We have faid "probably"—for it is not impoffible that it may be otherwife. If the abftraction at *d* be fuppofed more powerful than the fupplying force at *c*, the fame obftruction may perhaps keep the plate *c d* in an *abforbing* ftate, juft as water defcending in a vertical pipe, into which it is preffed by a very fmall head of water in the ciftern, inftead of preffing the fides of the pipe, rather draws them inwards, as is well known. This feems, at any rate, an interefting experiment; for we muft acknowledge, that there ftill hangs a myfterious curtain before a theory which deduces fo much from the prefence of a fubftance which we have never been able to exhibit alone, and where we do not know when it abounds and when it is deficient. It is like the phlogifton of Stahl, or the caloric of Lavoifier. It will be proper to ufe the thinneft plate of talc to be charged, and to connect it with another coated plate of half the diameter, or lefs, in order to increafe the accumulation. It feems by no means a defperate cafe.

The theory of coated glafs now explained, might have been treated with more precifion, and the formulæ deduced in the beginning of this article might have been employed for ftating the fum-total of the acting forces, and thus *demonftrating* with precifion the truth of the general refult; and indeed it was with fuch a view that they were premifed: but they would have been confiderably complicated in the prefent cafe; for however thin we fuppofe the tinfoil coatings to be, it is evident from n° 92, &c. that each coating will confift of three ftrata; of which the two outermoft are active, and muft have their forces ftated, and the ftatement of the force of each ftratum would have confifted of three terms. This would have been very embarraffing to fome readers; and the force of the conclufion would not, after all, have been much more convincing than we hope the above more loofe and popular account has been.

175
Does the charge refide in the coatings or in the glafs?

We have hitherto confidered the non-electric coatings only, and have not attended to what may chance to obtain in the fubftance of the coated electrics themfelves. May not part, at leaft, of the redundant fluid be lodged in one fuperficial ftratum of the glafs? or, if it do not penetrate it, may it not adhere to the furface, and drive off from the other furface, or ftratum, a part of what naturally adheres to it? Till Dr Franklin's notions on the fubject became prevalent, no perfon doubted this. The electric was fuppofed to contain or to accumulate in its furface all the electricity that we know. But the firft fuggeftion of Dr Franklin's experiments certainly was, that the electric plate or veffel acted merely as an obftacle, preventing the fluid from flying from the body where it was redundant to that where it was deficient. It is therefore an important queftion in the fcience, whether the glafs or electric concerned in thefe phenomena ferve any other purpofe befides the mere prevention of the redundant fluid from flying to the negative plate?

176
It is in the glafs.

Now it appears, at the very firft, that this is the cafe. For if a glafs be coated only on one fide, and be electrified on that fide, we obtain a ftrong fpark from the other fide by bringing the knuckle near it: and this may be obtained for fome time from one fpot of that furface; and, after this, we get no more from that fpot, but get fparks, with the fame vivacity, and in the fame number, from any other fpot that is oppofite to the coating on the other fide. In this manner we can obtain a fucceffion of fparks from every inch of furface oppofite to the coating, and from no other part. But what puts this queftion beyond all doubt is, that if we now lay a metal coating on the furface from which the fparks have been drawn in this manner, and make a communication between the two metallic coatings, by means of a bent wire, we obtain a perfect difcharge. To complete the proof, we need only obferve, that this experiment fucceeds whether the glafs has been electrified by excited glafs or by excited fealing-wax. Therefore the coated furface may receive the electric fluid by the coating, as we fee plainly that it is abftracted by the coating. The ufe of the coatings may be nothing more than to act as conductors to every part of the furface of the electric. None of thefe thoughts efcaped the penetrating and fagacious mind of Dr Franklin. He immediately put it to the teft of experiment: and, laying a moveable metallic coating on both furfaces, he found the glafs charge perfectly well. He lifted off the coatings; which operation was accompanied by flafhes of light between the metallic coverings and the glafs from which he feparated them. Having removed the coatings, he applied others, completed the circle, and obtained a perfect difcharge, not diftinguifhable from what he would have obtained from the firft coatings.

177
Charged glafs acquires redundant and deficient ftrata.

Thus was it demonftrated, that the glafs plate itfelf acquired by charging a redundant ftratum on one fide, and a deficient ftratum on the other fide; and we now fee, at once, the reafon why the accumulation turns out greater than what is determined by the theory. The

diftance

diſtance between the redundant and deficient ſtratum is leſs than the thickneſs of the glaſs; and this, perhaps, in an unknown proportion.

This precious experiment of Dr Franklin was repeated by every electrician, and varied in a thouſand ways. No philoſopher has carried this reſearch farther than Beccaria; and he has given ground for a moſt important diſcovery in the mechanical theory, namely, that the charged glaſs has ſeveral ſtrata, of inconceivable thinneſs, alternately redundant and deficient in electric fluid; and that by continuing the electrification, theſe ſtrata penetrate deeper into the glaſs, and probably increaſe in number. We have not room here to give even an account of his experiments, and muſt refer the philoſophical and curious reader to that part of his valuable Treatiſe where he treats of what he calls *vindicating* or *recovering electricity*; as alſo to a paper by Mr Henley in Phil. Tranſ. for 1766, giving account of experiments on Dutch plates by Mr Lane. The general form of the experiment is this. He puts two plates together; he coats the outer ſurfaces, and charges and diſcharges them as one thick plate. Their inner touching ſurfaces are found ſtrongly electrical after the diſcharge, having oppoſite electricities, and changing theſe electricities, by repeated ſeparations and replacings, in a way ſeemingly very capricious at firſt ſight, but which the attentive reader will find to be according to fixed laws, and agreeably to the ſuppoſition that the ſtrata gradually ſhift their places within the glaſs, very much reſembling what we obſerve on a long glaſs rod which we would render electric by induction. In this caſe, as was obſerved in n° 57. there are obſerved more than one neutral point, &c.

178 Mr Cavendiſh endeavours to give us ſome notion of the diſpoſition of the fluid in the ſubſtance of the glaſs in the following manner: Having ſeparated the coated plate from the machine and from the ground, ſuppoſe a little of the redundant fluid in B β δ D (fig. 33.) equal to the fluid wanting in E ε φ F. If we now ſuppoſe all the redundant fluid to be lodged in $b \beta \delta d$, and $e \varepsilon \varphi f$ to hold all the redundant matter, and the two coatings to be in their natural ſtate, a particle p, placed in the middle of the ſurface $b\ d$, will be nearly as much attracted by $\varepsilon\ e\ f\ \varphi$ as it is repelled by $b\ \beta\ \delta\ d$ (exactly ſo if the plates were infinitely extended); and if the coating be removed, keeping parallel and oppoſite to the ſurface that it quits, there will be very little, if any, tendency to fly from the glaſs to the coating: there will rather be ſome diſpoſition in the fluid to quit the coating and fly to the glaſs; becauſe the repulſion of $b\ \beta\ \delta\ d$ is more diminiſhed than the attraction of $\varepsilon\ e\ f\ \varphi$ (n° 42.). But the difference will be very ſmall indeed. (*N. B.* the reſult would be very different if electric action followed a different law. Were it as $\frac{1}{d^3}$, the coating would be much overcharged; and were it as $\frac{1}{d}$, it would be very much undercharged). Now the fact is, that when the coating is carefully removed, it is poſſeſſed of very little electricity, not more than may reaſonably be ſuppoſed to run into it by bringing away one part before another. It is impoſſible to keep it mathematically parallel.

Hence we may conclude that the greateſt part of the redundant fluid is lodged in the glaſs if the plates be thin, and the redundant fluid bear but a ſmall proportion to the natural quantity. Similar reaſoning ſhews that the greateſt part of the deficiency is in the other ſide of the glaſs; and that therefore the coatings are very nearly in their natural ſtate, and merely ſerve the purpoſe of conducting.

We have employed coatings of conſiderable thickneſs, having holes through them, oppoſite to which was ſome gold leaf of the heavieſt ſort, and almoſt free of cracks. We have examined the ſtate of the bottom of thoſe pits in Mr Coulomb's manner, and always found them void of electricity.

Thus we learn that glaſs, and probably all other electrics, acquire redundant and deficient ſtrata as well as the moſt perfect conductors, at the ſame time that they may be impervious to the fluid; and we get ſome mode of conceiving how the rupture happens by a ſtrong charge. This may very probably happen when the ſtrata have formed, in alternate order, ſo deep in the glaſs, that a ſtratum, in which the fluid is crowded cloſe together, may become contiguous to one deprived altogether of fluid. We cannot, however, ſay with confidence, what *ſhould* be the effect of this ſtate of things; or of one conſtipated ſtratum coming in contact with another. 179 Conjecture about the burſting of jars.

This view of the condition of charged glaſs explains (we think) ſeveral phenomena which ſeem not well underſtood by electricians.

The reſiduum of a diſcharge is frequently owing to a charge extending beyond the coating, where the action is conſiderably irregular, or different from what it would be if the plates were infinitely extended. This *outline* charge is taken up by the coated part after a very little while, and may again be diſcharged. But it alſo frequently ariſes from another ſtratum (much thinner, as it will always be) than the exterior one, coming to the ſurface ſome time after the firſt diſcharge, and being now in a condition for being diſcharged. It explains the ſparkling that is perceived in *ſucceſſion* between the parts of a jar that is coated in ſpots, during the charge, and the very ſenſible reſiduum of the charge of ſuch a veſſel. It explains the phenomena of Beccaria's *Electricitas Vindex* (ſee ELECTRICITY, *Encycl.* § 48.), and the great difference that may be found in the different kinds of glaſs in this reſpect. It explains the great difference between the ſenſation occaſioned by a ſpark from a perfectly conducting ſurface of conſiderable extent, and that occaſioned by a ſhock, which conveys the ſame quantity of fluid accumulated in a ſmall ſurface of glaſs. The diſcharge of the firſt is almoſt inſtantaneous, while that of the laſt requires a ſmall moment of time, and is therefore leſs deſultory and abrupt. The one is pungent and ſtartling; but the other is ſofter in the firſt inſtant, and ſwells to a maximum. Therefore, in the medical employment of electricity, when the purpoſe is to be effected by the tranſfuſion of a great quantity of electric fluid, we ſhould recommend very ſmall ſhocks from a very large ſurface of coated glaſs, very faintly electrified, in place of ſtrong ſparks. Patients of irritable conſtitutions are frequently alarmed by the quickneſs and pungency of ſtrong ſparks: but if the balls of Lane's ſhock-meaſurer be ſet ſo cloſe as to give four or five ſhocks in each 180 Several phenomena explained.

each turn of a ſeven inch cylinder, the ſhocks are not even diſagreeable. The balls ſhould be made of fine cupelled ſilver: in which caſe, the ſurface will never be hurt by the greateſt diſcharge; whereas the diſcharge of four ſquare feet of coated glaſs will raiſe ſuch a roughneſs on the ſurface of braſs as will cauſe it to ſputter, and deſtroy entirely the regularity of the expenditure of fluid. The ſame conſideration ſhould make us prefer a jar coated internally with amalgam. This cobweb coating gives a greater ſoftneſs to the ſhock. Laſtly, we ſee why a powerful and permanent electricity was not produced in the tube filled with melted ſealing-wax, and treated as mentioned in nº 101. The redundancy and deficiency intended to be produced could only be ſuperficial. And becauſe the wax cooled by degrees from the ſurface to the axis, and the wax is a conductor while liquid, it muſt have taken a charge at laſt; and therefore muſt appear but faintly electrical.

181 This account of the ſtate of charged glaſs promiſes us ſome aſſiſtance in our attempts to conceive what paſſes in the excitation of glaſs by friction. It appears from Beccaria's experiments, that the redundant fluid is lodged in the ſame manner in both caſes; for by rubbing one ſide of a glaſs tumbler, while points were preſented to the oppoſite ſurface, and were connected with a wire that communicated with the ground, he gave it a powerful charge.

182

The quantity of fluid in a body may be exceeding great.

It is obſerved, that when the laminæ of a piece of Muſcovy glaſs are ſeparated, by pulling them aſunder without inſerting any inſtrument between them, they are electrical when ſeparated; one being poſitive, and the other negative. Muſt we not conclude from this, that when conjoined they were in the ſtate of charged glaſs? If we take this view of it, a body may contain a prodigious quantity of electric fluid without exhibiting any appearance of it. Mr Nicholſon found, by a very fair computation from his experiments, that a cubic inch of talc, when ſplit into plates of 0,011 of an inch in thickneſs, and coated with gold leaf, gave a ſhock equal to the emptying 45 conductors, each ſeven inches in diameter and three feet long, electrified ſo that each gave a ſpark at nine inches diſtance. Now, the whole of this was moveable fluid, and no more than what the talc contains when unelectrified: for no more comes into the poſitive ſide than goes out of the negative ſide. Nay, there is no probability that the quantity moveable in our experiments bears a conſiderable proportion to the natural quantity. The quantity of moveable fluid in a man's body is therefore very great: and Lord Mahon is well authoriſed to ſay, that the ſudden diſplacing of this quantity in a *returning ſtroke*, which has been occaſioned by a diſcharge of a cloud in a very diſtant place, is fully adequate to the production of the moſt violent effects. But his Lordſhip has not attended to the circumſtance, that no ſuch diſplacement can happen. The accumulation that can be made in the human body is only ſuperficial; and therefore, although the whole fluid of a man's body may change its place, it will not change it with the rapidity that ſeems neceſſary for the violent effects of electricity, except in the very points of communication with the ſurrounding bodies.

183 We have now ſeen in what ſenſe the idio-electrics may be ſaid to be impervious to the electric fluid. It is moved in them only to very ſmall and imperceptible diſtances. When a conſiderable ſtratum is diſcharged, the fluid does not come from the extremity of it to the point of diſcharge through the glaſs, but through the coating. And when alternate ſtrata of redundant fluid and redundant matter are formed, the particles in each ſhift their places very little, moving perpendicularly to the ſtratum.

184

The impermeability of electrics denied by ſome.

Even this degree of obſtruction has been denied by ſome very active electricians, who have multiplied experiments to prove that the fluid paſſes freely through glaſs, and that the theory of coated electrics is totally different from what Franklin imagines. Mr Lyons of Dover has publiſhed a numerous liſt of ſingular experiments, which he has made with this view, with much trouble, and no ſmall expence. They may all be reduced to this: A wire is brought from the outſide of a phial, charged by the knob, and terminates in a ſharp point at a ſmall diſtance from a thin glaſs plate (it is commonly introduced into a glaſs tube, having a ball at the end, and the point of the wire reaches to the centre of the ball); and another wire is connected with the diſcharging rod, and alſo comes very near (and frequently cloſe) to the other ſide of the glaſs, oppoſite to the pointed wire. With this apparatus he obtains a diſcharge; and therefore ſays, that the glaſs is permeable to electricity. But he does not narrate all the circumſtances of the experiment. We have repeated all of them that have any real difference (for moſt of them are the ſame fact in different forms), and we have obtained diſcharges: But they were all very incomplete, except when the glaſs was perforated, which happened very frequently. The diſcharge was never made with a full, bright, undivided ſpark, and loud ſnap; but with ſputtering, and trains of ſparks, continued for a very ſenſible time; and the phial was never deprived of a conſiderable part of its charge: and (which Mr Lyons has taken no notice of) the glaſs is found to be charged, negative on the ſide connected with the poſitive ſide of the phial, and poſitive on the other. This charge was communicated to the glaſs over a pretty conſiderable ſurface round the points immediately oppoſite to the wires. This is quite conformable to the experiments of Dr Franklin and Beccaria, who charged a tumbler by graſping it with the hand, and preſenting the inſide to a point electrified by the prime conductor. The whole experiment is analogous to the one narrated in nº 176.

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Bars touched like magnets for electricity.

We may conclude our obſervations on coated glaſs with mentioning a curious experiment. A flat ſtick of fine ſealing-wax, warmed till it bent pretty readily, was rendered permanently electrical, with a poſitive and negative pole, in a manner analogous to the double touch of magnets. A ſmall jar was taken, having a hemiſphere on the end of its inſide wire, and another on the end of a ſtiff wire projecting from the outer coating, and then turned up parallel to the inſide wire; ſo that the two hemiſpheres ſtood equally high, and about three inches aſunder. This jar was electrified ſo weakly, as to run no riſk of a ſpontaneous diſcharge. The flat faces of the two hemiſpheres were now applied to the flat ſide of the ſealing-wax, and were moved to and fro along it, overpaſſing both ends about an inch with each hemiſphere. The experiment was very troubleſome; for the phial often diſcharged itſelf along the ſurface of the ſealing-wax, and all was to begin again.

again. But, by continuing this operation till the sealing-wax grew quite cold and hard, it acquired a very sensible electricity, which lasted several weeks when kept with care; but still it was not much more sensible than that of the sealing-wax, which congealed between two globes oppositely electrified.

186 Electrophorus.

After this application of the theory to the phenomena of coated glass, it will not be necessary to employ much time in its application to the electrophorus. The general propositions from n° 14. to 25. and their companions in n° 38—43. will enable us to state with precision (when combined with the law of electric action) the actions of every part of this apparatus; and considerable assistance will be derived from a careful consideration of our analysis of Professor Richmann's experiment in n° 156. But we must content ourselves with a general, popular view of these particulars, which may be sufficient for making us understand what will be the *kind*, and somewhat of the *intensity*, of the action of its different parts.

The electrophorus consists of three parts. The chief part is the cake ABCD (fig. 34.) of some electric; such as gum lac, sealing-wax, pitch, or other resinous composition. This is melted on some conducting plate, DCFE, and allowed to congeal; in which state it is found to be negatively electric. Another conducting plate GHBA is laid on it, and may be raised up by silk lines, or any insulating handle. We shall call ABCD the CAKE, DCFE the SOLE, and GHBA the COVER.

The general appearances not having been so scientifically classed in the article ELECTRICITY as could be wished, we shall here narrate them, very briefly, in a way more suited to our purpose. In comparing the theory with observation, it will be proper to make all the three parts of considerable thickness, and of no great breadth. Although this diminishes greatly the most remarkable of the actions, it leaves them sufficiently vivid, and it greatly increases the smaller changes which are instructive in the comparison. The general facts are,

Phenomena thereof.

1. If the sole has been insulated during the congelation of the electric, till all is cold and hard, the whole is found negatively electric, and the finger draws a spark from any part of it, especially from the sole. If allowed to remain in this situation, its electricity grows gradually weaker, and at last disappears: but it may be excited again by rubbing the cake with dry warm flannel, or, which is the best, with dry and warm cat or hare fur. If the cover be now set on the cake by its insulating handle, but without touching the cover, and again separated from the cake, no electricity whatever is observed in the cover.

2. But if it be touched while on the cake, a sharp pungent spark is obtained from it; and if at the same time, the sole be touched with the thumb, a very sensible shock is felt in the finger and thumb.

3. After this, the electrophorus appears quite inactive, and is said to be *dead;* neither sole nor cover giving any sign of electricity. But,

4. When the cover is raised to some distance from the cake (keeping it parallel therewith), if it be touched while in this situation, a smart spark flies, to some distance, between it and the finger, more remarkably from the upper side, and still more from its edge, which will even throw off sparks into the air, if it be not rounded off. As this diminishes the desired effects, it is proper to have the edge so rounded. This spark is not so sharp as the former, and resembles that from any electrified conductor.

5. The electricity of the cover, while thus raised, is of the opposite kind to that of the cake, or is positive.

6. The electricity of the cover while lying on the cake is the same with that of the cake, or negative.

7. The appearances n° 2, 3, 4, may be repeated for a very long time without any sensible diminution of their vivacity. The instrument has been known to retain its power undiminished even for months. This makes it a sort of magazine of electricity, and we can take off the electricity of the cake and of the cover as charges for separate jars, the cover, when raised, charging like the prime conductor of an ordinary electrical machine; and, when set on the cake, charging it like the rubber. This caused the inventor, Mr Volta, to give it the name of ELECTROPHORUS.

8. If the sole be insulated before putting on the cover, the spark obtained from the cover is not of that cutting-kind it was before: but the same shock will be felt if both cake and cover be touched together.

9. If the cover be again raised to a considerable height, the sole will be found electrical, and its electricity is that of the cake, and opposite to that of the cover.

10. After touching both cover and sole, if the cover be raised and again set down, without touching it while aloft, the whole is again inactive.

11. If both cover and sole be made inactive when joined, they shew opposite electricities when separated, the sole having the electricity of the cake.

12. If both cover and sole be made inactive when separate, they both shew the opposite to the electricity of the cake when joined. 187

Disposition of the fluid thereon.

Let us now attend to the disposition of the electrical fluid in the different parts of the instrument in their various situations, and to the forces which operate mutually between them. *N. B.* Experiments for examing this instrument are best made by setting the three plates vertically, supported on glass stalks, with leaden feet, to steady them. A very small electrometer may be attached to the outer surfaces of the cover and sole.

If the extent of the plates were incomparably greater than their thickness, we may infer from n° 92, &c. that the redundant fluid and matter would be disposed in parallel strata, and that the actions would be the same at all distances. But since this is not the case, the disposition of the fluid will be somewhat different; and whatever it is, the action of any stratum will be diminished by an increase of distance. The following description cannot be very different from the truth: 188

Explanation of the primitive state.

1. The cake grows negative by cooling; and if it were alone, it would have a negative superficial stratum on both sides, of greater thickness near the edges; and the fluid would probably grow denser by degrees to the middle, where it would have its natural density. This diposition may be inferred from n° 92, 93, and 98. But it cools in conjunction with the sole, and the attraction of the redundant matter in the cake for the moveable fluid in the sole disturbs its uniform diffusion in the sole, and causes it to approach the cake. And because this, in all probability, happens while the cake is still a conductor, the disposition of its fluid will be different

different from that defcribed above, and the final difpofition of the fluid in the cake and fole will refemble that defcribed in n° 95, where the plates E and A reprefent the cake and fole. But becaufe we do not know precifely the gradation of denfity, and aim only at general notions at prefent, it will be fufficient to confider the cake and fole as divided into two ftrata only; one redundant in fluid, and the other deficient, neglecting the neutral ftratum that is interpofed between them in each. The cake then, confifts of a ftratum AB *b a* A containing redundant matter, and a ftratum *a b* CD containing redundant fluid: and the fole has a ftratum DC *n m* containing redundant fluid: namely, all that belongs naturally to the fpace DCFE, and a ftratum *m n* FE containing redundant matter. This may be called the PRIMITIVE STATE of the cake and fole; and if once changed by communication with unelectrified bodies, it can never be recovered again without fome new excitement.

189 *Common ftate.* II. If the fole be touched by any body communicating with the ground, fluid will come in, till the repulfion of the redundant fluid in the fole for a fuperficial particle *y* is equal to the attraction of the redundant matter in the cake for the fame particle. What has been faid concerning infinitely extended plates rendered neutral on one fide, may fuffice to give us a notion of the prefent difpofition of the fluid in the fole. The under furface will be neutral, and the fluid will increafe in denfity toward the furface DC. The fole contains more than its natural quantity of fluid, but is neutral by the balance of oppofite forces. Let it now be infulated. This difpofition of fluid may be called the *common ftate* of the electrophorus.

190 III. Let the cover GHBA be laid on it. The particle *z*, at the upper furface of the cover, muft be more attracted by the redundant matter in the ftratum AB*b a* than it is repelled by the redundant fluid in the remoter ftrata; for the fluid in the cake is lefs than what belongs to it in its natural ftate, and therefore *z* is attracted by the cake. The redundant fluid which has come into the remote fide of the fole is lefs than what would faturate the redundant matter of the cake, becaufe it only balances the excefs of the remote action of this matter above the nearer action of the compreffed fluid in the fole; and this fmaller quantity of redundant fluid acts on *z* at a greater diftance than that of the redundant matter in the cake. On the whole, therefore, the particle *z* lying immediately within the furface GH, is attracted; therefore fome will move toward the cake, and its natural ftate of uniform diffufion through the cover will be changed into a violent ftate, in which it will be compreffed on the furface AB, being abftracted from the furface GH. It will now have a ftratum G *g p* H, containing redundant matter, and another *g p* BA, containing redundant fluid. But this will difturb the arrangement which had taken place in the fole, and had rendered it neutral on the under furface. We do not attend to the fluid in the cake, but confider it as immoveable, for any motion which it can get will be fo fmall, that the variations of its action will be altogether infignificant. The particle *y*, fituated in that furface, will be more repelled by the compreffed fluid in the ftratum *g p* CA than it is attracted by the equivalent, but more remote redundant matter in GH *p g*. Fluid is therefore difpofed to quit the furface EF, and the fole appears pofitively electric; very little indeed, if the cover be thin. All this may be obferved by attaching a fmall Canton's electrometer to the lower furface of the fole, or by touching the fole with the electrometer of fig. 8, and then trying its electricity by rubbed wax or glafs.

IV. A particle of fluid *z*, placed immediately without the furface GH, will be more attracted by the deficient ftratum GH *p g*, and by AB *b a* than it is repelled by the redundant ftrata beyond them, and the cover muft be fenfibly negative. This is the common ftate of the whole inftrument after fetting on the cover. It is flightly pofitive on the lower furface of the fole, and much more fenfibly negative on the upper furface of the cover. A fmart fpark will therefore be feen between it and the finger, fluid will enter, till the attraction of the redundant matter in AB *b a* is balanced by the repulfion of the redundant fluid in DCFE. 191

V. A fpark will now be obtained from the fole, becaufe it was faintly pofitive before, and there has been added the action of the fluid, which has entered into the cover. The fluid in the fole is therefore difpofed to fly to any body prefented to it. But when this has happened, the equilibrium at the furface GH is deftroyed, and that furface again becomes negative, and will attract fluid, although the cover already contains more than its natural quantity. A fmall fpark will therefore be feen between the cover and any conducting body prefented to it. By touching it, the neutrality or equilibrium is reftored at GH; but it is deftroyed again at EF, which will again give a pofitive fpark, which, in its turn, again leaves GH negative. This will go on forever in a feries of communications continually diminifhing, fo as foon to become infenfible, if the three parts of the electrophorus be thin. This makes it proper to make them otherwife, if the inftrument be intended for illuftrating the theory. 192 *Dead ftate.*

At laft the equilibrium is completed at the furfaces GH and EF, and both are neutral in relation to furrounding bodies, although both the cover and fole contains more than their natural fhare of electric fluid. We may call this the NEUTRAL or DEAD ftate of the electrophorus.

This ftate may be produced at once, inftead of doing it by thefe alternate touches of GH and EF. If we touch at once both thefe furfaces, we have a bright, pungent fpark, and a fmall fhock. If this be the object of the experiment, the ftate N° IV. which gives occafion to it, may be called the CHARGED ftate of the electrophorus. 193 *Charged ftate.*

When the inftrument has thus been rendered neutral in relation to furrounding bodies, it is plain that it may continue in this ftate for any length of time without any diminution of its capability of producing the other phenomena, provided only that no fluid pafs from the cover to the cake. We do not *fully* underftand what prevents this communication, nor indeed what prevents the rapid efcape from an overcharged body into the air. This caufe, whatever it be, operates here; and the beft way of preventing the diffipation, or the abforption by the cake, is to keep the electrophorus with its cover on. It will come into this neutral ftate by diffipation from the fole, and abforption by the cover, in in no very long time; and after this, will remain neutral, retaining its power with great obstinacy, especially if the cake and plates are very thin.

194 *Charging or active state.* VI. If the cover be now removed to a distance, both parts of the apparatus will shew strong marks of electricity. The cover contains much redundant fluid, and must appear strongly positive, and will give a bright spark which may be employed for any purpose. It may be employed for charging a jar positively by the knob, if we just touch the cover with the knob. The sole will attract fluid, or be negative, although it contain more than its natural quantity of fluid, and it will take a spark. The sole therefore, in the absence of the cover, may be employed to charge a jar negatively by the knob. By touching it with the finger, or with the knob of a jar held in the hand, it is reduced to the common state described in N° II.; and now all the former experiments may be repeated. We may call this the ACTIVE or the CHARGING state.

Electrophorus not a magazine of electricity, but a collecting machine. This state of the apparatus has caused it to get the name *Electrophorus*. Volta, its undoubted inventor, called it *Elettroforo perpetuo*; for it *appears*, as has been already observed, to contain a magazine of electricity. The cover, when removed, will charge a jar held in the hand positively; and having done this service, it will charge a jar negatively when again set on the cake. The sole, in the absence of the cover, will charge a third jar negatively; and then, when the cover, after being touched, is set down again, it will charge a fourth jar positively. It will not be difficult to contrive a simple mechanism, connected with the motion of the cover, which shall connect the joined parts with two jars, and shall connect them when separated, with two others; and thus charge all the four with great expedition. All this is done without any new excitation of the electrophorus. But it is by no means a *magazine* of electricity which it gradually expends: it is a COLLECTOR of electricity from the surrounding bodies, which it afterwards imparts to others, and may be employed to discharge jars in the same gradual manner as to charge them.

195 VII. If the electrophorus is not insulated, a shock may still be obtained, by first touching the sole, and then, without removing the finger, touching the cover: but this will not be so smart as when the negative cover is touched at the same time that we touch the sole, more highly positive than when it communicates with the ground. The difference must, however, be almost imperceptible when the pieces are thin.

196 VIII. If the electrophorus is not insulated, the cover, when put on, will give a spark in the manner already mentioned, and it will be somewhat stronger than when it is insulated; because the fluid is allowed to escape from the sole, and does not obstruct the entry into the cover. If we then, without removing the finger from the cover, touch the sole, nothing is felt; but if we first touch the sole, and, without removing the finger from it, touch the cover, we obtain a shock. This is evident from the theory. By this series of alternate touches, the period of the electrophorus is completed. The electrophorus is charged or rendered neutral, by touching the plates when joined; then, by touching both when separated, the whole is reduced to the common state. When separated, from being in the neutral state, they have opposite electricities, the sole shewing that of the cake. When brought together, each in the common state, they have opposite electricities, the cover shewing that of the cake.

197 How it may be re-created. IX. When, by long exposure to the air without its cover, the electrophorus has lost its virtue, it may be brought again into an active state in a variety of ways. Its surface may be rendered negative by friction with dry cat or hare skin, or warm flannel. It may be rendered negative by setting on it a jar charged negatively on the inside, and then touching the knob with any thing communicating with the ground. This is the most expeditious method, and will give it a high degree of excitation, if the jar be of size, and if the electrophorus be covered with a plate of tinfoil which comes into contact all over its surface. This however requires the previous charging of the jar; therefore it will be as expeditious and effectual to connect this surface with the rubber of an electrical machine. We had almost forgotten to remark, that the effects of bringing the cover edgewise to the cake, follow clearly from the theory, as will appear to the attentive reader without further explanation.

198 It is not similar to a charged pane. The electrophorus has been compared to a charged plate of coated glass. It is true that it *may be brought* into an external state which very much resembles a charged pane, namely, when the cover, in its natural state, is set on the electrophorus in its natural state; and accordingly it gives a shock, and the two exterior surfaces become neutral; but the internal constitution, and the acting forces, are totally and *essentially* different. The two coatings of the pane would not, when separated, exhibit the appearances of the electrophorus; nor when touched in their disjointed state, will they produce the same effects when joined. In the operation of coated glass, the constant or invariable part, the glass is not the *agent*, it is merely the *occasion* of the action, by *allowing* the accumulation. In the electrophorus, the electric, which is the constant invariable part, is the *agent producing* the accumulation. The electrophorus is an original, and a very ingenious and curious electrical machine. Nothing has so much contributed to spread some general, though slight, acquaintance with the mechanical principles of electricity. The numerous dabblers in natural knowledge had been diverted from scientific pursuit by the variety of the singular and amusing effects of electricity, and had really attained very little connected knowledge. The effects of the electrophorus *forced* this knowledge on them; because no use can be made of it without a pretty clear conception of the disposition of the electricity, and the kind and intensity of the actions. It is therefore most ungrateful in the experimenters who have attained better views, to attempt to rob Mr Volta of the real merit of discovery, by shewing that its effects are similar to those of Mr Symmer's stockings, or of Cigna's plates, or of Franklin's charged or discharged glass panes. And the attempt destroys itself: for it shews the ignorance or inattention of its author; for the similarity is not real, as will appear clear to any person who will examine things minutely and scientifically, proceeding in this examination on suppositions similar to those which we employed in the analysis of Richmann's experiment. It was indeed in subserviency to this examination that we entered into the detail of that experiment, it being a simpler case. The accurate examination of Richmann's experiment requires the fluxionary

fluxionary calculus in its refined form. In the present question five acting strata are to be considered, which renders the formulæ very complicated, and indeed intractable, unless we make the plates extremely thin; which, fortunately, is the best form of the instrument. We have completed this mathematical analysis; and the popular view here given is the result of that computation.

199 Condensator of electricity.

The electricians are no less obliged to Mr Volta for another machine, or instrument, from which the study of Nature's operations has derived, or may derive, immense advantages. We mean the CONDENSER, or COLLECTOR of electricity. We refer to the article ELECTRICITY in the *Encyclopædia* for a description of the instrument, and some account of its effects and properties. The general effect is to render sensible an accumulation or deficiency of electric fluid so slight that it will not affect the most delicate electrometer; and it produces (at least in the opinion of Mr Volta) this effect, by employing for the sole of an electrophorus a body which is an imperfect conductor, such as a plate of well dried marble, or well dried, but not baked, wood; or even a conducting body, covered with a bit of dry taffety or other silk. Mr Volta, Cavallo, and others, who have written a great deal on the subject, have attempted to shew how these substances are preferable (and they certainly are preferable in a high degree) to more perfect insulators: but not having taken pains to form precise notions of the disposition and action of the electric fluid in the situations afforded by the instrument, their reasonings have not been very clear. We think that an adequate conception of the essentials of the proposed instrument may be acquired by means of the following considerations:

200 Furnish the cover of an electrophorus with a graduated electrometer, which indicates the proportional *degrees of electricity*; electrify it positively to any degree, suppose six, while held in the hand, at some distance, right over a metal plate lying on a wine glass as an insulating stand, but communicating with the ground by a wire. Bring it gradually down toward the plate. Theory teaches, and we know it by experiment, that the electrometer will gradually subside, and perhaps will reach to 2° before the electricity is communicated in a spark. Stop it before this happens. In this state the attraction of the lying plate produces a compensation of four degrees of the mutual repulsion of the parts of the cover, by constipating the fluid on its under surface, and forming a deficient stratum above. This needs no farther explanation after what has been said on the charging of coated glass plates. Now we can suppose that the escape of the fluid from this body into the air begins as soon as electrified to the degree 6, and that it will fly to the lying plate with the degree 2, if brought nearer. If we can prevent this communication to the lying plate, by interposing an electric, we may electrify the cover again, while so near the metal plate, to the degree 6, before it will stream off into the air. If it be now removed from the lying plate, the fluid would raise the electrometer to 10, did it not immediately stream off; and an electric excitement of any kind which could only raise this body to the degree 6 by its intensity, will, by this apparatus, raise it to the degree 10, if only copious enough in extent. If we do the same thing when the wire is taken away which connects the lying plate with the ground, we know that the same diminution of the electricity of the other plate cannot be produced by bringing it down into the neighbourhood of the lying plate (see n° 134, &c. 151, &c.).

Here we see the whole theory of Mr Volta's condenser. He seems to have obscured his conceptions of it by having his thoughts running upon the electrophorus lately invented by him, and is led into fruitless attempts to explain the advantages of the imperfect conductor above the perfect insulator. But the apparatus is altogether different from an electrophorus, and is more analogous in its operations to a coated plate not charged nor insulated on the opposite side; and such a coated plate lying on a table is a complete condenser, if the upper coating be of the same size with the plate of the condenser. All the directions given by Mr Volta for the preparation of the imperfect conductors shew, that the effect produced is to make them as perfect conductors as possible for any degree of electricity that exceeds a certain small intensity, but such as shall not suffer this very weak electricity to clear the first step of the conduit. The marble must be thoroughly dried, and even heated in an oven, and either used in this warm state, or varnished, so as to prevent the reabsorption of moisture. We know that marble of slender dimensions, so as to be completely dried throughout, will not conduct till it has again become moist. A thick piece of marble is rendered so, superficially only, and still conducts internally. It is then in the best possible state. The same may be said of dry unbaked wood. Varnishing the upper surface of a piece of marble or wood is equivalent to laying a thin glass plate on it. Now this method, or covering the top of the marble, or of a book, or even the table, with a piece of clean dry silk, makes them all the most perfect condensators. This just view of the matter has great advantages. It takes away the mysterious indistinctness and obscurity which kept the instrument a quackish tool, incapable of improvement. We can now make one incomparably better and more simple than any proposed by the very ingenious inventor. We need only the simple moveable plate. Let this be varnished on the under side with a moderately thick coat of the purest and hardest *vernis de Martin*, or coach-painters varnish; and we have a complete condensator by laying this on a table. If it be connected by a wire with the substance in which the weak and imperceptible electricity is excited, it will be raised (provided there be enough of it of that small intensity) in the proportion of the thickness of the varnish to the fourth part of the diameter of the plate. This degree of condensation will be procured by detaching the connecting wire from the insulating handle of the condenser, and then raising the condenser from the table. It will then give sparks, though the original electricity could not sensibly affect a flaxen fibre.

Theory thereof.

It must be particularly noted, that it can produce this condensation only when there is fluid to condense; that is, only when the weak electricity is diffused over a greater space than the plate of the condenser. In this way it is a most excellent collector of the weak atmospheric electricity, and of all diffused electricity. But to derive the same advantage from it *in many very interesting cases*, such as the inquiry into the electricity excited in many operations of Nature on small quantities of of matter, we muſt have condenſers of various ſizes, ſome not larger than a ſilver penny. To conſtruct theſe in perfection, we muſt uſe the pureſt and hardeſt varniſh, of a kind not apt to crack, and highly coercive. This requires experiment to diſcover it. Spirit varniſhes are the moſt coercive; but by their difference of contraction by cold from that of metals, they ſoon appear froſty, and when viewed through a lens, they appear all ſhivered: They are then uſeleſs. Oil varniſhes have the requiſite toughneſs, but are much inferior in coercion. We have found amber varniſh inferior to copal varniſh in this reſpect, contrary to our expectation. On the whole, we ſhould prefer the fineſt coach-painters varniſh, new from the ſhop, into which a pencil has never been dipped: and we muſt be particularly careful to clear our pencils of moiſture and all conducting matter, which never fails to taint the varniſh. We ſcarcely need remark, that the coat of varniſh on theſe ſmall condenſers ſhould be very thin, otherwiſe we loſe all the advantage of their ſmallneſs.

201 Cavallo's improvement thereof.

Mr Cavallo has ingeniouſly improved Volta's condenſer by connecting the moveable plate, after removal, with a ſmaller condenſer. The effect of this is evident from n° 130. But the ſame thing would have been generally obtained by uſing the ſmall condenſer at firſt, or by uſing a ſtill thinner coat of varniſh.

202 It will readily occur to the reader, that this inſtrument is not inſtantaneous in its operation, and that the application muſt be continued for ſome time, in order to collect the minute electricity which may be excited in the operations of nature. He will alſo be careful that the experiment be ſo conducted that no uſeleſs accumulation is made anywhere elſe. When we expect electricity from any chemical mixture, it never ſhould be made in a glaſs veſſel, for this will take a charge, and thus may abſorb the whole excited electricity, accumulating it in a neutral or inſenſible ſtate. Let the mixture be made in veſſels of a conducting ſubſtance, inſulated with as little contact as poſſible with the inſulating ſupport; for here will alſo be ſomething like a charge. Suſpend it by ſilk threads, or let it reſt on the tops of three glaſs rods, &c.

203 Bennet's *doubler* of electricity.

After this account of the Leyden phial, electrophorus, and condenſer, it is ſurely unneceſſary to employ any time in explaining Mr Bennet's moſt ingenious and uſeful inſtrument called the *doubler of electricity*. The explanation offers itſelf ſpontaneouſly to any perſon who underſtands what has been ſaid already. Mr Cavallo has with induſtry ſearched out all its imperfections, and has done ſomething to remove them, by ſeveral very ingenious conſtructions, minutely deſcribed in his Treatiſe on Electricity. Mr Bennet's original inſtrument may be freed, we imagine, as far as ſeems poſſible, by uſing a plate of air as the intermedium between the three plates of the doubler. Stick on one of the plates three very ſmall ſpherules made from a capillary tube of glaſs, or from a thread of ſealing-wax. The other plate being laid on them, reſts on mere points, and can ſcarcely receive any friction which will diſturb the experiment. Mr Nicholſon's beautiful mechaniſm for expediting the multiplication has the inconveniency of bringing the plates towards each other edgewiſe, which will bring on a ſpark or communication ſooner than may be deſired: but this is no inconvenience whatever in any philoſophical reſearch; becauſe, before this happens, the electricity has become very diſtinguiſhable as to its kind, and the degree of multiplication is little more than an amuſement. The ſpark may even ſerve to give an indication of the original intenſity, by means of the number of turns neceſſary for producing it. If the fine wires, which form the alternate connections in ſo ingenious a manner, could be tipped with little balls to prevent the diſſipation, it would be a great improvement indeed. An alternate motion, like that of a pump-handle, might be adopted with advantage. This would allow the plates to approach each other face to face, and admit a greater multiplication, if thought neceſſary.

204 Diſſipation of electricity from ſharp points.

One of the moſt remarkable facts in electricity is the rapid diſſipation by ſharp points, and the impoſſibility of making any conſiderable accumulation in a body which has any ſuch, projecting beyond other parts of its ſurface. The diſſipation is attended with many remarkable circumſtances, which have greatly the appearance of the actual eſcape of ſome material ſubſtance. A ſtream of wind blows from ſuch a point, and quickly electrifies the air of a room to ſuch a degree, that an electrometer in the fartheſt corner of the room is affected by it. This diſſipation in a dark place is, in many inſtances, accompanied by a bright train of light diverging from the point like a firework. Dr Franklin therefore was very anxious to reconcile this appearance with his theory of plus and minus electricity, but does not expreſs himſelf well ſatisfied with any explanation which had occurred to him. From the beginning, he ſaw that he could not conſider the ſtream of wind as a proof of the eſcape of the electric fluid, becauſe the ſame ſtream is obſerved to iſſue from a ſharp negative point; which, according to his theory, is not diſperſing, but abſorbing it. Mr Cavendiſh has, in our opinion, given the firſt ſatisfactory account of this phenomenon.

To ſee this in its full force, the phenomenon itſelf muſt be carefully obſerved. The ſtream of wind is plainly produced by the eſcape of ſomething from the point itſelf, which hurries the air along with it; and this draws along with it a great deal of the ſurrounding air, eſpecially from behind, in the ſame manner as the very ſlender thread of air from a blow-pipe hurries along with it the ſurrounding air and flame from a conſiderable ſurface on all ſides. It is in this manner that it gathers the whole of a large flame into one maſs, and, at laſt, into a very point. If the ſmoke of a little roſin thrown on a bit of live coal be made to riſe quietly round a point projecting from an electrified body, continually ſupplied from an electrical machine, the vortices of this ſmoke may be obſerved to curl in from all ſides, along the wire, forming a current of which the wire is the axis, and it goes off completely by the point. But if the wire be made to paſs through a cork fixed in the bottom of a wide glaſs tube, and if its point project not beyond the mouth of the tube, the afflux of the air from behind is prevented, and we have no ſtream; but if the cork be removed, and the wire ſtill occupy the axis of the tube, but without touching the ſides, we have the ſtream very diſtinctly; and ſmoke which riſes round the far end of the tube is drawn into it, and goes off at the point of the wire. Now it is of importance to obſerve, that whatever prevents the formation of this ſtream of wind prevents the diſſipation of electricity (for we ſhall not ſay eſcape 205

of

of electric fluid) from the point. If the point project a quarter of an inch beyond the tube, or if the tube be open behind, the ſtream is ſtrong, and the diſſipation ſo rapid, that even a very good machine is not able to raiſe a Henly's electrometer, ſtanding on the conductor, a very few degrees. If the tube be ſlipped forward, ſo that the point is juſt even with its mouth, the diſſipation of electricity is next to nothing, and does not exceed what might be produced by ſuch air as can be collected by a ſuperficial point. If the tube be made to advance half an inch beyond the point which it ſurrounds, the diſſipation becomes inſenſible. All theſe facts put it beyond a doubt that the air is the cauſe, or, at leaſt, the occaſion of the diſſipation, and carries the electricity off with it, in this manner rendering electrical the whole air of a room. The problem is reduced to explain how the air contiguous to a ſharp electrified point is electrified and thrown off.

Theory of it. It was demonſtrated in n° 130, that two ſpheres, connected by an infinitely extended, but ſlender conducting canal, are in electrical equilibrium, if their ſurfaces contain fluid in the proportion of their diameters. In this caſe, the ſuperficial denſity of the fluid and its tendency to eſcape are inverſely as the diameters (n° 130). Now if, in imagination, we gradually diminiſh the diameter of one of the ſpheres, the tendency to eſcape will increaſe in a greater proportion than any that we can name. We know, that when the prime conductor of a powerful table-machine has a wire of a few inches in length projecting from its end, and terminating in a ball of half an inch in diameter, we cannot electrify it beyond a certain degree; for when arrived at this degree, the electricity flies off in ſucceſſive burſts from this ball. Being much more overcharged than any other part of the body, the air ſurrounding the ball becomes more overcharged by communication, and is repelled, and its place ſupplied by other air, not ſo much overcharged, which ſurrounded the other parts of the body, and is preſſed forwards into this ſpace by the general repulſion of the conductor and the confining preſſure of the atmoſphere; otherwiſe, being alſo overcharged, it would have no tendency to come to this place. Half a turn of the cylinder is ſufficient to accumulate to a degree ſufficient for producing one of theſe exploſions, and we have two of them for every turn of the cylinder. A point may be compared to an incomparably ſmaller ball. The conſtipation of the fluid, and its tendency to eſcape, muſt be greater in the ſame unmeaſurable proportion. This denſity and mutual repulſion cannot be diminiſhed, and muſt even be increaſed, by the matter of the wire forming a cone, of which the point is the apex; therefore, if there were no other cauſe, we muſt ſee that it is almoſt impoſſible to confine a collection of particles, mutually repelling, and conſtipated, as theſe are in a fine point.

206 Electricity unites chemically with air. But the chief cauſe ſeems to be a certain chemical union which takes place between the electric fluid and a correſponding ingredient of the air. In this ſtate of conſtipation, almoſt completely ſurrounded by the air, the little maſs of fluid muſt attract and be attracted with very great force, and more readily overcome the force which keeps the electrified fluid attached to the laſt ſeries of particles of the wire. It unites with the air, rendering it electric in the higheſt degree of redundancy. It is therefore ſtrongly repelled by the maſs of conſtipated fluid which ſucceeds it within the point. Thus is the electrified air continually thrown off, in a ſtate of electrification, that muſt rapidly diminiſh the electricity of the conductor. Hence the uninterrupted flow, without noiſe or much light, when the point is made very fine. When the point is blunt, a little accumulation is neceſſary before it attains the degree neceſſary for even this minute exploſion; but this is ſoon done, and theſe little exploſions ſucceed each other rapidly, accompanied by a ſputtering noiſe, and trains of bright ſparks. The noiſe is undoubtedly owing to the atoms of the highly electrified fluid. Theſe are, in all probability, rarefied of a ſudden, in the act of electrification, and immediately collapſe again in the act of chemical union, which cauſes a ſonorous agitation of the air. This electrified air is thus thrown off, and its place is immediately ſupplied by air from behind, not yet electrified, and therefore ſtrongly drawn forward to the point, from which they are thrown off in their turn. This rapid expanſion and ſubſequent collapſing of the air is verified by the experiments of Mr Kinnerſly, related by Dr Franklin, and is ſeen in numberleſs experiments made with other views in later times, and not attended to. Perhaps it is produced by the great heat which accompanies, or is generated in the transference of electricity, and it is of the ſame kind with what occaſions the burſting of ſtones, ſplitting of trees, exploding of metals, &c. by electricity. The expanſion is either inconſiderable, or it is ſucceſſively produced in very ſmall portions of the ſubſtance expanded; for when metal is exploded in cloſe veſſels, or under water, there is but a minute portion of gazeous matter produced; and in the diſſipation by a very fine point, ſufficiently great to give full employment to a powerful machine, the ſtream of wind is but very faint, and nine-tenths of this has been dragged along by the really electrified thread of wind in the middle.

From a collation of all the appearances of electricity, we muſt form the ſame conception of the forces which operate round a point that is negatively electrified, not diſperſing, but drawing in electric fluid. It is more completely undercharged than any other part of a body, and attracts the fluid in the ſurrounding air, and the air in which it is retained, with incomparably greater force. It therefore deprives the contiguous air of its fluid, and then repels it, and then produces a ſtream like the overcharged point.

If a conducting body be brought near to any part of an overcharged body, the fronting part of the firſt is rendered undercharged; and this increaſes the charge of the oppoſite part of the overcharged body. It becomes more overcharged in that part, and ſooner attains that degree of conſtipation that enables the fluid to quit the ſuperficial ſeries of particles, and to electrify ſtrongly the contiguous air. The exploſion is therefore made in this part in preference to any other; and the air thus exploded is ſtrongly attracted by the fronting part of the other body, and muſt fly thither in preference to any other point. If, moreover, the fronting part of A be prominent or pointed, this effect will be produced in a ſuperior degree; and the current of electrified air, which will begin very early, will increaſe this diſpoſition to transference in this way by rarefying the air; a change which the whole courſe of electric phenomena ſhews to be highly favourable to this transference, 207 ference, although we cannot perhaps form any very adequate notion how it contributes to this effect. This seems to be the reason why a great explosion and snap, with a copious transference of electricity, is generally preceded by a hissing noise like the rushing of wind, which swells to a maximum in the loud snap itself.

208 If two prominences, precisely similar, and electrified in the contrary way to the same degree, are presented to each other, we cannot say from which the current should take its commencement, or whether it should not equally begin from both, and a general dispersion of air laterally be the effect; but such a situation is barely possible, and must be infinitely rare. The current will begin from the side which has some superiority of propelling force. We are disposed to think that this current of material electrified substance must suffer great change during its passage, by mixing with the current in an opposite electrical state coming from the other body. Any little mass of the one current must strongly attract a contiguous mass of the other, and certain changes should surely arise from this mixture. These may, in their turn, make a great change in the *mechanical* motions of the air; and, instead of producing a *quaqua versum* dispersion of air from between the bodies, as should result from the meeting of opposite streams, it may even produce a collapsing of the air by the mutual strong attractions of the little masses. Many valuable experiments offer themselves to the curious inquirer. Two little balls may be thus presented to each other, and a smoke may be made with rosin to occupy the interval between them. Motions may be observed which have certain analogies that would afford useful information to the mechanical inquirer. There must be something of this mixture of currents in all such transferences, and the most minute differences in the condition of a little parcel of the air may greatly affect the future motions. The most promising form of such experiment would be to use two points of the same substance, shape, and size, and electrified to the same degree in opposite senses.

209 Characteristic differences of positive and negative electricity.

After all care has been taken to insure similarity, there remains one essential difference, that *the one current is redundant in electric fluid, and the other deficient*. This circumstance *must* produce characteristic differences of appearance. And are there not such differences? Is not the pencil and the star of light a characteristic difference? And does not this well-supported fact greatly corroborate the opinion of Dr Franklin, that the electric phenomena result from the redundancy and deficiency of *one* substance, and not from two distinct substances operating in a similar manner? For the distinction in appearance is a mechanical distinction. Motion, direction, velocity, are perceivable in it. Locomotive forces are concerned in it; but they are so implicated with forces which probably resemble chemical affinities, hardly operating beyond contact, that to extricate their effects from the complicated phenomenon seems a desperate problem. There is some hitherto inexplicable chemical composition and decomposition taking place in the transference of electricity. Of this a numerous train of observations made since the dawn of the pneumatic chemistry leaves us no room to doubt. The emersion or production of light and heat is a remarkable sign and proof. Now *this takes place along the whole path of transference*; therefore the process is by no means completed at the point from which the active cause proceeds; and although there be certain appearances that are pretty regular, they are still mixed with others of the most capricious anomaly. The zigzag form of the most condensed spark, totally unlike, by its sharp angles, to any motions producible by accelerating forces, which motions are without exception, curvilineal, makes us doubt exceedingly whether the luminous lines which we observe are successive appearances of the same matter in different places, or whether they be not rather simultaneous, or nearly simultaneous, coruscations of different parcels of matter in different places, indicating chemical compositions taking place almost at once; and this becomes more probable, when we reflect on what has been said already of the jumbling of opposite currents; such mixtures should be expected. We have seen a darted flash of lightning which reached (in a direction nearly parallel to the horizon) above three miles from right to left; and it seemed to us *to be co-existent*; we could not say at which end it began. The thunder began with a loud crack, and continued with a most irregular rumbling noise about 15 seconds, and seemed equal on both hands. We imagine that it was really a simultaneous snap, in the whole extent of the spark, but of different strength in different places; different portions of the sonorous agitation were propagated to the ear in succession by the sonorous undulations of air, causing it to seem a lengthened sound. Such would be the appearance to a person standing at one end of a long line of soldiers who discharge their firelocks at one instant. It will seem a running fire, of different strength in different parts of the line, if the muskets have been unequally loaded. It is inconceivable that this long zigzag spark can mark the track of an individual mass of electrified air. The velocity and momentum would be enormous, and would sweep off every thing in its way, and its path could not be angular. The same must be asserted of the streams of light in our experiments. The velocity is so unmeasurable that we cannot tell its direction. There may be very little local motion, just as in the propagation of sound, or of a wave on the surface of water. That particular change of mutual situation among the adjoining atoms which occasions chemical solution or precipitation may be produced in an instant, over a great extent, as we know that a parcel of iron filings, lying at random on the surface of quicksilver, will, in one instant, be arranged in a certain manner by the mere neighbourhood of a magnet. Is not this like the simultaneous precipitation of water along the whole path of a discharge?

But still there must be some cause which gives these simultaneous coruscations a situation with respect to each other, that has a certain regularity. Now the luminous *trains* (for they are not uniform *lines* of light) of almost continuous sparks which are arranged between a positive and a negative point, seem to us to indicate emanation from the positive, and reception by the negative point. The general line has a considerable resemblance to the path of a body projected from the positive point, repelled by it, and attracted by the negative point. This will appear to the mechanician on a very little reflection. If the curve were completely visible, it would somewhat resemble those drawn between P and N in fig. 35. PABN overpasses the point N, and

and comes to it from behind; $P\,a\,b\,N$ lies within the other, and arrives in a direction nearly perpendicular to the axis; $P\,\alpha\,BN$ deſcribes a ſtraight line, and arrives in the direction PN. As the chemical compoſition advances, the light is diſengaged or produced, and therefore the appearances are more rare as we advance farther in the direction in which they are produced; and there would perhaps be no appearance at all at the point where the motion ends, were it not that the few remaining parcels, where the compoſitions or decompoſitions have not been completed, are crowded together at the negative point, *incomparably* more than in any other part of the track. We think that theſe conſiderations offer ſome explanation of the appearance of the pencil and ſtar, which are ſo uniformly characteriſtic of the poſitive and negative electricities: but we ſee many grounds of uncertainty and doubt, and offer it with due diffidence.

210

Lichtenberg's electricwriting affords diſtinctive marks of + and —.

The curious figures obſerved by Mr Lichtenberg, formed by the duſt which ſettles on a line drawn on the face of a mirror by the poſitive and by the negative knobs of a charged jar, are alſo uniformly characteriſtic of the two electricities. Theſe are mechanical diſtinctions, indicating certain differences of accelerating forces. We muſt iefer the curious reader to Lichtenberg's Diſſertations in the *Gottengen Commentaries*; to the *Publication of the Haerlem Society*; to the *Gotha Magazine*; to *Diſſertations by Spath* at Altdorff, and other German writers.

211

Diſſipation of electricity into the air is proportional to the denſity.

It only remains for us to take notice of the general laws of the diſſipation of electricity into the air, and along imperfect inſulators. On this ſubject we have ſome valuable experiments of Mr Coulomb, publiſhed in the Memoirs of the Academy of Sciences of Paris for 1785.

Theſe experiments were made with the aſſiſtance of an electrometer of a particular conſtruction, which ſhall be deſcribed under the article ELECTROMETER.

The general reſult of Mr Coulomb's experiments was, that the momentary diſſipation of moderate degrees of electricity is proportional to the degree of electricity at the moment. He found that the diſſipation is not ſenſibly affected by the ſtate of the barometer or thermometer; nor is there any ſenſible difference in bodies of different ſizes or different ſubſtances, or even different figures, provided that the electricity is very weak.

212 But he found the diſſipation greatly affected by the different ſtates of humidity of the air. Sauſſure's hygrometer has its ſcale diſtinctly related to the quantity of water diſſolved in a cubic foot of the air. The following little table ſhews an evident relation to this in the diſſipation of electricity:

Hygrometer.	Grains water in cubic foot.	Diſſipation per minute.
69	6,197	$\frac{1}{60}$
75	7,295	$\frac{1}{41}$
80	8,045	$\frac{1}{29}$
87	9,221	$\frac{1}{14}$

Hence it follows, that the diſſipation is very nearly in the triplicate ratio of the moiſtuie of the air. Thus if

$\frac{60}{41}$ be conſidered as $= \left.\frac{7,197}{6,180}\right|^{m}$ we have $m = 2,764$.

$\frac{60}{29}$ . . $= \left.\frac{8,045}{6,180}\right|^{m}$ gives $m = 2,76$.

$\frac{60}{14}$ - - $= \left.\frac{9,220}{6,180}\right|^{m}$ gives $n = 3,61$

Hence, at a medium, $m = 3,40$.

We ſhould have obſerved, that the ingenious author took care to ſeparate this diſſipation by immediate contact with the air, from what was occaſioned by the imperfect inſulation afforded by the ſupports.

213

Diminution of repulſion is double of the diſſipation.

It muſt alſo be remarked here, that the immediate object of obſervation in the experiments is the diminution of repulſion. This is found to be, in any given ſtate of the air, a certain proportion of the whole repulſion at the moment of diminution: but this is double of the proportion of the denſity of the electric fluid; for it muſt be recollected, that the repulſions by which we judge of the diſſipation are mutual, exerted by every particle of fluid in the ball t of Coulomb's electrometer, on every particle in the ball a. It is therefore proportional to the electric denſity of each; and therefore, during the whole diſſipation, the denſities retain their primitive proportion; therefore, the diminution of the repulſion being as the diminution of the products of the denſities, it is as the diminution of the ſquares of either. If therefore the denſity be repreſented by d, the mutual repulſion is repreſentable by d^2, and its momentary diminution by the fluxion of d^2; that is, by $2\,d\,\dot{d}$, or $2\,\dot{d}\times d$. Now $2\,\dot{d}\times d$ is to d^2 as $2\,\dot{d}$ is to d; and therefore the diminution of repulſion obſerved in our experiment bears to the whole repulſion twice as great a proportion as the diminution of denſity, or the quantity of fluid diſſipated, bears to the whole quantity at the moment. For example, if we obſerve the repulſion diminiſhed $\frac{1}{40}$, we conclude that $\frac{1}{80}$ of the fluid has eſcaped.

Mr Coulomb has not examined the proportion between the diſſipations from bodies of different ſizes. A great and a ſmall ſphere, communicating by a very long canal, have ſuperficial denſities, and tendencies to eſcape, inverſely proportional to the diameters. A body of twice the diameter has four times the ſurface; and though the tendency to eſcape be twice as ſmall, the ſurface is four times as great. Perhaps the greater ſurface may compenſate for the ſmaller denſity, and the quantity of fluid actually gone off may be greater in a large ſphere. This may be made the ſubject of trial. 214

215

Diſſipation depends on the ſtate of the air.

It muſt be kept in mind, that the law of diſſipation aſcertained by theſe experiments, relates to one given ſtate of the air, and that it does not follow that in another ſtate, containing perhaps the ſame quantity of water, the diſſipation ſhall be the ſame. The air is ſuch a heterogeneous and variable compound, that it may have very different affinities with the electric fluid. Mr Coulomb thought that he ſhould infer from his numerous experiments, that the diſſipation did not increaſe in the ratio of the cube of the water diſſolved in the air, unleſs it was nearly as much as it could diſſolve in that temperature. This indeed is conformable to general obſervation: for air is thought dry when it dries quickly any thing expoſed to it; that is, when not nearly ſaturated with moiſture. Now it is well known, that what is thought dry air, is favourable to electricity.

216

Diſſipation by imperfect inſulators.

The diſſipation along imperfect inſulators is brought about in a way ſomewhat different from the manner of its

its eſcaping by electrifying the contiguous air and going off with it. It ſeems to be chiefly, if not ſolely, along the ſurface of the inſulating ſupport that the electricity is diffuſed, and that the diffuſion is produced there chiefly by the moiſture which adheres to it. It is not very eaſy to form a clear notion of the manner, but Mr Coulomb's explanation ſeems as ſatisfactory as any we have ſeen.

Procedure thereof.

Water adheres to all bodies, ſticking to their ſurfaces. This adheſion prevents it from going off when electrified; and it is therefore ſuſceptible of a higher degree of electrification. If we ſuppoſe that the particles of moiſture are uniformly diſpoſed along the ſurface, leaving ſpaces between them, the electricity communicated to one particle muſt attain a certain denſity before it can fly acroſs the inſulating interval to the next. Therefore, when ſuch an imperfect conductor is electrified at one end, the electricity, in paſſing to the other, will be weakened at every ſtep. If we take three adjacent particles *a*, *b*, *c*, of this conducting matter, we learn, from n° 105, that the motion of *b* is ſenſibly affected only by the difference of *a* and *c*; and therefore that the paſſage of electricity from *b* to *c* requires that this difference be ſuperior or equal to the force neceſſary for clearing this coercive interval. Let a particle paſs over. The electric denſity of the particle *b* of conducting matter is diminiſhed, while the denſity of the particle on the other ſide of *a* remains as before. Therefore ſome will paſs from *a* to *b*, and from the particle preceding *a* to *a*; and ſo on, till we come to the electrified end of this imperfect inſulator. It is plain from this conſideration, that we muſt arrive at laſt at a particle beyond *c*, where the whole repulſion of the preceding particle is juſt ſufficient to clear this interval. Some will come over, whoſe repulſion, now acting in the oppoſite direction, will hinder any fluid from ſupplying its place in the particle which it has quitted. Here the transference will ſtop, and beyond this the inſulation is complete. There is therefore a mathematical relation between the inſulating power, and the length of the canal, which may be aſcertained by our theory; and thus another opportunity obtained for comparing it with obſervation. That this inveſtigation may be as ſimple as poſſible, we may take a very probable caſe, namely, where the inſulating, or, to name it more graphically, the coercive interval is equal in every part of the canal.

217 Theory thereof.

Let R be the coercive power of the inſulator; that is, let R be the force neceſſary for clearing the coercive interval. Let a ball C (fig. 36) be ſuſpended by a ſilk thread AB, and let C repreſent the quantity of its redundant fluid; and let the denſity in the different points of the canal be as the ordinates AD, P *d*, &c. of ſome curve line D *d* B, which cuts the axis in B where the thread begins to inſulate completely. Let P *p* be an element of the axis. Draw the ordinate *p f*, the tangent *d f* F, and the normal *d* E, and *f e* perpendicular to P *d*. Let AC be $= r$, AP $= x$, P $d = y$. Then P $p = \dot{x}$, and $d e = -\dot{y}$. We have ſeen, that the only ſenſible action on the particle of fluid in P is $-\frac{y\dot{y}}{\dot{x}}$ (ſee n° 105), when the action of the redundant fluid in the globe on the particle P having the denſity y, is repreſented by $\frac{C y}{(r + x)^2}$. Therefore we have $\frac{y\dot{y}}{\dot{x}} =$ R, the coercive power of the thread. This is ſuppoſed to be conſtant. Therefore $\frac{P d \times d e}{P p}$ is equal to ſome conſtant line R. But P *p*, or $f e : d e = P d :$ PE. Therefore the ſubnormal PE is a conſtant line. But this is the property of the parabola alone; and the curve of denſity D *d* B is a parabola, of which the parameter is 2 PE, or 2 R.

218 Variation of denſity in the inſulator.

Cor. 1. The denſities in different points of an imperfect inſulator, are as the ſquare roots of their diſtance from the point of complete inſulation: For $P d^2 : AD^2 = BP : BA$.

219 Length neceſſary for inſulation ÷ denſity²

2. The length of canal required for inſulating different denſities of electricity are as the ſquares of the denſities. For $AB = \frac{AD^2}{2 PE}$; and PE has been ſhewn to be a conſtant quantity. Indeed we ſee in the demonſtration, that BP would inſulate a ball, whoſe electric denſity is P *d*, and $BA : BP = AD^2 : P d^2$.

220 Alſo ÷ $\frac{1}{\text{coercion.}}$

3. The length neceſſary for inſulation is inverſely as the coercive force of the canal, and may be repreſented generally by $\frac{D^2}{R}$. For AB is $= \frac{DA^2}{2 PE} = \frac{D^2}{2 R}$

Mr Coulomb has verified theſe concluſions by a very ſatisfactory ſeries of experiments, by the aſſiſtance of his delicate electrometer, which is admirably ſuited for this trial. The ſubject is ſo intereſting to every zealous ſtudent of electricity, that Mr Canton, Dr B. Wilſon, Mr Waitz, Wilcke, and others, have made experiments for eſtabliſhing ſome meaſure of the conducting powers of different ſubſtances. It was one of the firſt things that made the writer of this article ſuppoſe that electric action was in the inverſe duplicate ratio of the diſtances: for, as early as 1763, he had found, that the lengths of capillary tubes neceſſary for inſulation were as the ſquares of the repulſions of the ball which they inſulated. The mode of reaſoning offers of itſelf, and the fluxionary expreſſion of the inſulating power, *viz.* $\frac{\dot{d}}{\dot{x}}$ led immediately to a force proportional to $\frac{1}{x^2}$.

Numerous experiments were made, which we do not give here, becauſe the public are already poſſeſſed of thoſe of Mr Coulomb.

Explanation of the efficacy of Volta's *condenſer*.

This diſcuſſion explains, in a ſatisfactory manner, the operation of the condenſer, as deſcribed by Mr Volta. The weak degrees of electricity, which are rendered ſufficiently ſenſible by the inſulation of the plate of dry marble, are completely inſulated by the perhaps thin ſtratum that has been ſufficiently dried, while the reſt conducts with an efficacy ſufficient for permitting the accumulation.

221 When we reflect on the theory now delivered, we ſee that the formulæ determine the diſtribution of the fluid along an imperfect conductor in a certain manner, on the ſuppoſition that a *certain determinate* doſe has been imparted to the ball: Becauſe this doſe, by diffuſing itſelf from particle to particle of the conducting matter, will diffuſe itſelf all the way to B, in ſach a manner that the repulſion ſhall everywhere be in equilibrio with the *maximum* of the coercive force of the inſulating interval. But it muſt be farther noticed, that this reſiſtence is not *active*, but coercitive, and we may compare it to friction or viſcidity. Any repulſion of electric fluid, which falls ſhort of this, will not diſturb the ſtability of the fluid ſpread along the canal, according

Fig. 29.

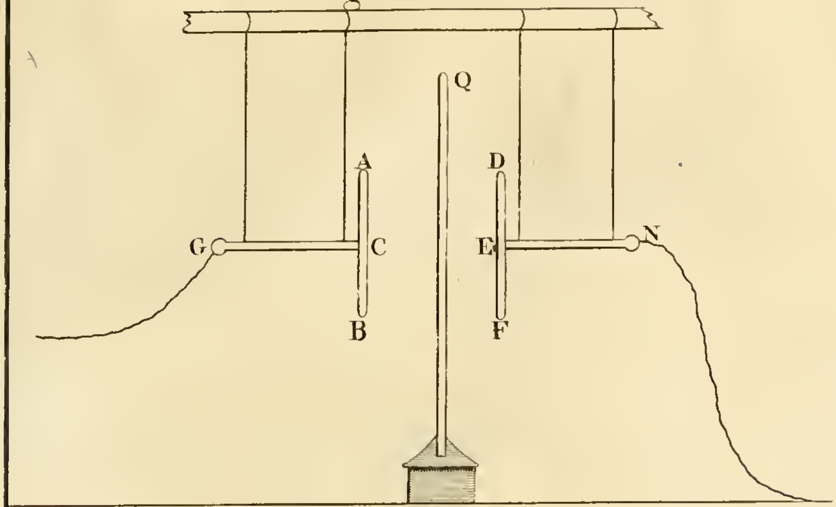


Fig. 30.

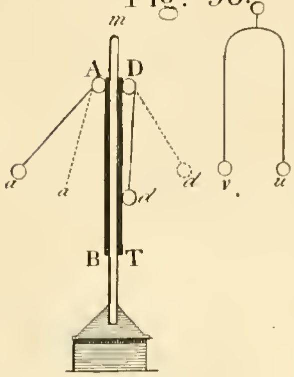


Fig. 31.

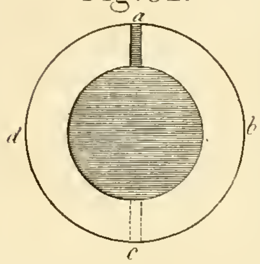


Fig. 32.

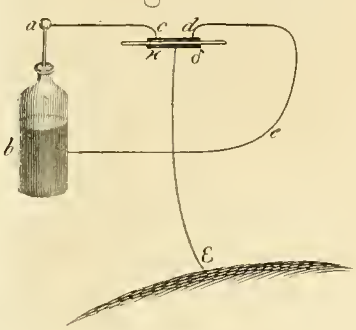


Fig. 34.

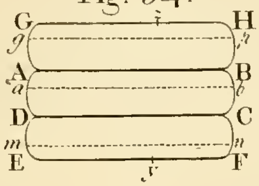


Fig. 33.

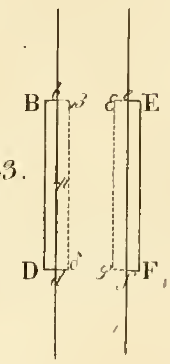


Fig. 35.

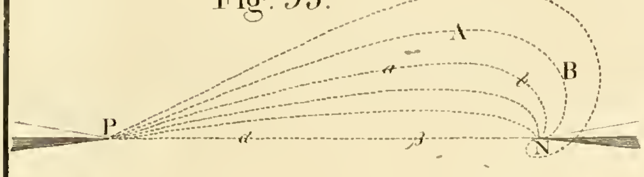


Fig. 36.

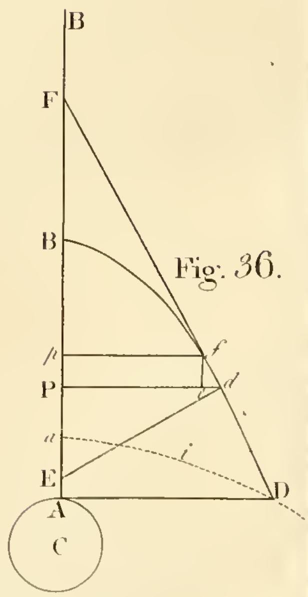


Fig. 37.

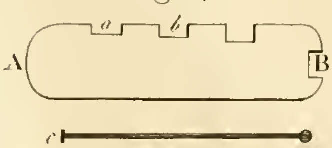
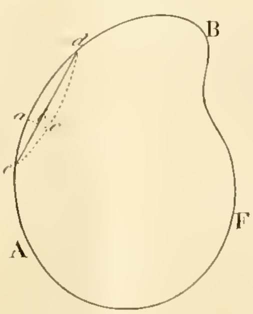


Fig. 38.



ing to any law whatever. So that if AD represent the electric density of the globe, and remain constant, any curve of density will answer, if $\frac{dd}{\dot{x}}$ be everywhere less than R. It is therefore an indeterminate problem to assign, in general, the disposition of fluid in the canal. The density is as the ordinates of a parabola only on the supposition that the maximum of R is everywhere the same. And, in this case, the distance AB is a minimum: for, in other cases of density, we must have $\frac{dd}{\dot{x}}$ less than R. If, therefore, we vary a single element of the curve D d B, in order that the stability of the fluid may not be disturbed, having d constant, we must necessarily have $\dot{x}$ larger, that $\frac{dd}{\dot{x}}$ may still be less than R; that is, we must lengthen the axis.

We see also, that to ascertain the distribution in a conducting canal is a determinate problem; whereas, in imperfect conductors, it is indeterminate, but limited by the state of the fluid, when it is so disposed that in every point the action of the fluid is in equilibrio with the maximum of resistance. This consideration will be applied to a valuable purpose in the article MAGNETISM.

222 Explanation of a curious and important fact; and method of increasing a charge.

This doctrine gives, in our opinion, a very satisfactory explanation of the curious observations of Mr Brookes and Mr Cuthbertson, mentioned in n° 167. namely, that damping the inside of a coated jar diminishes the risk of explosion, and enables it to hold a higher charge. We learn here, that there is no density so great but that the least imperfect conductor will insulate it, if long enough; and that the coercive quality of an imperfect conductor may be conceived so constituted from A towards B, that the densities shall diminish in any ratio that we please, so that the variation of density (the cause of motion) may everywhere, even to the insulating point B, be very small. However great the constipation at the edge of the metallic coating may be, an imperfect conductor may be continued outward from that edge, and may be so constituted, that the constipation shall diminish by such gentle gradations, that an explosion shall be impossible. An uniform dampness will not do this, but it will diminish the abruptness of the variation of density. The state of density beyond the edge of the coating of a charged jar, very clean and dry, may be represented by the parabolic arch D i a. This may be changed by damping, or properly dirtying (to use Mr Brookes's phrase), to D f B; which is evidently preferable. We think it by no means difficult to contrive such a continuation of imperfectly conducting coating. Thus, if gold leaf can be ground to an impalpable powder, it may be mixed with an oil varnish in various proportions. Zones of this gold varnish may be drawn parallel to the edge of the coating, decreasing in metal as they recede from the edge. By such contrivances it may be possible to increase the retentive power to a great degree.

223 Cautions in deducing measures from experiments.

This doctrine farther teaches us, that many precautions must be taken when we are making experiments from which measures are to be deduced; and it points them out to the mathematician. In particular, when bodies, supported by insulators, are electrified to a high degree, the supports may receive a quantity of fluid, which may greatly disturb the results; and this quantity, by exerting but a weak action on the parts of the canal, may continue for a very long time, and not be removed but with great difficulty. In such cases, it will be necessary to use new supports in every experiment. Not knowing, or not attending to this circumstance, many erroneous opinions have been formed in some delicate departments of electrical research.

Mr Coulomb's experiments on this subject are chiefly valuble for having stated the relation between the intensity of the electricity, or, as he expresses it, the electric density, and the lengths of support necessary for the complete insulation. But, as the absolute intensities have all been measured by his electrometer, and he has not given its particular scale, we cannot make much use of them till this be done by some electrician.

224 Insulating powers of various substances.

Mr Coulomb found, that a thread of gum lac was the most perfect of all insulators, and is not less than ten times better than a silk thread as dry as it can be made, if we measure its excellence by its shortness. In a considerable number of experiments, he found that a thread of gum lac, of 1,5 inches long, insulated as well as a fine silk thread of 15 inches. When the thread of silk was dipped in fine sealing-wax, it was equal to the pure lac, if six inches long, or four times its length. If we measure their excellence by the intensities with which they insulate, lac is three times better than the dry thread, and twice as good as the thread dipped in sealing wax: so that a fibre of silk, even when included in the lac, diminishes its insulating power. We also learn, that the dissipation along these substances is not entirely owing to moisture condensed or adherent on their surfaces, but to a small degree of conducting power. We have repeated many of these experiments, and find that the conducting power of silk thread depends greatly on its colour. When of a brilliant white, or if black, its conducting power seems to be the greatest, and a high golden yellow, or a nut brown, seemed to be the best insulators; doubtless the dyeing drug is as much concerned as the fibre.

Glass, even in its dryest state, and in situations where moisture could have no access to it, *viz.* in vessels containing caustic alkali dried by red heat, or holding fresh made quicklime, appeared in our experiments to be considerably better than silk; and where drawn into a slender thread, and covered with gum lac (melted), insulated when three times the length of a thread of lac; but we found at the same time, that extreme fineness was necessary, and that it dissipated in proportion to the square of its diameter. It was remarkably hurt by having a bore, however fine, unless the bore could also be coated with lac. Human hair, when completely freed from every thing that water could wash out of it, and then dried by lime, and coated with lac, was equal to silk. Fir, and cedar, and larch, and the rose-tree, when split into filaments, and first dried by lime, and afterwards baked in an oven which just made paper become faintly brown, seemed hardly inferior to gum lac.

The *white woods*, as they are called, and mahogany, were much inferior. Fir baked, and coated with melted lac, seems therefore the best support when strength is required. The lac may be rendered less brittle by a minute portion of pure turpentine, which has been cleared of water by a little boiling, without sensibly increasing its conducting power. Lac, or sealing-wax, dissolved in spirits, is far inferior to its liquid state by heat.

These observations may be of use for the construction of electrical machines of other electrics than glass.

General reflections

We have now given a comparison of the hypothesis of Mr Æpinus with the chief facts observed in electricity, diversified by every circumstance that seemed likely to influence the result, or which is of importance to be known. We trust that the reader will agree with us in saying that the agreement is as complete as can be expected in a theory of this kind; and that the application not only seems to explain the phenomena, but is practically useful for directing us to the procedures which are likely to produce the effect we wish. Thus, should our physiological opinions suggest that copious transference of fluid is proper, our hypothesis points out the most effectual and the most convenient methods for producing it. We learn how to constipate the fluid in a quiescent state, or how to abstract as much of it as possible from any part of a patient; we can do this even in the internal parts of the body. We had once an opportunity of seeing what we thought the cure of a paralysis of the gullet. Electricity was tried, first in the way of sparks, and then small shocks taken across the trachea. These could not be tolerated by the patient. The surgeon wished to give a shock to the œsophagus without affecting the trachea. We recommended a leaden pistol bullet at the end of a strong wire, the whole dipped in melted sealing-wax. This was introduced a little way, we think not more than three inches, into the gullet, which the palsy permitted. A very slight charge was given to it in a few seconds; and the first shock produced a convulsion in the muscle, and the second removed the disorder completely. Here the ball formed the inner, and the gullet the outer, coating of the little Leyden phial.

The theory of Æpinus is only a hypothesis.

Notwithstanding the flattering testimony given by the great conformity of this doctrine with the phenomena, we still choose to present it under the title of a hypothesis. We have never seen the electric fluid in a separate state; nor have we been able to say in what cases it abounds, or when it is deficient. After what we have seen in the late experiments of that philanthropic philosopher Count Rumford on the production of heat by friction, we think that we cannot be too cautious on what grounds we admit invisible agents to perform the operations of Nature. We think that all must acknowledge that those experiments tend very much to stagger our belief in the existence of a fluid *sui generis*, a fire, heat, caloric, or what we please to call it; and all will acknowledge, that no better proofs can be urged for the existence of an electric fluid.

225
The reality of an electric fluid is denied.

Accordingly, many acute and ingenious persons have rejected the notion of the existence of an electric fluid, and have attempted to shew that the phenomena proceed, not from the presence of a peculiar *substance*, but from peculiar *modes*; as we know that sound, and some concomitant motions and other mechanical appearances, are the results of the elastic undulations of air; and as Lord Bacon and others have explained the effects of fire by elastic undulations of the integrant particles of tangible matter.

Requisites for a just theory.

We have seen nothing, however, of this kind that appears to give any explanation of the motions, pressures, and other mechanical appearances of electricity. We peremptorily require, that every doctrine which claims the name of an explanation, shall be perfectly consistent with the acknowledged laws of mechanism; and that the explanation shall consist in pointing out those mechanical laws of which the facts in electricity are particular instances. It is no difficult matter to present an intricate or complex phenomenon to our view, in such a form, that it shall have some resemblance to some other complex physical fact, more familiar, perhaps, but not better understood. The specious appearance of similarity, and the more familiar acquaintance with the other phenomenon, dispose us to consider the comparison as a sort of explanation, or, at least, an illustration, and to have a sort of indolent acquiescence in it as a theory.

But this will not do in the present question: For we have here selected a particular circumstance, the observed motions occasioned by electricity, and called *attractions* and *repulsions*—a circumstance which admits of the most accurate examination and comparison with any explanation that is attempted. In such a case, a vague picture would speedily vanish into air, and prove to be nothing but figurative expressions. 226

No advantage is gained by the hypothesis of two fluids.

Many philosophers, and among them some respectable mathematicians, have supported the doctrine of Du Fay, Symmer, Cigna, &c. who employ two fluids as agents in all electrical operations. It must be granted that there are some appearances, where the explanation by means of two fluids seems, at first sight, more palpable and easier conceived. But whenever we attempt to obtain *measures*, and to say what will be the precise kind and degree of the action, we find ourselves obliged to assign to the particles of those fluids actuating mechanical forces precisely equivalent to those assigned by Æpinus to his single fluid. Then we have to add some mysterious unexplained connections, both with each other and with the other particles of tangible matter. If we except Mr Prevost, in his *Essai sur les Forces Magnetiques et Electriques*, we do not recollect an author who has ventured to subject his system to strict examination, by pointing out to us the laws of action according to which he conceives the particles influence each other. We shall have a proper opportunity, in the article Magnetism, to give this author's theory the attention it really merits. We venture to say, that all the chemical theories of electricity labour under these inconveniences, and have acquired their influence merely from the inattention of their partisans to the laws of mechanical motion, and require, in order to reconcile them with those laws, the adoption of powers similar to Æpinus's attractions and repulsions. Slight resemblances to phenomena, which stand equally in need of explanation, have contented the partisans of such theories, and figurative language and metaphorical conceptions have taken place of precise discussion. It would be endless to examine them all. 227

Hypothesis of Professor Russel.

The most specious of any that we know was publicly read in the university of Edinburgh by the late Mr James Russel, Professor of natural philosophy; a person

ſon of the moſt acute diſcernment, and an excellent reaſoner. It was delivered to his pupils, not as a *theory*, but as a *conjecture*, founded on Lord Kames's theory of ſpontaneous evaporation, which had obtained a very general reception; a conjecture, ſaid the Profeſſor, founded on ſuch reſemblances as made a ſimilarity of operation very probable, and was an incitement and direction to the philoſopher to a proper train of experimental diſcuſſion. We ſay this on the authority of his pupils in the years 1767, 1768, and 1769, and of ſome notes in his own hand writing now in our poſſeſſion.

Mr Ruſſel conſidered the electrical phenomena as the reſults of the action of a ſubſtance which may be called the *electrical fluid*, which is connected with bodies by attractive and repulſive forces acting at a diſtance, and diminiſhing as the diſtance increaſes.

Mr Ruſſel ſpeaks of the electric fluid as a compound of ſeveral others; and, particularly, as containing elementary fire, and deriving from it a great elaſticity, or mutual repulſion of its particles. This, however, is different from the elaſticity or mutual repulſion of the particles of air, becauſe it acts at a diſtance; whereas the particles of air act only on the adjoining particles. By this conſtitution, bodies containing more electric fluid than the ſpaces around them repel each other.

The particles of this electric fluid attract the particles of other bodies with a force which diminiſhes by diſtance.

The characteriſtic ingredient of this fluid is ELECTRICITY *properly ſo called*. This is united with the elaſtic fluid by chemical affinity, which Mr Ruſſel calls *elective attraction*, a term introduced into chemiſtry by Dr Cullen and Dr Black. This extends to all diſtances, but not preciſely by the ſame law as the mutual repulſion of the particles of the other fluid, and in general, it repreſſes the repulſions of that fluid while in this ſtate of compoſition. This *electricity*, moreover, attracts the particles of other bodies, but with certain elections. Non-electric or conducting bodies are attracted by it at all diſtances; but electrics act on it only at very ſmall and inſenſible diſtances. At ſuch diſtances its particles alſo attract each other.

By this conſtitution, the compound electric fluid repels its own particles at all conſiderable diſtances, but attracts at very ſmall diſtances. It attracts conducting bodies at all diſtances, but non-conductors, only at very ſmall diſtances. The phenomena of light and heat are conſidered as marks of partial decompoſition, and as proofs of the preſence of elementary fire in the compound: the ſmell peculiar to electricity, and the effect on the organ of taſte, are proofs of decompoſition and of the complex nature of the fluid.

Bodies (conductors) containing electric fluid, repel each other at conſiderable diſtances, but, if forced very near, attract each other. Electrics can contain it only in conſequence of the *electricity* in the compound. Part of this electricity muſt be attached to the ſurface in a non-elaſtic ſtate; becauſe when it is brought ſo near as to be attracted, its particles are within the ſpheres of each other's action, and this redoubled attraction overcomes the repulſion occaſioned by its union with the other ingredient; and the electric fluid is partly decompoſed, and the *electricity*, properly ſo called, adheres to the ſurface of the electric, *as the water of damp air adheres to a cold pane of glaſs in our windows*. Alſo, by this conſtitution, electric fluid may appear in two ſtates; elaſtic, like air, when entire; and unelaſtic, like water, when partly decompoſed by the attraction of electrics.

Electricity may be forced into this unelaſtic union by various means; by friction, which forces the electric fluid contained in the air into cloſe contact, and thus occaſions this decompoſition of the fluid and the union of its *electricity* with the ſurface. This operation is compared by Mr Ruſſel to the forcible wetting of ſome powders, ſuch as lycoperdon, which cannot be wetted without ſome difficulty and mechanical compreſſion; after which it adheres to water ſtrongly. It may be thus united in ſome natural operations, as is obſerved in the melting and freezing of ſome ſubſtances in contact with electrics; and it may be thus forced into union by means of metallic coatings, into which the electric fluid is forced by an artful employment of its mutual repulſions. This operation is compared to the condenſation of the moiſture of damp air by a cold pane of the window; and the evacuation of the other ſide of the coated pane is compared to the evaporation of the moiſture from the other ſide of the window pane, in conſequence of the heat which muſt emerge from the condenſed vapour. We find in the Profeſſor's notes abovementioned many ſuch partial analogies, employed to ſhew the ſtudents that *ſuch* things are ſeen in the operations of Nature, and that his conjecture merits attention.

The intelligent reader will ſee that the general reſults of this conſtitution of the electric fluid will tally pretty well with the ordinary electrical phenomena; and, accordingly, this *conjecture* was received with great ſatisfaction. We remember the being much pleaſed with it, as we heard it applied by Mr Ruſſel's pupils, many of whom will recollect what is here put on record. But the attentive reader will alſo ſee, that all this intricate combination of different kinds of attraction and repulſion is nothing but mere accommodations of hypothetical forces to the phenomena. How incomparably more beautiful is the ſimple hypotheſis of Æpinus, which, without any ſuch accommodations, tallies ſo preciſely with all the phenomena that have yet been obſerved? Here no diſtinction of action is neceſſary, and all the varieties are conſequences of a circumſtance perfectly agreeable to general laws; namely, that the internal ſtructure of ſome ſubſtances may be ſuch as obſtructs the motion of the electric fluid through the pores—Nothing is more likely.

228 Hypotheſis of Mr de Luc.

Several years after the death of the Scotch Profeſſor in 1773, a theory very much reſembling this acquired great authority, being propoſed to the philoſophers by the celebrated naturaliſt Mr de Luc. This gentleman having long cultivated the ſtudy of meteorology with unwearied aſſiduity and great ſucceſs, and having been ſo familiarly converſant with expanſive fluids, and the affinities of their compounds, was diſpoſed to ſee their operations in almoſt all the changes on the ſurface of this globe. Electricity was too buſy an actor in our atmoſphere to eſcape his particular notice. While the mechanical philoſophers endeavoured to explain its effects by accelerating forces attracting and repelling, Mr de Luc endeavoured to explain them by means of the expanſive properties of aeriform fluids and gaſes, and by their chemical affinities, compoſitions, and decompoſitions. He had formed to himſelf a peculiar

culiar opinion concerning the conſtitution of our atmoſphere, and had explained the condenſation of moiſture, whether of ſteam or of damp aeriform fluids, in a way much more refined than the ſimple theory of Dr Hooke, *viz.* ſolution in air. He conſiders the compound of air and fire as the *carrier* of the water held in ſolution in damp air, and the fire as the general carrier of both the air and the moiſture. Even *fire* is conſidered by him as a *vapour*, of which *light* is the *carrier*. When this damp air or ſteam is applied to a cold ſurface, ſuch as that of a glaſs pane, it is decompoſed. The water is attracted by the pane by chemical affinity, and attaches itſelf to the ſurface. The fire, thus ſet at liberty, acts on the pane in another way, producing the equilibrium of temperature, and the expanſion of the pane. Acting in the ſame manner on the moiſture which chances to adhere to the other ſide, in a proportion ſuited to its temperature, it deſtroys their union, enters into chemical combination with the moiſture, and fits it for uniting with the air on the other ſide, or carries it off. Having read Mr Volta's theory of *electric influences*, by which that philoſopher was enabled to give a ſcientific narration and arrangement of the phenomena of the *electrophorus* newly invented by himſelf, and which is called an explanation of thoſe phenomena, Mr de Luc imagined that he ſaw a cloſe analogy between thoſe *influences* on the plates of the electrophorus and the *hygroſcopic* phenomena of the condenſation and evaporation of moiſture. In ſhort, he was ſtruck with the reſemblance between the condenſation of moiſture on one ſide of a glaſs pane, and its evaporation from the other; and the accumulation of electric fluid on one ſide of a coated pane, and the abſtraction of it from the other. Subſequent examination pointed out to him the ſame analogy between all other *hygroſcopic* and *electric* phenomena.

He therefore immediately formed a ſimilar opinion concerning the electric operations. It may be expreſſed briefly as follows:

229 The electrical phenomena are the operations of an expanſive ſubſtance, called the *electric fluid*. This conſiſts of two parts: 1. *Electric matter*, which is the gravitating part of the compound; and *electric deferent fluid*, or *carrying fluid*, by which alone the electric matter ſeems to be carried from one body to another. The reſemblance between the hygroſcopic and electrical phenomena are affirmed to be*,

* See *Idées ſur la Météorologie*, § 266, &c.

1. As watery vapour or ſteam is compoſed of fire, the deferent fluid, and water, the gravitating part, ſo *electric fluid* is compoſed of the *electric deferent fluid*, and *electric matter*.

2. As *vapours* are partly decompoſed when too denſe for their temperature, and then their *deferent fluid* becomes free, and ſhews itſelf as *fire*; ſo *electric fluid* that is too denſe is decompoſed, and its *deferent fluid* manifeſts itſelf in the *phoſphoric* and *fiery* phenomena of *electricity*.

3. As *fire* quits the *water* of *vapour*, to unite itſelf with a body leſs warm; ſo the *electric deferent* quits the *electric matter*, in part, to go to other bodies which have proportionally leſs of it.

In this analogy, however, there is a diſtinction. *Fire*, in quitting the *water* in *vapour*, remains actuated by nothing but its expanſive force; remains free, and extends itſelf till the equilibrium of temperature is reſtored; but the *electric deferent*, when diſengaged from *electric matter*, in order to reſtore its peculiar equilibrium, is actuated by *tendencies* to diſtinct bodies, and acts by this *tendency* in thus reſtoring the *electric equilibrium*; and it is only in conſequence of this *tendency* that it quitted the *electric matter*. This *tendency* is then directed to ſome body in the vicinity.

4. As the *fire* of *vapour* pervades all bodies, to reſtore the *equilibrium of temperature*, depoſiting the *water*; ſo the *electric deferent* quits the *electric matter*, to reſtore the *electric equilibrium* in an inſtant, and for this purpoſe pervades all bodies, depoſiting on them the *electric matter* which it carried, but differently, according to their natures.

5. As *fire* and *water*, while compoſing *vapour*, retain their *tendencies* and *affinities* by which they produce the *hygroſcopic* phenomena; ſo the ingredients of the *electric fluid*, even in their ſtate of union, retain their *tendencies* and *affinities*, which produce the greateſt part of the *electric phenomena*.

6. In particular, the *electric matter* retains its *tendencies* and *affinities*; and farther, the *electric affinities* are, like the *hygroſcopic*, without any choice.

Here, however, there is a farther diſtinction. The affinities of *water* reſpect only *hygroſcopic* ſubſtances; but thoſe of *electric matter* reſpect all ſubſtances, and therefore reſpect the common atmoſpheric fluids.

7. When *fire* quits the *water* of *vapour*, to form the *equilibrium of temperature*, it remains in the place where *vapour* moſt abounds, but is partly *latent*, not exerting its powers; ſo in the reſtoration of the equilibrium of the *electric deferent* among neighbouring bodies, thoſe which have proportionally moſt *electric matter* alſo retain moſt *deferent fluid*, but in a *latent* ſtate.

8. As two maſſes of *vapour* may be in *expanſive equilibrium* (which others call balancing each others elaſticity) although the *vapours* contain very different proportions of *fire* and *water*; ſo two maſſes of *electric fluid* may be in *expanſive equilibrium*, although one contains much more *electric matter* in the ſame bulk, provided that the *electric deferent* be alſo more copious.

The chief diſtinction that mingles with theſe analogies is, that the *affinity* of *water* to *hygroſcopic* ſubſtances operates only in contact, whereas *electric matter* tends to diſtant bodies; and theſe diſtances are very different in regard to different bodies.

Such is the reſemblance which has appeared ſo ſtrong to Mr de Luc. It is evidently the ſame which furniſhed the conjecture to Mr Ruſſel, and which he conſidered mechanically, in order to explain the phenomena of electric motions to ſtudents of mechanical philoſophy. The only reſemblance ſeems to us to appear in the condenſation of moiſture contained in damp air.

Mr de Luc, led by the habits of his former ſtudies, attempts to explain every thing by the relations which were moſt familiar to him, *affinities* and *expanſive forces*. Let us attend a little to the manner in which he explains one or two of the moſt general facts.

1. *The conditions of conductors and non-conductors.* 230

This diſtinction depends on the differences in the *tendency* to diſtant bodies: there are great differences in theſe diſtances according to the nature of the bodies; and from this ariſe great differences of phenomena, independent of inſulation or non-inſulation, which are only the ſenſible diſtinctions of theſe claſſes of bodies.

Electric

Electric matter tends to *conductors* at great distances; but having reached them, it does not adhere, and remains free to move round them, being dragged by the *deferent fluid*; but its tendency to *non-conductors* is only at small and insensible distances; and having come into contact, it adheres, and can no longer be dragged by the *deferent fluid*.

Hence the operation of *conductors* and *non-conductors*; and there is no other foundation for the notion of *idio-electrics* and *non-electrics*, or electrics by communication. A part of a *non-conductor* takes as much *electric matter* as it can from the substance furnishing it; but cannot communicate it to another part, except very slowly; therefore, to communicate it to the whole surface, we must cover it with a conductor (Surely this is a distinction in the body, independent of the distance of mutual tendency!).

Hence, too, the property of *non-conductors* by which the electric fluid is *benumbed* (*engourdi*) or cramped; therefore we can accumulate a great deal in them; and it will remain long, being *benumbed*; and if it be determined to quit them at once, the current will be much more dense than when quitting an equal conducting surface.

Since *conductors* do not fix the *electric fluid*, it *must circulate round them*. It is urged to this motion by its *expansive power*, by which it would disperse from a body with inconceivable velocity, and perhaps the rapidity of its motion would decompose it, and cause some *light* to emerge; but it is at the same time impelled by its *tendency* to bodies. Thus, by these two forces, it runs to a *conducting body*, and must circulate round it as the planets do round the sun. In this circulation, if it come to any great projection, it cannot follow the outline, because so abrupt; it therefore flies off at all points and protuberances. It will be the more difficult to keep to an abrupt outline as the stratum in circulation is more copious or deeper, because a greater mass is with greater difficulty turned round a sharp angle. It is more inclined to escape if another body be near, and it immediately becomes a satellite to that body.

Thus all bodies get a share of electric fluid, circulating round conductors, and *benumbed* or *cramped* in *non-conductors*. Bodies of this last class receive their portion by the air as *hygroscopic substances* receive their water by the *fire*.

All the differences in the tendencies to bodies proceed from the *electric matter*. The *deferent fluid* follows other laws; namely, 1. Its tendency to all substances is greater than that of the *electric matter* to any one. 2. The tendency (and also that of the *electric matter*) is always from the body which contains most of it to that which contains least. 3. The body which contains most of the one also contains most of the other. 4. The *deferent fluid* has a particular affinity (chemical) with the *electric matter*. 5. All these tendencies are lessened by an increase of distance. 6. the *electric matter*, when composing *electric fluid*, has more or less *expansive force* as it is united to more or less *deferent fluid*.

Explanation of Charged Plates.

231 Mr de Luc says (§ 286.), that his SYSTEM was suggested by Volta's *Theory of Electric Influences*. These (says he) had been pretty well generalised before, but with little improvement to the science, till Mr Volta discovered a circumstance which, in his opinion, connected by a general theory many phenomena which had formerly no observed relation to any thing. This was, that *when a body electrified positively brings a neighbouring body communicating with the ground into the negative state, its own positive electricity is weakened while it remains in that neighbourhood, but is recovered when the other body is removed.* "Such is the distinguishing law of Mr Volta's theory, which brings all the phenomena of electric influences under his theory, beginning with those of coated glass, which were formerly so obscure, because they were not referred to their true cause, &c.

"My SYSTEM (Mr de Luc says) concerning the nature of the *electric fluid* explains the laws of Mr Volta's theory; and of consequence explains, like it, all the phenomena which it comprehends: but it reaches much farther, seeing that more general laws comprehend a greater number of phenomena.

"In the phenomena of coated glass, I plainly saw one of the procedures of *watery vapour*. Suppose a glass pane, moistened on both sides, and having the temperature of the surrounding bodies. Suppose that warmer *vapour* comes to one side. It is condensed on the surface; that is, it is decomposed, the *water* adheres to the surface, and the *fire* penetrates the glass, heats it, and increases the evaporation from the other side, by entering into combination with the *water*, and carrying it off with it. More *vapour* is condensed on the side A; more *fire* reaches the side B, and carries off more *water*. But as this happens only because the *fire* also raises the *temperature* of the pane, it is evident that the condensation on the side A, and the evaporation from B, must gradually slacken, and the *maximum of accumulation* in A, and of evaporation from B, will take place when the temperature of the pane is the same with that of the hot *vapour*.

"The electrical phenomena of coated glass are perfectly similar. The *electric fluid* reaches the side A, is decomposed, and the *electric matter* is there *benumbed* and fixed. The *deferent fluid* penetrates the pane, and carries off the *electric matter* from the side B. This goes on, but slackens; and the maximum of accumulation and evacuation obtains when the side A has acquired the same intensity of electricity with the charging machine. More is accumulated in A than is abstracted from B: because B is farther from the source (he might have added, that part of the fire is expended in raising the temperature of the pane): but the accumulation is inactive, because the *electric matter* is *benumbed* and fixed. Though the *electric matter* is much diminished in B, yet the *electric fluid* in its coating has as much expansive force as that of the ground; because it has a surplus of deferent fluid. The absolute quantity of *electric matter* in both sides is somewhat augmented."

This explanation of the Leyden phial comprehends 232
the whole of Mr de Luc's theory; and the constitution of the electric fluid, and its various affinities, expansive powers and tendencies, are all assigned to it in subserviency to this explanation, or deduced from these phenomena. As the author, in all his writings, claims some superiority over other naturalists for more general and comprehensive views, and for more scrupulous attention to precision and measurement, and particularly for more solicitude that no natural agent be omitted that

that has any ſhare in the procedure,—he ſurely will not be offended, although we ſhould ſtate ſuch difficulties and objections as occur to us in the conſideration of this SYSTEM (as he chooſes to call it) of electricity.

We wiſh that it had been expreſſed in the plain and preciſe language of mechanical and chemical ſcience; for he reaſons entirely from the nature of expanſive forces, tendencies, and affinities. His language will appear to ſome readers, as it does to us, rather to expreſs the conduct of intelligent beings, acting with choice, and for a purpoſe, than the laws of lifeleſs matter. His account would have been leſs agreeable, it is true, but more inſtructive, and leſs apt to be miſtaken. Metaphorical language is ſeldom uſed without the riſk of metaphorical conceptions; and the reader is very apt to think that he has acquired a notion of the ſubject, while he is really thinking of a thing of a different nature. We apprehend that a great deal of this happens in this inſtance, and that when the narration is ſtripped of its figurative language, it will be found without that connection and analogy which it ſeems to poſſeſs.

We alſo wiſh that the explanation had been derived from ſome well eſtabliſhed principle. The whole of it is *profeſſedly* founded on a reſemblance between the *phenomena* of electricity and ſome things ſaid of watery vapour; but theſe are not the *phenomena* of watery vapour, but Mr de Luc's *hypotheſis* (he will pardon us the term, which we prefer to *ſyſtem*) concerning *watery vapours*. We do not think it philoſophical to explain one hypotheſis by another. Our illuſtrious countrymen Bacon and Newton, diſapproved of this practice; and their rules of philoſophiſing have ſtill currency among philoſophers. Explanation, in our opinion, is the pointing out ſome acknowledged general fact in nature, and ſhewing that the particular phenomenon is an example of it. We do not ſee this in Mr de Luc's explanation; becauſe we do not ſee the *facts* in the caſe of watery vapours to which the *phenomena* of electricity are ſaid to have a reſemblance. The phenomena we mean are chiefly the *motions*, and the *transferences* of the powers producing ſuch motions; we do not ſpeak of the *light*, and ſome other phenomena, becauſe Mr de Luc does not ſpeak of them in this explanation. We ſhall even admit the *transference* as a *phenomenon*, although we do not ſee any ſubſtance transferred: but we ſee a power of producing certain motions, where that power did not formerly appear; and the appearance of this power is all the authority adduced, even by Mr de Luc, for the transference. We muſt now add, that the electric phenomena, which Mr de Luc calls like the phenomena of watery vapour, are all *ſuppoſitions*; and that therefore the explanation is a ſyſtem of ſuppoſitions, *framed* ſo as to be like the ſyſtem of watery vapour. For Mr de Luc will grant, that, on the one hand, we ſee nothing like the water in the electric phenomena; and, on the other hand, there is nothing in watery vapour like the motions of the electrometers, which are the only PHENOMENA from which Mr de Luc profeſſes to reaſon.

We alſo fear that the very curious experiments of Count Rumford on the melting of ice, and the propagation of heat through liquids, will oblige Mr de Luc to change the taſks of the ingredients, both of *vapour* and of *electric* fluid. *Water*, and not *fire*, ſeems to be the *carrier* or *deferent fluid*; and we think that Franklin and Æpinus have made it highly probable that electricity, and not air, is the carrier.

We have alſo great difficulty in conceiving (indeed we cannot conceive) how the *deferent fluid*, from which the *electric matter* has been detached by its ſuperior *affinity* with the ſide A, can overcome the *ſame ſuperior affinity* of the *electric matter* with the ſide B (A), and carry it off: how the *deferent fluid* penetrates the non-conducting pane, in order to carry off the *electric matter* in the form of *fluid*; and how it cannot do this, except by means of a *conducting canal*, into which *it is expreſsly ſaid that it does not penetrate*. It muſt not be ſaid that it runs along the ſurface of this canal: for the ſmalleſt wire will be a ſufficient conductor, covered a foot thick with ſealing-wax. This indeed, according to Mr de Luc, allows the deferent *fluid* to paſs; but it muſt alſo, according to him, ſtrain it pretty clear of all *electric matter*. For we cannot help thinking, that the proceſs (although purely ideal) has a cloſer reſemblance to what we ſhould obſerve in a ſtream of muddy water poured on a ſtrainer, both ſides of which are previouſly foul. If we were diſpoſed to amuſe ourſelves with a figurative hypotheſis, we could give one on the principle of filtration that is very pretty, and pat to the purpoſe, of glaſs coated, and charged and diſcharged by conducting canals.

With reſpect to the ſuggeſtion of this theory by Volta's theory of electric influences, and the ignorance of naturaliſts before that time of the true ſtate of things, we muſt obſerve, that Mr Ruſſel propoſed the ſame analogy to the conſideration of his hearers many years before; and it was very generally known. The electric influences had been fully detailed by Æpinus and Wilcke in 1759, and applied with peculiar addreſs and force of evidence by Mr Cavendiſh before 1771; and they were deſcribed nearly in the ſame way by Lane, Lichtenberg, and others.

And with reſpect to Mr Volta's general principle, which Mr de Luc prizes ſo highly, and by which he explains every thing, we muſt obſerve, that *it is not true as a phenomenon in electricity*; but, on the contrary, *the poſitive ſtate of a body is rendered ſtronger, or more remarkable, by inducing the negative ſtate on a neighbouring body*. See nº 52. and 66. Mr Volta was miſled by the appearances of the electrophorus, which had engaged all his attention, and modelled all his notions on theſe ſubjects. His obſervations had been confined to diſks; and though theſe are excellent inſtruments for producing very ſenſible effects, they are quite unfit for examining the general nature of electric influences. Even without much knowledge of dynamics, a perſon muſt perceive that the action of their different parts on the electrometer may be very different, by reaſon of their different poſitions and diſtances from it. Beſides the electrometers of the apparatus deſcribed by Mr de Luc in ſect. 440. &c. *did not* indicate the real condition of the diſks to which they were attached, but the condition of the remote

(A) We may here aſk, How comes there to be ſuch a quantity of electric matter already lodged in B?—Is it benumbed? or in what ſtate is it?

remote ends of overcharged conductors of considerable length. Therefore, although all the electrometers fell lower when the other group of disks was brought near, the positive state of the nearest disk was greatly augmented. The most unexceptionable apparatus for this purpose would be a row of polished balls on insulating stands, placed in contact, the whole charged positive; and when another such group, or a long body, is brought near, let the balls be separated at once, and examined apart by a very small electrometer, made in the form of our figure 8. We presume to say that, if the other group is properly managed, and made to communicate thoroughly with the ground, the positive electricity of the balls nearest to it will be found greatly augmented, and that every one of them will be found in that precise state of electrification that is pointed out by the Æpinian theory. Mr de Luc has made and narrated the experiments with the disks, and the curious figures observed by Lichtenbergh, with great judgment and fidelity; and they are classical and valuable experiments for the examination of the theory. We may here mention a very neat way of executing the apparatus of balls, which was practised by a young friend who was so kind as to make the experiments for us, when our thoughts were turned to Mr de Luc's theory. Each ball was mounted on a slender glass rod varnished. The lower end of the stalk was fixed in a little block of wood which had a square hole through it, by which it slided steadily along a horizontal bar of mahogany, supported at the ends about an inch from the table. The balls were made to separate at once, and equally, from each other, by a chequer-jointed frame, such as is seen in the toy-shops, carrying a company of foot soldiers, who open and close their ranks and files by pulling or pushing the ends of the frame. Taking out the pins of the middle joints of this checquered frame-work, and widening the holes for receiving the glass stalks, it is plain, that all the balls will separate at once, in the very state of electricity in which they were when in the neighbourhood of the non-insulated group. This apparatus consisted of six balls. We found the ball next the other group much more strongly positive than before bringing that group near, and it was generally the third ball which seemed equally electric in both situations. We added nine balls more, connecting the whole by a similar contrivance, and found it a most instructive apparatus for the theory of the distribution of the electric fluid. We wish that it had occurred to us when the n° 62. &c. were under consideration.

With respect to the condition in which the electric matter is said to be lodged in the side A of the coated pane, where Mr de Luc says that it is fixed, *(engourdi)*, in the *non conducting surface* (which condition Mr de Luc considers as characteristic of such substances), we must say that the description of its state is by no means agreeable to what we have observed. The powers of this *electric matter* are no more *benumbed* or enervated (it is a very unphilosophical phrase), than if it were in a *conducting* body at the same distance from the opposite coating. If coatings be applied to a block of glass of two or three inches in thickness, and if the electrification be so moderate that it would not fly from the one coating to the other when the glass is removed—no sensible difference will be found between the electricity of the two coatings with or without the glass. The electric matter in the side A has not its powers *engourdi*; they are *balanced* by the powers of the side B.

But how will Mr de Luc explain the charging a pane negatively? How will he bring off a quantity of *electric matter*, greater (according to his own account) than what will be *benumbed* on the other side? Nay, we must ask, where does he find it? Is there a quantity already *benumbed* there? What is to revive it?

Let us now consider a little the constitution of the ingredients of this electric fluid, by which all these things are brought about. And in doing this, let us banish, when possible, all figurative language; and, in the precise and dry phraseology of dynamics, let us speak of the motion of single particles of the *electric fluid*, *deferent fluid*, and *electric matter*. By *expansive power*, must certainly be meant such a power as that by which air, gases, inflamed gunpowder, steam, and the like, enlarge their bulk, and which is clearly manifested as a mechanical pressure, by bursting vessels, impelling bullets or pistons, &c. as well as by the actual enlargement of the bulk of the fluid. We have no other indications of its being a *force*; and therefore our notions of its mode of acting must be derived solely from what we *understand* of this power in air or the other fluids. Newton's *Principia* are our authority for saying, that all that we know of it is, that it acts as a number of corpuscles would act, which repel each other with a force inversely proportional to their distances; this action not extending beyond the adjoining corpuscle, not even to the second. We know a good deal of the propagation of pressure and progressive motion through such a fluid, when it is confined in a vessel or system of vessels, of any form, and some few simple circumstances which take place in the elastic undulations which may be excited and propagated through it. We have but a *very indistinct notion* of the motions which one mass of such a fluid will produce in another mass, when both are at liberty to expand. This is very indistinct; but we are certain that it will be like the motion of two masses of air blown or driven against each other. Now these electric fluids, by their expansive powers, must act like those others with which we are more familiarly acquainted. And here we venture to say, that the appearances in electricity are so far from being like these, that we cannot imagine any thing more remarkably different. We shall mention but one thing. Every mark that we have for the presence of *electric fluid* obliges us to grant, that in an overcharged body it is crowded into the external surface, so that the quantity has little or no relation to the quantity of matter in any body, but merely to its surface. This is quite unlike air, or any other expansive fluid, which is uniformly distributed through the whole space comprehended by the surface which bounds it. We never saw any thing like streams of this *electric fluid*, impelling, or any way acting on each other, except in the transference by sparks; and there it was indeed like the motions of air, for it was not *electric fluid*, nor *electric matter*, but *electrified air*.

Let us next consider the *tendencies* by which the relations of these expansive fluids to other bodies are produced, and the electric motions are said to be explained. We observe that Mr de Luc avoids the use of the words *attraction* and *repulsion*, so much employed by the British philosophers. He considers these tendencies as determinate impulsions, and adopts the doctrine of *Le Sage*

Sage of Geneva, who has not only laid Newton under great obligations, by a mechanical explanation of gravity, but has alfo explained expanfion, elafticity, chemical affinity, and all fpecific tendencies, to the fatisfaction of the moft eminent mathematicians. To fuch only Mr de Luc profeffes to addrefs himfelf, who are not contented with a doctrine which fuppofes bodies to act where they are not. But, unfortunately, Mr le Sage has never obliged the world with this explanation. We are not moft eminent mathematicians; but we are able to prove, that Mr le Sage's favourite theorem, mentioned by Mr de Luc in §157, 158, as demonftrated by Mr Prevoft, the editor of *Lucrece Neutonien*, is a complete dereliction of the firft principles of Mr le Sage, and is alfo incompatible with mechanical laws. Mr de Luc fhould have given a demonftration of the theorem on which all his fyftem refted; otherwife it is only reviving "*dixit philofophus, ergo verum.*"

But let us fee what thefe tendencies perform. Mr de Luc fays, that the fluid, fetting out from a body by its expanfive power, would move in a ftraight line with inconceivable velocity, and would immediately defert even this globe, were it not deflected by its tendency to other bodies. We do not fee whence this immenfe velocity is derived. But let it go off; it is deflected from its rectilineal courfe by its tendency to fome conducting body, which it reaches, but cannot or does not enter; and therefore *muft continually circulate round it, as the planets circulate round the fun*, following its outline, if not too abrupt, but flying off from all points in the direction of the axis of the point, &c. Here we are at home, for this is a plain dynamical problem of central forces. All that we fhall fay on this head is, that Mr de Luc has certainly not confidered the planetary motions with attention, when he hazarded this very comprehenfive propofition. If he will take the trouble to do this, he will fee that every part of it is inconfiftent with the acknowledged laws of mechanifm, and that the motions are abfolutely impoffible. Befides, we know that it will not fly off from a hundred points placed together, which is a ftill more abrupt outline, if they do not project beyond the brim of a pit in which they ftand; yet this pit only makes the outline more abrupt. We farther believe, that no perfon can form to himfelf any diftinct notion of fuch circulations round every conducting body; they will be more numerous, and infinitely more confufed and jarring, than all the vortices of Des Cartes. How can fuch motions take place round a bunch of brafs wire buried in fealing-wax? Yet he muft grant that they really happen there? or what prevents the *electric fluid* from being *ftrained* clear of all electric matter in paffing thro' the air?

We would alfo afk, why the tendency is always *from the body containing moft of the fluid to that containing leaft?* It is not enough to fay that it is fo; this would only be contriving a thing to fuit a purpofe; a reafon fhould be given if we pretend to explain. Now the tendency to a diftant body *is to the matter* in that body, without any relation to the fluid in it, or in the body from which it came.

On the whole, we cannot think this theory is any thing but telling a ftory of ideal beings, in very figurative language, which gives it fome animation and intereft. The different affinities, tendencies, and powers, are only ways of expreffing certain *fuppofed* events, and fuited to thofe events; but it gives no explanation of the *obferved mechanical phenomena* of electricity, fhewing from acknowledged principles that they muft be fo.

What a difference between this laboured and intricate mechanifm, and the fimple, perfpicuous and diftinct theory of Æpinus! Even Mr Ruffel's explanation is more intelligible, and more applicable to the *motions* which are really obferved. That gentleman faw the neceffity of confidering them as the fubjects of *mechanical difcuffion*, and that all that was wanted was to find out what law of diftant action would tally with the phenomena. The Scotch philofopher was careful to warn his hearers that he only propofed a *conjecture*. The Swede calls his performance *Tentamen Theoriæ*, &c. and begins and concludes it with exprefsly faying, that it is only a *hypothefis*. The Englifh nobleman calls his differtation an *Attempt* to explain fome of the phenomena, &c. None of thefe philofophers call their works a SYSTEM, which comprehends all theories, whether that of Volta, or of any other fuccefsful inquirer.

We hope to be excufed for treating fo largely of this fubject. It ftruck us as a very proper example of the bad confequences of indulging in figurative language. It muft be very feducing, when fo fcrupulous and fo eminent a philofopher as Mr de Luc is led aftray by it.

WE conclude this long article by obferving, that 233
whatever may be the fate of Mr Æpinus's *hypothetical theory*, his claffification of the facts, and his precife determination of the *mechanical phenomena* to be expected from any propofed fituation and condition of the fubftances, will ever remain, and be an unerring direction in future experiments; and the whole is an illuftrious fpecimen of ingenuity, addrefs and good reafoning. We hope to make this ftill more evident, when we apply it to the quiet and manageable phenomena of MAGNETISM.

Pondere et menfurâ.

APPENDIX;

CONTAINING AN ABSTRACT OF MR COULOMB'S EXPERIMENTS.

MR COULOMB in the *Mem. de l'Acad. de Paris* for 1786, relates feveral experiments made for afcertaining the difpofition or diftribution of the electric fluid in an overcharged body. Their general refults were,

1. That the fluid is diftributed among bodies according to their figure, without any elective affinity to any kind of fubftance.

For when a ball, or body of conducting matter, and of any fhape, is electrified to any particular degree, as indicated by his electrometer, if it be touched by another equal and fimilar body, fimilarly fituated in refpect of the touching points, the electricity is always reduced to $\frac{1}{2}$.

2. In an overcharged conducting body, the fluid diffufes itfelf entirely along the furface, without penetrating into the interior parts.

The conducting body AB (fig. 37.) had pits *a*, *b*, &c. made in various parts of its furface. They were half an inch in diameter, and fome of them $\frac{1}{10}$th, others, $\frac{2}{10}$ths, others $\frac{3}{10}$ths, &c. in depth. *c* reprefents the edge of a fmall circle of gilt paper, $\frac{1}{4}$th of an inch in diameter, fixed perpendicularly on the end of a fine thread

thread of gum lac. The body was electrified and touched with this little electroscope, by setting it flat down on the surface. The circle *c* was then presented to an electrometer which moved 90 degrees by a force not exceeding $\frac{1}{6000}$th of a French grain. When this contact was made with the even surface of the conductor, it was strongly electrified, and particularly when it touched any eminence, or the ends of long cylinders, &c. The paper being exceedingly thin, and placed in full contact, it may be supposed to bring off with it the quantity of fluid corresponding to that part of the surface, or rather a greater quantity. But when it was made to touch the bottom, even of the shallowest of these pits, it did not affect the electrometer in the least.

He demonstrates the following elementary theorem: The attraction or repulsion being supposed to be proportional to the inverse of any power *m* of the distance; that is, being as $\frac{1}{x^m}$: if *m* be greater than 3, the action of all the masses of fluid which are at a finite distance is nothing in comparison with the action in contact; and therefore the fluid must be uniformly diffused, in the same way as if each particle acted only on the adjoining particles.

But if *m* be less than 3, for example if *m* be 2, as seems to be the case in electricity, the action of all the masses at a finite distance is not infinitely small in comparison with the action in contact, and the redundant fluid must go toward the surface, and no redundant fluid will be retained in the interior parts. The demonstration is to this effect.

Let A *a* BF (fig. 38) be a perfectly conducting body of any shape, and let *d a e* be a thin slice separated from the rest by the plane *d e*; let *d c e* be precisely equal and similar to *d a e*, and let *a b c* be perpendicular to the separating plane; then the action of all the particles in the thin slice *d a e* (when estimated in the direction *a b*) on the particle *b*, must balance the action of all the rest of the fluid in the body; for *b* is supposed to be at rest. Now, as the law of continuity will be observed in *any* distribution of the fluid, *through the whole body*, it is plain that, by taking *a b* sufficiently small, the difference of density at *a* and at *c* may be infinitely small; therefore the action of the fluid in *d a e* will be infinitely near to an equilibrium with the action of *d c e*; and the action of the fluid in the rest of the body on the particle *b* will be infinitely small. This cannot be, when the action of a mass of fluid at a finite distance is not infinitely small in comparison with the action in contact, unless we suppose that the quantity of fluid at a finite distance is also infinitely small, or nothing; that is, unless the whole redundant fluid is constipated on the surface, and the interior parts are merely saturated.

The preceding propositions are quite analogous to propositions in Mr Cavendish's dissertation in the Philosophical Transactions for 1771.

In the Memoirs of the same Academy for 1787, Mr Coulomb endeavours to ascertain the density of the fluid in different bodies which touch each other. When the bodies do not differ extremely in magnitude, he determines this by the immediate application of them to the electrometer; but when one is extremely small in comparison with the other, he first determines the force of the large body, and then touches it 20 or 40 times with the small one, till the force of the large body is reduced to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, &c. The general result was, that when the surfaces of the spheres had the proportion expressed in the first column of the following table, then the density in the small one had the proportion expressed by the numbers of the second column, and never attained the magnitude 2.

1	1.
4	1,08.
16	1,3.
64	1,65.
Infinite	2.

This is extremely different from the proportions which obtain when the two spheres communicate by very long slender canals, which he found exactly conformable to the determinations of the theory: but in Mr Coulomb's experiments the spheres touched each other, and had no other communication.

He then endeavours to ascertain the density of the fluid in the different parts of the surface of these touching spheres, in order to obtain some experimental knowledge of the distribution. He touched them (while in mutual contact) with the little paper circle, and examined its electricity by his electrometer, and made his estimation, on the supposition that it brought off one-half of the electricity of the touched part.

When the globes were equal, he found the density to be 0 in the point of contact, and scarcely sensible till he took the paper 30 degrees from the point of contact. From this it increased rapidly to 60°; slowly from thence to 90°; and from thence to 180° it was almost uniform. The densities were nearly.

0	at	0°.
1	—	30.
4	—	60.
5	—	90.
6	—	180.

He also found, that the more the globes differed in bulk, the more is the density changed in the small globe, and it is the more uniform in the great one, increasing rapidly from 0, at the point of contact, to about 7°, and beyond this being sensibly uniform.

Hence we may conclude, that the electricity is diffused with almost perfect uniformity in a globe communicating with another at a great distance by a slender canal (as Mr Cavendish has demonstrated); while, from the reasoning employed before, it is probable that it is also uniformly diffused all along the canal; and therefore, that the quantities in two such globes are very nearly as the diameters, and the densities inversely as the diameters, as Mr Cavendish demonstrated, on the supposition that the fluid in the canal is incompressible.

He found that a small globe, placed between two equally large ones, shewed electricities of the same kind with that of the other two, when the radius of the great one was not more than five times that of the middle one, but shewed no electricity when the disproportion was greater.

When three equal globes were in contact, the density of fluid in the middle globe was $\frac{1}{1,34}$ of that of the other two. A small globe being removed to a very small distance from an overcharged great one, *after having been in contact*, shewed opposite electricity in the fronting point; when a little farther off, it was neutral; and beyond this, it was overcharged.

The

The diameters being 11 and 8, the fronting point of the small one was negative till the distance was 1; here it was neutral, and when it was removed farther, it was positive. When the diameters were 11 and 4, the small globe was negative till their distance was 2, where it was neutral. When the diameters were 11 and 2, the distance which rendered the small globe neutral in the fronting point was $2\frac{1}{2}$.

All these facts are perfectly conformable to a mathematical deduction, from the supposition that the redundant fluid is spread over the surface, and that the interior points are neutral. If any sort of doubt should remain in the minds of those who are not conversant in such discussions, it must be greatly removed by the fact, that it is quite indifferent whether one or both globes be solid, or be an extremely thin shell.

When an electrified body is touched with a long wire, and by another of equal diameter and length, coated to any thickness with lac or sealing-wax, the two wires take off precisely the same quantity of electricity. This was demonstrated by touching a globe repeatedly till the electricity was reduced to $\frac{1}{2}$.

Hence we must conclude, that the electric fluid does not form active atmospheres around bodies, by the action of whose particles in contact (mathematical or physical) the phenomena of attraction and repulsion are produced, but by the action of the fluid in the body, agreeable to the theory of Æpinus.

Such are the observations of Mr Coulomb. They are extremely valuable, because they confirm in the completest manner the legitimate consequences of the theory.

We think that the materiality of that which is transferred from place to place in the exhibition of electric phenomena, is greatly confirmed by some observations of Mr Wilson's in the Pantheon. When a spark was taken from the whole of the long wire extended in that vast theatre, the sensation was so different from a spark which conveyed even a much greater quantity of fluid from a pretty large, but compact, surface, that they could hardly be compared. The last was like the abrupt twitch with the point of a hooked pin, as if pulling off a point of the skin; the spark from the long wire was more like the forcible piercing with a needle, not very sharp, breaking the skin, and pushing it inward. We had this account from the Doctor in conversation. He ascribed it, with seeming justice, to the momentum acquired by the fluid accelerated along that great extent of wire.

Animal ELECTRICITY. See GALVANISM, in this Supplement.

END OF THE FIRST VOLUME.

ERRATA.

Page 141. col. 2. last 5 lines, and 142. col. 1. line 1. dele; and in their place *read*, "which though Lord "Auchinleck and his son took the same side, they took it with very different degrees of ardour. The judge "saw not the propriety of illuminating his windows, when the cause was finally decided by the House of "Peers; and to compel him to illuminate, the advocate got possession of a Chinese *gong*.

Page 228. col. 2. line 53. *For* "Henry VI." *read* "Henry II."

301. col. 1. line 30. *For* sulphuret *read* sulphat.

CHEMISTRY-*Index*, page 449. col. 1. line 2. After 466 *add*, "and Part 3. chap. 2. sect. 11.

Page 512. col. 2. line 52. *For* "Diderot," *read* "D'Alembert."

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