THE

GALLERY

OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

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THE GALLERY OF NATURE AND ART.

PART II.

A R T.

BOOK I.

CHEMISTRY.

CHAPTER I.

ON THE RISE AND PROGRESS OF CHEMISTRY.

The beginnings of every art, which tended either to supply the necessities, or to alleviate the more pressing inconveniencies of human life, were probably coeval with the first establishment of civil societies, and preceded, by many ages, the inventions of letters, of hieroglyphics, and of every other mode of transmitting to posterity the memory of past transactions. In vain shall we inquire who invented the first plough, baked the first bread, shaped the first pot, wove the first garment, or hollowed out the first canoe. Whether men were originally left, as they are at present, to pick up casual information concerning the properties of bodies, and to investigate by the strength of natural genius the various relations of the objects surrounding them; or were, in the very infancy of the world, supernaturally assisted in the discovery of matters essential, as it should seem, to their existence and well being, must ever remain unknown to us.

There can be little doubt, that in the space of, at least, 1656 years, from the creation of the world to the deluge, a great variety of economical arts must have been carried to a very considerable degree of perfection. The knowledge of many of these perished, in all likelihood, with the then inhabitants of the earth: it being scarcely possible for that single family, which escaped the general ruin, to have either practised, or been even superficially acquainted with them all. When men have been long united in civil societies, and human nature has been exalted by a reciprocal communication of knowledge, it does not often happen, that any useful invention is entirely lost: but were all the present inhabitants of the earth, except eight persons, to be destroyed by one sudden calamity, who sees not that most of those serviceable and elegant arts, which at present constitute the employment, and contribute to the happiness of the greatest part of the human race, would probably be buried in long oblivion? Many centuries might slip away, before the new inhabitants of the globe would again become acquainted with the nature of the compass; with the arts of painting, printing, or dying; of making porcelain, gun-powder, steel, or brass.

The interval of time which elapsed from the beginning of the world to the first deluge, is reckoned, by profane historians, to be wholly uncertain as to the events which happened in it: it was antecedent, by many centuries, not only to the era when they supposed history to commence, but to the most distant ages of heroism and fable. The only account relative to it, which we can rely upon, is contained in the first six chapters of the book of Genesis; three of which being employed in the history of the creation, and of the fall of man; and a fourth containing nothing but a genealogical narration of the patriarchs from Adam to Noah; it cannot reasonably be expected, that the other two should enable us to trace the various steps by which the human intellect advanced in the cultivation of arts and sciences; or to ascertain, with much precision, the time when any of them was first introduced into the world. It is somewhat remarkable, that from this account, short as it is, the chemists should be authorized, with some propriety, to exalt the antiquity of their art to the earliest times. Tubal-cain is there mentioned as an instructor of every artificer in copper and iron*. This circumstance proves, beyond dispute, that one part of metal-

* Gen. iv. 22.

lurgic chemistry was well understood at that time; for copper and iron are of all the metals most difficultly extracted from their ores, and cannot, even in our days, be rendered malleable without much skill and trouble; and it proves also, that the arts in general, were in an improved state amongst the antediluvians. It is said, indeed, that some tribes of Hottentots (who can have no pretensions to be ranked amongst the cultivators of the arts) know how to melt both iron and copper *; but this knowledge of theirs, if they have not derived it from an intercourse with the Europeans, is a very extraordinary circumstance, since the melting and manufacturing of metals are justly considered, in general, as indications of a more advanced state of civilization than the Hottentots have yet arrived at. But not to dwell upon this; Cain we know built a city, and some would thence infer, that metals were in use before the time of Tubal-cain, and that he is celebrated principally for his ingenuity in fabricating them for domestic purposes. History seems to support our pretensions thus far. As to the opinion of those who, too zealously contending for the dignity of chemistry, make the discovery of its mysteries to have been the *pretium amoris* which angels paid to the fair daughters of men, we, in this age, are more disposed to apologize for it, than to adopt it. We may say of arts, what the Roman historian has said of states—*datur hæc venia antiquitati, ut, miscendo humana divinis, primordia* artium *augustiora faciat* †.

For many ages after the flood, we have no certain accounts of the state of chemistry. The art of making wine, indeed, was known, if not before, soon after the deluge; this may be collected from the intoxication of Noah ‡, there being no inebriating quality in the unfermented juice of the grape. The Egyptians were skilled in the manufacturing of metals, in medicinal chemistry, and in the art of embalming dead bodies, long before the time of Moses; as appears from the mention made of Joseph's cup §, and from the physicians being ordered to embalm the body of Jacob ‖. They practised also the arts of dying, and of making coloured glass, at a very early period; as has been gathered, not only from the testimony of Strabo, but from the relics found with their mummies, and from the glass beads with which their mummies are sometimes

* Forster's Voy. vol. 1. p. 81.
† Livy's Præf.
‡ Gen. xliv. 2.
§ Gen. ix. 21.
‖ Gen. l. 2.

studded *. But we cannot, from these instances, conclude that chemistry was then cultivated as a separate branch of science, or distinguished in its application, from a variety of other arts which must have been exercised for the support and convenience of human life. All of these had probably some dependence on chemical principles, but they were then, as they are at present, practised by the several artists without their having any theoretical knowledge of their respective employments. Nor can we pay much attention in this inquiry to the obscure accounts which are given of the two great Egyptian philosophers, Hermes the elder, supposed to be the same with Mizraim, grandson of Noah; and Hermes, surnamed Trismegistus, the younger, from whom chemistry has by some been affectedly called the Hermetic art.

The chemical skill of Moses, displayed in his burning, reducing to an impalpable powder, and rendering potable the golden calf in the wilderness, has been generally extolled by writers on this subject; and constantly adduced as a proof of the then flourishing state of chemistry amongst the Egyptians, in whose learning he is said to have been well versed. If Moses had really reduced the gold of which the calf consisted, into ashes, by calcining it in the fire; or made it any other way soluble in water, this instance would have been greatly in point; but neither in Exodus nor in Deuteronomy, where the fact is mentioned, is there any thing said of its being dissolved in water. The enemies of revelation, on the other hand, conceiving it to be impossible to calcine gold, or to render it potable, have produced this account as containing a proof of the want of veracity in the sacred historian. Both sides seem to be in an error; Stahl, and other chemists, have shewn that it is possible to make gold potable, but we have no reason to conclude that Moses either used the process of Stahl, or any other chemical means for effecting the purpose intended—"he took the calf which they had made, and burnt it in the fire, and ground it to powder, and strewed it upon the water, and made the children of Israel to drink of it †." Here is not the least intimation given of the gold having been dissolved, chemically speaking, in water; it was stamped and ground, or, as the Arabic and Syriac versions

* See Delaval's ingenious Inquiry into the Cause of the Changes of Colours, Pref. LVI.; and Dutens' learned Inquiry into the Discoveries attributed to the Moderns, p. 241.

† Exod. xxxii. 20.

have it, filed into a fine dust, and thrown into the river, of which the children of Israel used to drink: part of the gold would remain, notwithstanding its greater specific gravity, suspended for a time (as happens in the washing of copper and lead ores), and might be swallowed in drinking the water; the rest would sink to the bottom, or be carried away by the flux of the stream.

Nevertheless, though nothing satisfactory can be concluded concerning the Egyptian chemistry, from what is said of Moses in this instance; yet the structure of the ark, and the fashion of Aaron's garments, clearly indicate to us that the arts of manufacturing metals, of dying leather red, and linen blue, purple, and scarlet; of distinguishing precious stones, and engraving upon them, were at that time practised in a very eminent degree*. The Israelites had unquestionably learned these arts in Egypt, and there is great reason to suppose, not only that learning of every kind first flourished in Egypt, but that chemistry in particular, was much cultivated in that country, when other sciences had passed into other parts of the world. Pliny, in speaking of the four periods of learning which had preceded the times in which he lived, reckons the Egyptian the first: and Suidas, who is thought to have lived in the tenth century, informs us, that the Emperor Diocletian ordered all the books of chemistry to be burned, lest the Egyptians learning from them the art of preparing gold and silver, should thence derive resources to oppose the Romans. It is worthy of notice, that Suidas uses the word chemistry in a very restricted sense, when he interprets it by—the preparation of gold and silver;—but all the chemists in the time of Suidas, and for many ages before and after him, were alchemists. The edict of Diocletian in the third century, had little effect in repressing the ardour for that study in any part of the world, since we are told, that not less than five thousand books, to say nothing of manuscripts, have been published upon the subject of alchemy, since his time†.

At what particular period this branch of chemistry, respecting the transmutation of the baser metals into gold, began to be distinguished by the name of alchemy, cannot be determined. An author of the fourth century, in an astrological work, speaks of the science of alchemy as well understood at that time; and

* Exod. xxvi. and xxviii.

† Chem. Walleri, p. 40.

this is said to be the first place in which the word alchemy is used*. But Vossius asserts that we ought, in the place here referred to, instead of alchemia, to read chemia †: be this as it may, we can have no doubt of alchemia being compounded of the Arabic al (the) and chemia, to denote excellence and superiority, as in almanack, al koran, and other words. Whether the Greeks invented, or received from the Egyptians, the doctrine concerning the transmutation of metals, or whether the Arabians were the first who professed it, is uncertain. To change iron, lead, tin, copper, or quicksilver into gold seems to be a problem more likely to animate mankind to attempt its solution, than either that of squaring the circle, or of finding out perpetual motion; and as it has never yet been proved, perhaps never can be proved, to be an impossible problem, it ought not to be esteemed a matter of wonder, that the first chemical books we meet with, are almost entirely employed in alchemical inquiries.

Chemistry, with the rest of the sciences, being banished from the other parts of the world, took refuge among the Arabians. Geber, in the seventh, or as some will have it in the eighth, and others in the ninth century, wrote several chemical, or rather alchemical books, in Arabic. In these works of Geber are contained such useful directions concerning the manner of conducting distillation, calcination, sublimation, and other chemical operations; and such pertinent observations respecting various minerals, as justly seem to entitle him to the character, which some have given him, of being the father of chemistry; though, in one of the most celebrated of his works, he modestly acknowledges himself to have done little else than abridge the doctrine of the ancients, concerning the transmutation of metals ‡. Whether he was preceded by Mesue and Rhazes, or followed by them, is not in the present inquiry a matter of much importance to determine; since the forementioned physicians, as well as Avicenna, who, from all accounts, was posterior to Geber, speak of many chemical preparations, and thus

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* Jul. Fermi. Mater. Astronomicon. Lib. III. c. 15.

† Voss. Etymo. Vox Alchemia.

‡ Totam nostram metallorum transmutandorum scientiam, quam ex libris antiquorum philosophorum abbreviavimus, compilatione diversa, in nostris voluminibus, hic in unam summam redegimus. Gebri Alch. cap. 1, edition by Zetzner, in 1512. In Tancken's edition, in 1681, the words, metallorum transmutandorum, are omitted.

thoroughly establish the opinion, that medical chemistry, as well as alchemy, was in those dark ages well understood by the Arabians.

Towards the beginning of the thirteenth century, Albert the Great, in Germany, and Roger Bacon, in England, began to cultivate chemistry with success, excited thereto, probably by the perusal of some Arabic books, which about that time were translated into Latin. These two monks, especially the latter, seem to have as far exceeded the common standard of learning in the age in which they lived, as any philosophers who have appeared in any country, either before their time or since. They were succeeded in the fourteenth and fifteenth centuries, by a great many eminent men, both of our own country and foreigners, who, in applying themselves to alchemy, made, incidentally, many useful discoveries in various parts of chemistry: such were Arnoldus de Villa Nova, in France; our countryman George Ripley; Raymund Lully, of Majorca, who first introduced, or at least more largely explained, the notion of an universal medicine; and Basile Valentine, whose excellent book, intitled *Currus Antimonii Triumphalis*, has contributed more than any thing else, to the introduction of that most useful mineral into the regular practice of most physicians in Europe; it has given occasion also to a variety of beneficial, as well as (a circumstance which might be expected, when so ticklish a mineral fell into the hands of interested empirics), to many pernicious nostrums. To this, rather than to the arrogant severity with which Basile Valentine treats the physicians, his cotemporaries, may we attribute the censure of Boerhaave; who, in speaking of him, says, "he erred chiefly in this, that he commended every antimonial preparation, than which nothing can be more foolish, fallacious, and dangerous; but this fatal error has infected every medical school from that time to this*."

The attempting to make gold or silver by alchemical processes, had been prohibited by a constitution of Pope John the 22d, who was elevated to the pontificate in the year 1316†; and within about one hundred and twenty years from the death of Friar Bacon, the nobility and gentry of England had become so infatuated with the notions of alchemy, and wasted so much of their substance in search of the philosopher's stone, as to render the interposition of government necessary to restrain their folly. The fol-

* Boerh. Ch. vol. 1. p. 18. † Kirch. Mun. Sub. l. xi. sect. iv. c. 1.

lowing act of parliament, which Lord Coke calls the shortest he ever met with, was passed 5 H. 4. "None from henceforth shall use to multiply gold or silver, or use the craft of multiplication; and if any the same do, he shall incur the pain of felony." It has been suggested, that the reason of passing this act, was not an apprehension lest men should ruin their fortunes by endeavouring to make gold, but a jealousy lest government should be above asking aid of the subject. "After Raymund Lully, and Sir George Ripley, had so largely multiplied gold, the lords and commons, conceiving some danger that the regency, having such immense treasure at command, would be above asking aid of the subject, and might become too arbitrary and tyrannical, made an act against multiplying gold and silver*." This act, whatever might be the occasion of passing it, though it gave some obstruction to the public exercise of alchemy, yet it did not cure the disposition for it in individuals, nor remove the general credulity; for in the 35 H. 6, Letters patent were granted to several people, by which they were permitted to investigate an universal medicine, and to perform the transmutation of metals into real gold and silver, with a non-obstante of the forementioned statute, which remained in full force till the year 1689, when being conceived to operate to the discouragement of the melting and refining of metals, it was formally repealed†.

The beginning of the sixteenth century was remarkable for a great revolution produced in the European practice of physic, by means of chemistry. Then it was that Paracelsus, following the steps of Basile Valentine, and growing famous for curing the venereal disease, the leprosy, and other virulent disorders, principally by the means of mercurial and antimonial preparations, wholly rejected the Galenical pharmacy, and substituted in its stead the chemical. He had a professor's chair given him by the magistracy of Basil, was the first who read public lectures in medicine and chemistry, and subjected animal and vegetable, as well as mineral substances to an examination by fire.

It seldom happens that a man of but common abilities, and in

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* Opera Mineralia explicata, p. 10.

† Mr. Boyle is said by his interest to have procured the repeal of this singular statute, and to have been probably induced thereto, in consequence of his having been persuaded of the possibility of the transmutation of metals into gold. See his Life, prefixed to the folio edition of his works, p. 83.

the most retired scenes of life, observes such a strict uniformity of conduct, as not to afford prejudice and partiality sufficient materials for drawing his character in different colours; but such a great and irregular genius as Paracelsus, could not fail of becoming alike, the subject of the extremes of panegyric and satire. He has accordingly been esteemed by some, a second Esculapius; others have thought that he was possessed of more impudence than merit, and that his reputation was more owing to the brutal singularity of his conduct, than to the cures he performed. He treated the physicians of his time with the most sottish vanity and illiberal insolence, telling them, that the very down of his bald pate, had more knowledge than all their writers; the buckles of his shoes more learning than Galen or Avicenna, and his beard more experience than all their universities*. He revived the extravagant doctrine of Raymund Lully, concerning an universal medicine, and untimely sunk into his grave at the age of forty-seven, whilst he boasted himself to be in possession of secrets able to prolong the present period of human life, to that of the antediluvians.

But in whatever estimation the merit of Paracelsus as a chemist may be held, certain it is, that his fame excited the envy of some, the emulation of others, and the industry of all. Those who attacked, and those who defended his principles, equally promoted the knowledge of chemistry; which from his time, by attracting the notice of physicians, began every where to be systematically treated, and more generally understood.

Soon after the death of Paracelsus, which happened in the year 1541, the arts of mining and fluxing metals, which had been practised in most countries from the earliest times, but had never been explained by any writers in a scientific manner, received great illustration from the works of Georgius Agricola, a German physician. The Greeks and Romans had left no treatises worth mentioning upon the subject; and though a book or two had appeared in the German language, and one in the Italian, relative to metallurgy, before Agricola published his twelve books *De Re Metallica*, yet he is justly esteemed the first author of reputation in that branch of chemistry.

Lazarus Erckern (assay-master general of the empire of Germany) followed Agricola in the same pursuit. His works were

* Preface to his book entitled Paragranum, where there is more in the same style.

first published at Prague, in 1574, and an English translation of them by Sir John Pettus, came out at London, in 1683. The works of Agricola and Erckern are still highly esteemed, though several others have been published, chiefly in Germany, upon the same subject, since their time. Amongst these we may reckon Schindler's Art of Assaying Ores and Metals; the metallurgic works of Orschall; the works of Henckell; of Schutter; of Cramer; of Lehman; and of Gellert. Germany, indeed, has for a long time been the great school of metallurgy for the rest of Europe; and we, in this country, owe the present flourishing condition of our mines, especially of our copper mines, as well as of our brass manufactory, to the wise policy of Queen Elizabeth, in granting great privileges to Daniel Houghsetter, Christopher Schutz, and other Germans; whom she had invited into England, in order to instruct her subjects in the art of metallurgy.

It was not, however, till towards the middle of the last century, that general chemistry began to be cultivated in a liberal and philosophical manner. So early as the year 1645, several ingenious persons in London, in order to divert their thoughts from the horrors of the civil war, which had then broken out, had formed themselves into a society, and held weekly meetings, in which they treated of, what was then called, the new, or experimental philosophy. These meetings were continued in London, till the establishment of the Royal Society, in 1662; and before that time, by the removal of some of the original members to Oxford, similar meetings were held there, and those studies brought into repute in that university. Mr. Boyle, who had entered upon his chemical studies about the year 1647, was a principal person in the Oxford meetings; he published at that place, his Sceptical Chemist, in 1661, and by his various writings and experiments, greatly contributed to the introducing into England, a taste for rational chemistry.

Next to Boyle, or perhaps before him as a chemist, stands his cotemporary, the unfortunate Beccher, whose *Physica Subterranea*, justly entitled *opus sine pari*, was first published in 1669. After having suffered various persecutions in Germany, he came over into England, and died at London, in 1682, at the age of 57. He resided some time before his death in Cornwall, which he calls the mineral school, owning that, from a teacher, he was there become a learner. He was the author of many improvements in the manner of working mines, and of fluxing metals; in particular, he first introduced into Cornwall, the method of fluxing tin by means of the flame of pit-coal, instead of wood or charcoal *.

Lemery's very accurate course of practical chemistry, appeared in 1675. Glauber's works had been published at different times, from 1651 to 1661, when his tract, entitled Philosophical Furnaces, came out at Amsterdam. Kunckel died in Sweden, in 1702; he had practised chemistry for above 50 years, under the auspices of the elector of Saxony, and of Charles XI. of Sweden. He wrote his chemical observations in the German Language, but had them translated into Latin, in the year 1677: the translation is dedicated by its author, to our Royal Society. They were afterwards translated into English, in 1704. Having had the superintendency of several glass-houses, he had a fine opportunity of making a great variety of experiments in that way; and I have been informed by our enamellers, and makers of artificial gems, that they can depend more upon the processes and observations of Kunckel, than of any other author upon the same subject. The chemical labours of these and many other eminent men, too numerous to mention, were greatly forwarded by the establishment of several societies, for the encouragement of natural philosophy, which took place in various parts of Europe about that period.

The Philosophical Transactions, at London; the Histoire de l'Academie Royale des Sciences, at Paris; the Saggi d'Esperienze di Academia del Cimento, at Florence; the Journal des Sçavans, in Holland; the Ephemerides Academiæ Naturæ Curiosorum, in Germany; the Acts of the Academy of Copenhagen; and the Acta Eruditorum, at Leipsic; all these works began to be published within the space of twenty years from 1665, when our Royal Society first set the example, by publishing the Philosophical Transactions. To these may be added, the works of the Academies

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* Beccher wrote his Alphabethum Minerale, at Truro, in Cornwall, in 1682, not long before his death. In his dedication of this tract to Mr. Boyle, he has the following words:—" ignis usus, ope flammarum lithantracum stanoum et mineralia fuodendi, Coroubiæ hactenus iocogoitus, sed a me introductus."—This account which Beccher gives of himself, is not quite agreeable to what is advanced by an author every way qualified to come at the truth of this matter. —" Necessity at last suggested the introduction of pit-coal for the smelting of tin ore; and, among others, to Sir Bevil Granville, of Stow, in this county, temp. Car. I. who made several experiments, though without success; neither did the effectual smelting of tin ore with pit-coal, take place till the second year of Queen Anne." Pryce's Miner. Cornub. p. 282.

of Berlin, Petersburgh, Stockholm, Upsal, Bononia, Bourdeaux, Montpelier, Gottingen, and of several others which have been established within the course of the present century. Near a thousand volumes have been published by these learned societies, within less than 120 years. The number of facts which are therein related respecting chemistry, and every other branch of natural philosophy, is exceedingly great; but the subject is still greater, and must for ever mock the efforts of the human race to exhaust it. Well did Lord Bacon compare natural philosophy to a pyramid! Its basis is indeed the history of nature, of which we know a little and conjecture much; but its top is, without doubt, hid high in the clouds; it is "the work which God worketh from the beginning to the end," infinite and inscrutable.

By the light which has been incidentally thrown upon various parts of chemistry, from those vast undertakings of public societies, as well as from the more express labours of Stahl, Newman, Hoffman, Juncker, Geoffry, Boerhaave, and of many others equally worthy of commendation; by the theoretic conclusions and systematic divisions which have been introduced into it; from the didactic manner in which the students of this art have been instructed in every medical school; chemistry has quite changed its appearance. It is no longer considered merely in a medical view, nor restricted to some fruitless efforts upon metals; it no longer attempts to impose upon the credulity of the ignorant, nor affects to astonish the simplicity of the vulgar, by its wonders; but is content with explaining them upon the principles of sound philosophy. It has shaken off the opprobrium which had been thrown upon it, from the unintelligible jargon of the alchemists, by revealing all its secrets, in a language as clear and as common as the nature of its subjects and operations will admit.

Considered as a branch of physics, chemistry is but yet in its infancy: however, the mutual emulation and unwearied endeavours of so many eminent men as are in every part of Europe engaged in its cultivation, will, in a little time, render it equal to any part of natural philosophy, in the clearness and solidity of its principles. In the utility resulting to the public from its conclusions, with respect to the practice of medicine, of agriculture, arts, and manufactures of every kind, it is even in its present state inferior to none.

The uses of chemistry, not only in the medical, but in every economical art, are too extensive to be enumerated, and too notorious to want illustration; it may just be observed, that a variety of manufactnres, by a proper application of chemical principles, might, probably, be wrought at a less expense, and executed in a better manner, than they are at present. But to this improvement there are impediments on every hand, which cannot easily be overcome. Those who by their situations in life are removed from any design or desire of augmenting their fortunes, by making discoveries in the chemical arts, will hardly be induced to diminish them by engaging in expensive experimental inquiries, which not only require an uninterrupted attention of mind, but are attended with the wearisomeness of bodily labour. It is not enough to employ operators in this business; a man must blacken his own hands with charcoal, he must sweat over the furnace, and inhale many a noxious vapour, before he can become a chemist. On the other hand, the artists themselves are generally illiterate, timid, and bigoted to particular modes of carrying on their respective operations. Being unacquainted with the learned, or modern, languages, they seldom know any thing of new discoveries, or of the methods of working practised in other countries. Deterred by the too frequent, but much-to-be lamented examples of those, who, in benefiting the public by projects and experiments, have ruined themselves, they are unwilling to incur the least expense in making trials, which are uncertain with respect to profit. From this apprehension, as well as from the mysterious manner in which most arts, before the invention of printing, and many still continue to be taught, they acquire a certain *opiniâtreté*, which effectually hinders them from making improvements by departing from the ancient traditionary precepts of their art. It cannot be questioned, that the arts of dyeing, painting, brewing, distilling, tanning, of making glass, enamels, porcelain, artificial stone, common salt, sal ammoniac, salt-petre, potash, sugar, and a great variety of others, have received much improvement from chemical inquiry, and are capable of receiving much more.

Metallurgy in particular, though one of the most ancient branches of chemistry, affords matter enough for new discoveries. There are a great many combinations of metals which have never been made; many of which, however, might be made, and in such a variety of proportions, as, very probably, would furnish us with metallic mixtures more serviceable than any in use. The method of extracting the greatest possible quantity of metal from a given quantity of the same kind of ore, has, perhaps, in no one instance been ascertained with sufficient precision. There are many sorts of iron and copper ores, which cannot be converted into malleable metals, without much labour, and a great expense of fuel; it is very probable, that by a well-conducted series of experiments, more compendious ways of working these minerals might be found out. In our own times three new metallic substances have been discovered *, and their properties abundantly ascertained by experiment; and it may reasonably be conjectured, that future experience will yet augment their number. Till Marggraaf shewed the manner of doing it, no metallic substance could be extracted from calamine, and all Europe was supplied with zinc † either from India or from Germany. A manufactory of this metallic substance has not many years ago been established in our own country, and the copper works near Bristol have supplied Birmingham with zinc extracted from calamine. *Black-jack* was not long since employed in Wales for mending the roads; its value is not yet generally known in Derbyshire; but it is now well understood by some individuals to answer the purpose of calamine for the making of brass ‡. Mons. Von Swab, in 1738, was, I believe, the first person who distilled zinc from black-jack §; and a work which he erected, probably gave the hint to the establishers of our English manufactory: indeed, I have been well informed, that they purchased the secret from him when he was in England. The various kinds of black lead, from which neither tin nor iron can at present be procured to advantage; the mundicks, some cobalt ores, cawk, kebble, and other mineral substances, which are now thought to be useless, may some or time other, perhaps, be applied to good purpose. Cawk and kebble, which are found in great quantities in mining countries, especially in Derbyshire, and which are universally thrown away, may, perhaps, be nothing but different kinds of spar, and

* Platina, regulus of cobalt, and nickel.

† Zinc is a metallic substance of the colour of lead; when united with copper, it constitutes brass, pinchbeck, and other metallic mixtures resembling gold.

‡ The cobalt ores in Hesse, which at present produce a nett profit of about 14,000l. a-year, were formerly used for the same purpose as black-jack was lately in Wales.—Born's Travels by Raspe, Pre. xxvi.

§ Cronstedt's Miner. sec. 231.

destitute of all metallic matter*; yet it may not be improper to remark, that the external appearance of the yellowish cawk is wholly similar to that of calcined black-jack. That it is much of the same weight as black-jack may appear from the annexed table:

Weight of a cubic foot of

	Avoirdup. oz.
White cawk	4047
Yellow cawk . . .	4112
Kebble	4319
Black-jack . . .	4093
Water	1000

In a word, the improvement of metallurgy, and the other mechanic arts, dependent on chemistry, might best be made by the public establishment of an academy, the labours of which should be destined to that particular purpose. The utility of such establishments has been experienced in Saxony, and other places; and as mines and manufactures are to the full as important to us, as to any other European state, one may hope, that the constituting a Chemical Academy may, in times of peace and tranquillity, become an object not unworthy the attention of the King, or the Legislature of the British nation †.

[*Bishop Watson.*

This last patriotic recommendation addressed to the public by Dr. Watson, in 1781, though not carried into effect in the precise manner he suggested, has by no means been altogether neglected. If the legislature have not adopted the scheme, it has not been lost sight of by scientific and public-spirited individuals. The Royal Institution led the way, and by the splendid chemical discoveries which have issued from its laboratory and apparatus, under the di-

* See Mr. Woulfe's ingenious Experiments, in Philos. Trans. 1779, p. 15.

† The reader who wishes to become more fully acquainted with the history of chemistry, may consult what Borrichius has said in his Dissertation de Ortu et Progressu Chemiæ, published at Copenhagen, in 1668; and in his book entitled Hermetis, Ægyptiorum, et Chemicorum, Sapientia ab Hermanni Couringii Animadversionibus vindicata, published at the same place, in 1674. He will also find something worth his notice on this subject, in Boerhaave's Chemistry; and in a work of Wallerius, called, Chemiæ Physicæ Pars Prima, published at Stockholm, in 1760; where there is an useful catalogue of the most approved writers on the various parts of chemistry.

rection of Sir Humphry Davy, and been described in his lectures, as chemical professor to the establishment, has acquired a very distinguished reputation. To this have succeeded several other scientific institutions in this metropolis, which have, in different degrees, contributed towards the same object; the Geological Society, and the Wernerian Society of Edinburgh; both which, more especially, have been labouring for some years, in the immediate department to which the observations before us are peculiarly directed. From these, and similar establishments, and more particularly from the successful labours of Sir Humphry Davy, we have obtained a more comprehensive insight into the principles of bodies; have assured ourselves, that many of the earths are only metallic oxyds, which may be reduced to a reguline or pure metallic state, by detaching the oxygen, which alone gives them their oxyd form; and have hence been led to believe, that all the other earths, which have not yet been analyzed with the same success, are formed of similar principles. We have been able to decompose the fixed alkalies; have made no small progress in decomposing ammonia, and the simple combustibles; and have ascertained the very singular fact, that the first of these, whether potash or soda, are themselves metallic oxyds, capable of being reduced, by an abstraction of their oxygen, to metals of an extraordinary character, their levity enabling them to float not only upon water or alkohol, but in one instance upon naphtha, the lightest fluid we know of. We have also, from the same sources, discovered that oxygen is by no means the only simple supporter of combustion; that there are at least two other substances, *chlorine* and *iodine*, (and we have reason to believe there are more) which make a near approach to it in this and various other respects: and which, at the same time have a peculiarity of character that seems to establish them as distinct bodies.

[*Editor.*

CHAP. II.

ON ELECTRICITY.

SECTION I.

Introduction.

THE study of this interesting and amusing science belongs equally to the chemist, the mechanical philosopher, and the physiologist; for the effects of the electrical fluid are in some instances chemical, in some mechanical, and in some, and peculiarly those which belong to voltaic electricity, physiological. We shall here give it a place in the first of these divisions of science: and shall endeavour to trace the nature of the fluid as it appears when quiescent, or in a state of rest or equilibrium; and when in activity, or in a state of motion. We shall also notice the more curious of the different modes by which it may be accumulated and discharged, and particularly that of the galvanic or voltaic circle.

[*Editor.*

SECTION II.

Electricity in Equilibrium.

THE phænomena of electricity are as amusing and popular in their external form, as they are intricate and abstruse in their intimate nature. In examining these phænomena, a philosophical observer will not be content with such exhibitions as dazzle the eye for a moment, without leaving any impression that can be instructive to the mind, but he will be anxious to trace the connection of the facts with their general causes, and to compare them with the theories which have been proposed concerning them: and although the doctrine of electricity is in many respects yet in its infancy, we shall find that some hypotheses may be assumed, which are capable of explaining the principal circumstances in a simple and satisfactory manner, and which are extremely useful in connecting a multitude of detached facts into an intelligible system. These hypotheses, founded on the discoveries of Franklin, have been gradually formed into a theory, by the investigations of Aepinus and Mr. Cavendish, combined with the experiments and inferences of Lord Stanhope, Coulomb, and Robinson.

We shall first consider the fundamental hypotheses on which this system depends; and secondly, the conditions of equilibrium of the substances concerned in it; determining the mode of distribution of the electric fluid, and the forces or pressures derived from its action when at rest; all which will be found to be deduced from the theory, precisely as they are experimentally observable. The motions of the electric fluid will next be noticed, as far as we can form any general conclusions respecting them; and the manner in which the equilibrium of electricity is disturbed, or the excitation of electricity, will also be considered; and, in the last place, it will be necessary to take a view of the mechanism, or the practical part of electricity, and to examine the natural and artificial apparatus concerned in electrical phænomena, as well as in those effects which have been denominated galvanic.

It is supposed that a peculiar ethereal fluid pervades the pores, if not the actual substance, of the earth, and all other material bodies; passing through them with more or less facility, according to their different powers of conducting it: that the particles of this fluid repel each other, and are attracted by the particles of common matter: that the particles of common matter also repel each other: and that these attractions and repulsions are equal among themselves, and vary inversely as the squares of the distances of the particles.

The effects of this fluid are distinguished from those of all other substances, by an attractive or repulsive quality, which it appears to communicate to different bodies, and which differs in general from other attractions and repulsions, by its immediate diminution or cessation, when the bodies, acting on each other, come into contact, or when they are touched by other bodies. The name electricity is derived from electrum, amber; for it was long ago observed that amber, when rubbed, continues for some time to attract small bodies; but at present electricity is usually excited by other means. In general a body is said to be electrified, when it contains, either as a whole, or in any of its parts, more or less of the electric fluid than is natural to it; and it is supposed that what is called positive electricity depends on a redundancy, and negative electricity on a deficiency, of the fluid.

These repulsions and attractions are supposed to act, not only between two particles which are either perfectly or very nearly in contact with each other, but also between all other particles, at all distances, whatever obstacles may be interposed between them. Thus, if two electrified balls repel each other, the effect is not impeded by the interposition of a plate of glass: and if any other substance interposed appears to interfere with their mutual action, it is in consequence of its own electrical affections. In these respects, as well as in the law of their variation, the electrical forces differ from the common repulsion which operates between the particles of elastic fluids, and resemble more nearly that of gravitation. Their intensity, when separately considered, is much greater than that of gravitation, and they might be supposed to be materially concerned in the great phænomena of the universe; but in the common neutral state of all bodies, the electrical fluid, which is every where present, is so distributed, that the various forces hold each other exactly in equilibrium, and the separate results are destroyed; unless we choose to consider gravitation itself as arising from a comparatively slight inequality between the electrical attractions and repulsions.

The attraction of the electric fluid to common matter is shewn by its communication, from one body to another, which is less copiously supplied with it, as well as by many other phænomena; and this attraction of the fluid of the first body, to the matter of the second, is precisely equal to its repulsion for the quantity of the fluid, which naturally belongs to the second, so as to saturate the matter. For the excess or deficiency of the fluid in the first body, does not immediately produce either attraction or repulsion, so long as the natural distribution of the fluid in the second body remains unaltered.

Since also two neutral bodies, the matter which they contain being saturated by the electric fluid, exhibit no attraction for each other, the matter in the first must be repelled by the matter in the second; for its attraction for the fluid of the second would otherwise remain uncompensated. We are, however, scarcely justified in classing this mutual repulsion among the fundamental properties of matter; for useful as these laws are in explaining electrical appearances, they seem to deviate too far from the magnificent simplicity of nature's works, to be admitted as primary consequences of the constitution of matter: they may, however, be considered as modifications of some other more general laws, which are yet wholly unknown to us.

When the equilibrium of these forces is destroyed, the electric fluid is put in motion; those bodies, which allow the fluid a free passage, are called perfect conductors; but those which impede its motion, more or less, are nonconductors, or imperfect conductors. For example, while the electric fluid is received into the metallic cylinder of an electrical machine, its accumulation may be prevented by the application of the hand to the cylinder which receives it, and it will pass off through the person of the operator to the ground; hence the human body is called a conductor. But when the metallic cylinder, or conductor, of the machine is surrounded only by dry air, and supported by glass, the electric fluid is retained, and its density increased, until it becomes capable of procuring itself a passage, some inches in length, through the air, which is a very imperfect conductor. If a person, connected with the conductor, be placed on a stool with glass legs, the electricity will no longer pass through him to the earth, but may be so accumulated, as to make its way to any neighbouring substance, which is capable of receiving it, exhibiting a luminous appearance, called a spark; and a person or a substance, so placed as to be in contact with nonconductors only, is said to be insulated. When electricity is subtracted from the substance thus insulated, it is said to be negatively electrified, but the sensible effects are nearly the same, except that in some cases the form of the sparks is a little different.

Perfect conductors, when electrified, are in general either overcharged or undercharged with electricity, in their most distant parts, at the same time; but nonconductors, although they have an equal attraction for the electric fluid, are often differently affected in different parts of their substance, even when those parts are similarly situated in every respect, except that some of them have had their electricity increased or diminished by a foreign cause. This property of nonconductors may be illustrated by means of a cake of resin, or a plate of glass, to which a local electricity may be communicated in any part of its surface, by the contact of an electrified body; and the parts thus electrified may afterwards be distinguished from the rest, by the attraction which they exert on any small particles of dust or powder projected near them; the manner in which the particles arrange themselves on the surface, indicating also in some cases the species of electricity, whether positive or negative, that has been employed; positive electricity producing an appearance somewhat resembling feathers; and negative electricity an arrangement more like spots. The inequality in the distribution of the electric fluid in a nonconductor, may remain for some hours, or even some days, continually diminishing till it becomes imperceptible.

These are the fundamental properties of the electric fluid, and of the different kinds of matter as connected with that fluid. We are next to examine its distribution, and the attractive and repulsive effects exhibited by it, under different forms. Supposing a quantity of redundant fluid to exist in a spherical conducting body, it will be almost wholly collected into a minute space contiguous to the surface, while the internal parts remain but little overcharged. For we may neglect the actions of the portion of fluid which is only occupied in saturating the matter, and also the effect of the matter thus neutralised, since the redundant fluid is repelled as much by the one, as it is attracted by the other; and we need only to consider the mutual actions of the particles of this superfluous fluid on each other. It may then be shewn, in the same manner as it is demonstrated of the force of gravitation, that all the spherical strata which are remoter from the centre than any given particle, will have the whole of their action on it annihilated by the balance of their forces, and that the effective repulsion of the interior strata will be the same, as if they were all collected in the centre. This repulsion will, therefore, impel the particles of the fluid towards the surface, as long as it exists; and nothing will impede the condensation of the redundant fluid there, until it is exhausted from the neighbourhood of the centre. In the same manner it may be shewn, that if there be a deficiency of fluid, it will be only in the external parts, the central parts remaining always in a state of neutrality: and since the quantity of electric fluid taken away from a body, in any common experiment, bears but a very small proportion to the whole that it contains, the deficiency will also be found in a very small proportion of the sphere, next to its surface. And if, instead of being spherical, the body be of any other form, the effects of electricity will still be principally confined to its surface. This proposition was very satisfactorily investigated by Mr. Cavendish; and it was afterwards more fully shewn, by Dr. Gray's experiments, that the capacities of different bodies, for receiving electricity, depend much more on the quantity of their surfaces, than on their solid contents: thus, the conductor of an electrical machine will contain very nearly or quite as much electricity if hollow as if solid.

If two spheres be united by a cylindrical conducting substance, of small dimensions, there will be an equilibrium, when the actions of the redundant fluid in the spheres, on the whole fluid in the cylinder, are equal; that is, when both the spheres have their surfaces electrified in an equal degree: but if the length of the cylinder is considerable, the fluid within it can only remain at rest when the quantities of redundant fluid are nearly equal in both spheres, and consequently when the density is greater in the smaller. And, for a similar reason, in bodies of irregular forms, the fluid is always most accumulated in the smallest parts; and when a conducting substance is pointed, the fluid becomes so dense at its extremity, as easily to overcome the forces which tend to retain it in its situation.

In this distribution we find a very charisteristic difference between the pressure of the electric fluid, and the common hydrostatic pressure of liquids, or of simple elastic fluids; for these exert on every surface, similarly situated, a pressure proportionate to its magnitude; but the electric fluid exerts a pressure on small and angular surfaces, greater, in proportion to their magnitudes, than the pressure on larger parts: so that if the electric fluid were in general confined to its situation, by the pressure of the atmosphere, that pressure might easily be too weak to oppose its escape from any prominent points. It does not appear, however, that this pressure is the only cause which prevents the escape of the electric fluid; nor is it certain that this fluid can pass through a perfect vacuum, although it has not yet been proved, that a body placed in a vacuum is perfectly insulated. Whatever the resistance may be, which prevents the dissipation of electricity, it is always the more easily overcome, as the electrified substance is more pointed, and as the point is more prominent; and even the presence of dust is often unfavourable to the success of electrical experiments, on account of the great number of pointed terminations which it affords.

The general effect of electrified bodies on each other, if their bulk is small in comparison with their distance, is, that they are mutually repelled when in similar states of electricity, and attracted when in dissimilar states. This is a consequence immediately deducible from the mutual attraction of redundant matter, and redundant fluid, and from the repulsion supposed to exist between any two portions, either of matter or of fluid; and it may also easily be confirmed by experimental proof. A neutral body, if it were a perfect nonconductor, would not be affected either way by the neighbourhood of an electrified body: for while the whole matter contained in it remains barely saturated with the electric fluid, the attractions and repulsions balance each other. But, in general, a neutral body appears to be attracted by an electrified body, on account of a change of the disposition of the fluid which it contains, upon the approach of a body either positively or negatively electrified. The electrical affection produced in this manner, without any actual transfer of the fluid, is called induced electricity.

When a body positively electrified approaches to a neutral body, the redundancy of the fluid expels a portion of the natural quantity from the nearest parts of the neutral body, so that it is accumulated at the opposite extremity; while the matter, which is left deficient, attracts the redundant fluid of the first body, in such a manner as to cause it to be more condensed in the neighbourhood of the second than elsewhere; and hence the fluid of this body is driven still further off, and all the effects are redoubled. The attraction of the redundant fluid of the electrified body, for the redundant matter of the neutral body, is stronger than its repulsion for the fluid which has been expelled from it, in proportion as the square of the mean distance of the matter is smaller than that of the mean distance of the fluid: so that in all such cases of induced electricity, an attraction is produced between the bodies concerned. And a similar attraction will happen, under contrary circumstances, when a neutral body and a body negatively electrified, approach each other.

The state of induced electricity may be illustrated by placing a long conductor at a little distance from an electrified substance, and directed towards it; and by suspending pith balls, or other light bodies from it, in pairs, at different parts of its length: these will repel each other, from being similarly electrified, at the two ends, which are in contrary states of electricity, while at a certain point towards the middle they will remain at rest, the conductor being here perfectly neutral. It was from the situation of this point that Lord Stanhope first inferred the true law of the electric attractions and repulsions, although Mr. Cavendish had before suggested the same law as the most probable supposition.

The attraction, thus exerted by an electrified body upon neutral substances, is strong enough, if they are sufficiently light, to overcome their gravitation, and to draw them up from a table at some little distance: upon touching the electrified body, if it is a conductor, they receive a quantity of electricity from it, and are again repelled, until they are deprived of their electricity by contact with some other substance; which, if sufficiently near to the first, is usually in a contrary state, and therefore renders them still more capable of returning, when they have touched it, to the first substance, in consequence of an increased attraction, assisted also by a new repulsion. This alteration has been applied to the construction of several electrical toys; a little hammer, for example, has been made to play between two bells; and this instrument has been employed for giving notice of any change of the electrical state of the atmosphere. The repulsion which takes place between two bodies, in a similar state of electricity, is the cause of the currents of air which always accompany the discharge of electricity, whether negative or positive, from pointed substances; each particle of air, as soon as it has received its electricity from the point, being immediately repelled by it; and this current has also been supposed to facilitate the escape of the electricity, by bringing a continual succession of particles not already overcharged.

If two bodies approach each other, electrified either positively or negatively, in different degrees, they will either repel or attract each other, according to their distance; when they are very remote they exhibit a repulsive force, but when they are within a certain distance, the effects of induced electricity overcome the repulsion which would necessarily take place, if the distribution of the fluid remained unaltered by their mutual influence.

When a quantity of the electric fluid is accumulated on one side of a nonconducting substance, it tends to drive off the fluid from the other side; and if this fluid is suffered to escape, the remaining matter exerts its attraction on the fluid which has been imparted to the first side, and allows it to be accumulated in a much greater quantity than could have existed in an equal surface of a conducting substance. In this state the body is said to be charged; and for producing it the more readily, each surface is usually coated with a conducting substance, which serves to convey the fluid to and from its different parts with convenience. The thinner any substance is, the greater quantity of the fluid is required for charging it in this manner, so as to produce a given tension, or tendency to escape: but if it be made too thin, it will be liable to break the attractive force of the fluid; for the matter on the opposite side overcoming the cohesion of the substance, and perhaps forcing its way through the temporary vacuum which is formed.

When a communication is made in any manner, by a conducting substance, between the two coatings of a charged plate or vessel, the equilibrium is restored, and the effect is called a shock. If the coatings be removed, the plate will still remain charged, and it may be gradually discharged by making a communication between its several parts in succession, but it cannot be discharged at once, for want of a common connection: so that the presence of the coating is not absolutely essential to the charge and discharge of the opposite surfaces. Such a coated substance is most usually employed in the form of a jar. Jars were formerly filled with water, or with iron filings; the instrument having been principally made known from the experiments of Musschenbroek and others, at Leyden, it was called the Leyden phial; but at present a coating of tin foil is commonly applied on both sides of the jar, leaving a sufficient space at its upper part, to avoid the spontaneous discharge, which would often take place between the coatings, if they approached too near to each other; and a ball is fixed to the cover, which has a communication with the internal coating, and by means of which the jar is charged, while the external coating is allowed to communicate with the ground. A collection of such jars is called a battery; and an apparatus of this kind may be made so powerful, by increasing the number of jars, as to exhibit many striking effects by the motion of the electric fluid, in its passage from one to the other of the surfaces.

The conducting powers of different substances are concerned, not only in the facility with which the motions of the electric fluid are directed into a particular channel, but also in many cases of its equilibrium, and particularly in the properties of charged substances, which depend on the resistance opposed by nonconductors to the ready transmission of the fluid. These powers may be compared, by ascertaining the greatest length of each of the substances to be examined, through which a spark or a shock will take its course, in preference to a given length of air, or of any other standard of comparison. The substances which conduct electricity the most readily, are metals, well burnt charcoal, animal bodies, acids, saline liquors, water, and very rare air. The principal nonconductors are glass, ice, gems, dry salts, sulphur, amber, resins, silk, dry wood, oils, dry air of the usual density, and the barometrical vacuum. Heat commonly increases the conducting powers of bodies; a jar of glass may be discharged by a moderate heat, and liquid resins are capable of transmitting shocks, although they are by no means good conductors: it is remarkable also that a jar may be discharged by minute agitation, when it is caused to ring by the friction of the finger. It has been observed that, in a great variety of cases, those substances which are the best conductors of heat, afford also the readiest passage to electricity; thus, copper conducts heat more rapidly, and electricity more readily, than iron; and platina less than almost any other metal: glass also presents a considerable resistance to the transmission of both these influences. The analogy is, however, in many respects imperfect, and it affords us but little light, with regard either to the nature of heat, or to that of the electric fluid.

[*Young's Nat. Phil.*

SECTION III.

Electricity in Motion.

The manner in which the electric fluid is transferred from one body to another, the immediate effects of such a transfer, the causes which originally disturb the equilibrium of electricity, and the practical methods by which all these circumstances are regulated and measured, require to be considered as belonging to the subject of electricity in motion. Among the modes of excitation by which the equilibrium is originally disturbed, one of the most interesting is the galvanic apparatus, which has been of late years a very favourite subject of popular curiosity, and of which the theory and operation will be briefly examined, although the subject appears rather to belong to the chemical than to the mechanical doctrine of electricity.

The progressive motion of the electric fluid through conducting substances is so rapid, as to be performed in all cases without a sensible interval of time. It has indeed been said, that when very weakly excited, and obliged to pass to a very great distance, a perceptible portion of time is actually occupied in its passage; but this fact is somewhat doubtful, and attempts have been made, in vain, to estimate the interval employed in the transmission of a shock through several miles of wire. We are not to imagine that the same particles of the fluid which enter at one part, pass through the whole conducting substance, any more than that the same portion of blood which is thrown out of the heart, in each pulsation, arrives at the wrist at the instant that the pulse is felt there. The velocity of the transmission of a spark, or shock, far exceeds the actual velocity of each particle, in the same manner as the velocity of a wave exceeds that of the particles of water concerned in its propagation; and this velocity must depend both on the elasticity of the fluid, and on the force with which it is confined to the conducting substance. If this force were merely derived from the pressure of the atmosphere, we might infer the density of the fluid from the velocity of a spark or shock, compared with that of sound; or we might deduce its velocity from a determination of its density. It has been supposed, although perhaps somewhat hastily, that the actual velocity is nearly equal to that of light.

When a conducting substance approaches another, which is electrified, the distribution of the electric fluid within it is necessarily altered by induction, before it receives a spark, so that its remoter extremity is brought into a state similar to that of the first body: hence it happens that when the spark passes, it produces less effect at the remoter end of the substance, while the part presented to the electrified body is most affected, on account of its sudden change to an opposite state. But if both ends approach bodies in opposite states of electricity, they will both be strongly affected when the shock takes place, while the middle of the circuit undergoes but little change.

The manner in which the electric fluid makes its way through a more or less perfect conductor, is not completely understood: it is doubtful whether the substance is forced away on each side, so as to leave a vacuum for the passage of the fluid, or whether the newly formed surface helps to guide it in its way; and in some cases it has been supposed, that the gradual communication of electricity has rendered the substance more capable of conducting it, either immediately, or, in the case of the air, by first rarefying it. However this may be, the perforation of a jar of glass by an overcharge, and that of a plate of air by a spark, appear to be effects of the same kind, although the charge of the jar is principally contained in the glass, while the plate of air is perhaps little concerned in the distribution of the electricity.

The actual direction of the electric current has not in any instance been fully ascertained, although there are some appearances which seem to justify the common denominations of positive and negative. Thus, the fracture of a charged jar of glass, by spontaneous explosion, is well defined on the positive, and splintered on the negative side, as might be expected from the passage of a foreign substance from the former side to the latter; and a candle, held between a positive and a negative ball, although it apparently vibrates between them, is found to heat the negative ball much more than the positive. We cannot, however, place much dependance on any circumstance of this kind, for it is doubtful whether any current of the fluid, which we can produce, possesses sufficient momentum to carry with it a body of sensible magnitude. It is in fact of little consequence to the theory, whether the terms positive and negative be correctly applied, provided that their sense remain determined; and that, like positive and negative quantities in mathematics, they be always understood of states which neutralise each other. The original opinion of Dufay, of the existence of two distinct fluids, a vitreous and a resinous electricity, has at present few advocates, although some have thought such a supposition favoured by the phænomena of the galvanic decomposition of water.

When electricity is simply accumulated without motion, it does not appear to have any effect, either mechanical, chemical, or physiological, by which its presence can be discovered; the acceleration of the pulse, and the advancement of the growth of plants, which have been sometimes attributed to it, have not been confirmed by the most accurate experiments. An uninterrupted current of electricity, through a perfect conductor, would perhaps be also in every respect imperceptible, since the best conductors appear to be the least affected by it. Thus, if we place our hand on the conductor of an electrical machine, the electricity will pass off continually through the body, without exciting any sensation. A constant stream of galvanic electricity, passing through an iron wire, is, however, capable of exciting a considerable degree of heat; and if it be transmitted through the hands of the operator, it will produce a slight numbness, although in general some interruption of the current is necessary, in order to furnish an accumulation sufficient to produce sensible effects; and such an interruption may even increase the effect of a single spark or shock; thus, gunpowder is more readily fired by the discharge of a battery passing through an interrupted circuit, than through a series of perfect conductors.

The most common effect of the motion of the electric fluid is the production of light. Light is probably never occasioned by the passage of the fluid through a perfect conductor; for when the discharge of a large battery renders a small wire luminous, the fluid is not wholly confined to the wire, but overflows a little into the neighbouring space. There is always an appearance of light whenever the path of the fluid is interrupted by an imperfect conductor; nor is the apparent contact of conducting substances sufficient to prevent it, unless they are held together by a considerable force; thus, a chain, conveying a spark or shock, appears luminous at each link, and the rapidity of the motion is so great, that we can never observe any difference in the times of the appearance of the light in its different parts; so that a series of luminous points, formed by the passage of the electric fluid, between a string of conducting bodies, represents at once a brilliant delineation of the whole figure in which they are arranged. A lump of sugar, a piece of wood, or an egg, may easily be made luminous in this manner; and many substances, by means of their properties as solar phosphori, retain for some seconds the luminous appearance thus acquired. Even water is so imperfect a conductor, that a strong shock may be seen in its passage through it; and when the air is sufficiently moistened or rarefied to become a conductor, the track of the fluid through it is indicated by streams of light, which are perhaps derived from a series of minute sparks passing between the particles of water, or of rarefied air. When the air is extremely rare, the light is greenish; as it becomes more dense, the light becomes blue, and then violet, until it no longer conducts. The appearance of the electrical light of a point enables us to distinguish the nature of the electricity with which it is charged; a pencil of light, streaming from the point, indicating that its electricity is positive; while a luminous star, with few diverging rays, shows that it is negative. The sparks, exhibited by small balls, differently electrified, have also similar varieties in their forms, according to the nature of their charges.

The production of heat by electricity frequently accompanies that of light, and appears to depend in some measure on the same circumstances. A fine wire may be fused and dissipated by the discharge of a battery; and without being perfectly melted, it may sometimes be shortened or lengthened, accordingly as it is loose or stretched during the experiment. The more readily a metal conducts, the shorter is the portion of it which the same shock can destroy; and it has sometimes been found, that a double charge of a battery has been capable of melting a quadruple length of wire of the same kind.

The mechanical effects of electricity are probably in many cases the consequences of the rarefaction produced by the heat which is excited; thus, the explosion attending the transmission of a shock or spark through the air, may easily be supposed to be derived from the expansion caused by heat; and the destruction of a glass tube, which contains a fluid in a capillary bore, when a spark is caused to pass through it, is the natural consequence of the conversion of some particles of the fluid into vapour. But when a glass jar is perforated, this rarefaction cannot be supposed to be adequate to the effect. It is remarkable that such a perforation may be made by a very moderate discharge, when the glass is in contact with oil or with sealing wax; and no sufficient explanation of this circumstance has yet been given.

A strong current of electricity, or a succession of shocks or sparks, transmitted through a substance, by means of fine wires, is capable of producing many chemical combinations and decompositions, some of which may be attributed merely to the heat which it occasions, but others are wholly different. Of these the most remarkable is the production of oxygen and hydrogen gas from common water, which are usually extricated at once, in such quantities, as, when again combined, will reproduce the water which has disappeared; but in some cases the oxygen appears to be disengaged most copiously at the positive wire, and the hydrogen at the negative.

When the spark is received by the tongue, it has generally a subacid taste; and an explosion of any kind is usually accompanied by a smell somewhat like that of sulphur, or rather of fired gunpowder. The peculiar sensation which the electric fluid occasions in the human frame, appears in general to be derived from the spasmodic contractions of the muscles through which it passes; although in some cases it produces pain of a different kind; thus, the spark of a conductor occasions a disagreeable sensation in the skin, and when an excoriated surface is placed in the galvanic current, a sense of smarting, mixed with burning, is experienced. Sometimes the effect of a shock is felt most powerfully at the joints, on account of the difficulty which the fluid finds in passing the articulating surfaces which form the cavity of the joints. The sudden death of an animal, in consequence of a violent shock, is probably owing to the immediate exhaustion of the whole energy of the nervous system. It is remarkable that a very minute tremor, communicated to the most elastic parts of the body, in particular to the chest, produces an agitation of the nerves, which is not wholly unlike the effect of a weak electricity.

The principal modes in which the electric equilibrium is primarily destroyed are, simple contact, friction, a change of the form of aggregation, and chemical combinations and decompositions. The electricity produced by the simple contact of any two substances is extremely weak, and can only be detected by very delicate experiments: in general it appears that the substance, which conducts the more readily, acquires a slight degree of negative electricity, while the other substance is positively electrified in an equal degree. The same disposition of the fluid is also usually produced by friction, the one substance always losing as much as the other gains; and commonly, although not always, the worst conductor becomes positive. At the instant in which the friction is applied, the capacities or attractions of the bodies for electricity appear to be altered, and a greater or less quantity is required for saturating them; and upon the cessation of the temporary change, this redundancy or deficiency is rendered sensible. When two substances of the same kind are rubbed together, the smaller or the rougher becomes negatively electrified; perhaps because the smaller surface is more heated, in consequence of its undergoing more friction than an equal portion of the larger, and hence becomes a better conductor; and because the rougher in itself is a better conductor than the smoother, and may possibly have its conducting powers increased by the greater agitation of its parts which the friction produces. The back of a live cat becomes positively electrified, with whatever substance it is rubbed; glass is positive in most cases, but not when rubbed with mercury in a vacuum, although sealing wax, which is generally negative, is rendered positive by immersion in a trough of mercury. When a white and a black silk stocking are rubbed together, the white stocking acquires positive electricity, and the black negative; perhaps because the black dye renders the silk both rougher, and a better conductor.

Those substances, which have very little conducting power, are sometimes called electrics, since they are capable of exhibiting readily the electricity which friction excites on their surfaces, where it remains accumulated, so that it may be collected into a conductor; while the surfaces of such substances as have greater conducting powers, do not so readily imbibe the fluid from others with which they are rubbed, since they may be supplied from the internal parts of the substances themselves, when their altered capacity requires it; thus, glass, when heated to 110° of Fahrenheit, can with difficulty be excited, becoming an imperfect conductor: but a thin plate of a conducting substance, when insulated, may be excited almost as easily as an electric, commonly so called.

Vapours are generally in a negative state, but if they rise from metallic substances, or even from some kinds of heated glass, the effect is uncertain, probably on account of some chemical actions which interfere with it. Sulphur becomes electrical in cooling, and wax candles are said to be sometimes found in a state so electrical, when they are taken out of their moulds, as to attract the particles of dust which are floating near them. The tourmalin, and several other crystallized stones, become electrical when heated or cooled, and it is found that the disposition assumed by the fluid, bears a certain relation to the direction in which the stone transmits the light most readily; some parts of the crystal being rendered always positively and others negatively electrical, by an increase of temperature.

The most remarkable of the phænomena attending the excitation of electricity of chemical changes, are those which have lately received the appellation of galvanic. Some of the effects which have been considered as belonging to galvanism are probably derived from the electrical powers of the animal body, and the rest have been referred by Mr. Volta, and many other philosophers on the continent, to the mere mechanical actions of bodies possessed of different properties with regard to electricity. Thus, they have supposed that when a circulation of the electric fluid is produced through a long series of substances in a certain direction, the differences of their attractions and of their conducting powers, which must remain the same throughout the process, keep up this perpetual motion, in defiance of the general laws of mechanical forces. In this country it has been generally maintained, that no explanation founded on such principles could be admissible, even if it were in all other respects sufficient and satisfactory, which the mechanical theory of galvanism certainly is not.

The phænomena of galvanism appear to be principally derived from an inequality in the distribution of the electric fluid, originating from chemical changes, and maintained by means of the resistance opposed to its motion, by a continued alteration of substances of different kinds, which furnishes a much stronger obstacle to its transmission than any of those substances alone would have done. The substances employed must neither consist wholly of solids nor of fluids, and they must be of three different kinds, possessed of different powers of conducting electricity; but whether the difference of their conducting powers is of any other consequence than as it accompanies different chemical properties, is hitherto undetermined. Of these three substances, two must possess a power of acting mutually on each other, while the other appears to serve principally for making a separate connexion between them: and this action may be of two kinds, or perhaps more; the one is oxidation, or the combination of a metal or an inflammable substance with a portion of oxygen derived from water or from acid; the other sulphuration, or a combination with the sulphur contained in a solution of an alkaline sulphuret.

We may represent the effects of all galvanic combinations, by considering the oxidation as producing positive electricity in the acting liquid, and the sulphuration as producing negative electricity, and by imagining that this electricity is always communicated to the best conductor of the other substances concerned, so as to produce a circulation in the direction thus determined. For example, when two wires of zinc and silver, touching each other, are separately immersed in an acid, the acid, becoming positively electrical, imparts its electricity to the silver, and hence it flows back into the zinc: when the ends of a piece of charcoal are dipped into water and into an acid, connected together by a small tube, the acid, becoming positive, sends its superfluous fluid through the charcoal into the water; and if a wire of copper be dipped into water and a solution of alkaline sulphuret, connected with each other, the sulphuret, becoming negative, will draw the fluid from the copper on which it acts: and in all these cases the direction of the current is truly determined, as it may be shewn by composing a battery of a number of alterations of this kind, and either examining the state of its different parts by electrical tests, or connecting wires with its extremities, which, when immersed into a portion of water, will exhibit the production of oxygen gas where they emit the electric fluid, and of hydrogen where they receive it. These processes of oxidation and of sulphuration may be opposed to each other, or they may be combined in various ways, the sum or difference of the separate actions being obtained by their union; thus it usually happens, that both the metals employed are oxidable in some degree, and the oxidation, which takes place at the surface of the better conductor, tends to impede the whole effect, perhaps by impeding the passage of the fluid through the surface. The most oxidable of the metals, and probably the worst conductor, is zinc; the next is iron; then come tin, lead copper, silver, gold, and platina.

In the same manner as a wire charged with positive electricity causes an extrication of oxygen gas, so the supply of electricity through the more conducting metal promotes the oxidation of the zinc of a galvanic battery; and the effect of this circulation may be readily exhibited, by fixing a wire of zinc and another of silver or platina, in an acid, while one end of each is loose, and may be brought together or separated at pleasure: for at the moment that the contact takes place, a stream of bubbles rising from the platina, and a white cloud of oxid falling from the zinc, indicate both the circulation of the fluid and the increase of the chemical action. But when, on the other hand, a plate of zinc is made negative by the action of an acid on the greater part of its surface, a detached drop of water has less effect on it, than in the natural state: while a plate of iron, which touches the zinc, and forms a part of the circle with it, is very readily oxidated at a distant point: such a plate must therefore be considered, with regard to this effect, as being made positive by the electricity which it receives from the acid or the water; unless something like a compensation be supposed to take place, from the effects of induced electricity. Instead of the extrication of hydrogen, the same causes will sometimes occasion a deposition of metal which has been dissolved, will prevent the solution of a metal which would otherwise have been corroded, or produce some effects which appear to indicate the presence of an alkali, either volatile or fixed. All these operations may, however, be very much impeded by the interposition of any considerable length of water, or of any other imperfect conductor.

It is obvious, that since the current of electricity, produced by a galvanic circle, facilitates those actions from which its powers are derived, the effect of a double series must be more than twice as great as that of a single one: and hence arises the activity of the pile of Volta, the discovery of which forms the most important era in the history of this department of natural knowledge. The intensity of the electrical charge, and the chemical and physiological effects of a pile or battery, seem to depend principally on the number of alterations of substances; the light and heat more on the joint magnitude of the surfaces employed. In common electricity, the greatest heat appears to be occasioned by a long continuation of a slow motion of the fluid; and this is perhaps best furnished in galvanism by a surface of large extent, while some other effects may very naturally be expected to depend on the intensity of the charge, independently of the quantity of charged surface. It may easily be imagined, that the tension of the fluid must be nearly proportionate to the number of surfaces, imperfectly conducting, which are interposed between the ends of a pile or battery, the density of the fluid becoming greater and greater by a limited quantity at each step: and it is easily understood, that any point of the pile may be rendered neutral, by a connection with the earth, while those parts, which are above or below it, will still preserve their relations unaltered with respect to each other: the opposite extremities being, like the opposite surface of a charged jar, in contrary states, and a partial discharge being produced, as often as they are connected by a conducting substance. The various forms in which the piles or troughs are constructed, are of little consequence to the theory of their operation: the most convenient are the varnished troughs, in which plates of silvered zinc are arranged side by side, with intervening spaces for the reception of water, or of an acid.

It is unquestionable that the torpedo, the gymnotus electricus, and some other fishes, have organs appropriated to the excitation of electricity, and that they have a power of communicating this electricity at pleasure to conducting substances in their neighbourhood. These organs somewhat resemble in their appearance the plates of the galvanic pile, although we know nothing of the immediate arrangement from which their electrical properties are derived; but the effect of the shock which they produce, resembles in all respects that of the weak charge of a very large battery. It has been shewn by the experiments of Galvani, Volta, and Aldini, that the nerves and muscles of the human body possess some electrical powers, although they are so much less concerned in the phænomena which were at first attributed to them by Galvani, than he originally supposed, that many philosophers have been inclined to consider the excitation of electricity as always occasioned by the inanimate substances employed, and the spasmodic contractions of the muscles as merely very delicate tests of the influence of foreign electricity on the nerves.

Such is the general outline of the principal experiments and conclusions which the subject of galvanism afforded before Mr. Davy's late ingenious and interesting researches, which have thrown much light, not only on the foundation of the whole of this class of phænomena, but also on the nature of chemical actions and affinities in general. Mr. Davy is inclined to infer from his experiments, that all the attractions, which are the causes of chemical combinations, depend on the opposite natural electricities of the bodies concerned; since such bodies are always found by delicate tests, to exhibit, when in contact, marks of different species of electricity; and their mutual actions may be either augmented or destroyed, by increasing their mutual charges of electricity, or by electrifying them in a contrary way. Thus an acid and a metal are found to be negatively and positively electrical with respect to each other; and by further electrifying the acid negatively, and the metal positively, their combination is accelerated; but when the acid is positively electrified, or the metal positively, they have no effect whatever on each other. The acid is also attracted, as a negative body, by another positively electrified, and the metal by a body negatively electrified, so that a metallic salt may be decomposed in the circuit of Volta, the positive point attracting the acid, and the negative point the metal: and these attractions are so strong, as to carry the particles of the respective bodies through an intervening medium, which is in a fluid state, or even through a moist solid; nor are they intercepted in their passage by substances, which in other cases, have the strongest elective attractions for them. Alkali, sulphur, and alkaline sulphurets, are positive with respect to the metals, and much more with respect to the acids: hence they have a very strong natural tendency to combine with the acids and with oxygen; and hydrogen must also be considered as belonging to the same class with the alkalies.

Supposing now a plate of zinc to decompose a portion of water: the oxygen, which has a negative property, unites with the zinc, and probably tends to neutralise it, and to weaken its attractive force; the hydrogen is repelled by the zinc, and carries to the opposite plate of silver its natural positive electricity; and if the two plates be made to touch, the energy of the plate of zinc is restored, by the electricity which it receives from the silver: and it receives it the more readily, as the two metals, in any case of their contact, have a tendency to become electrical, the zinc positively, and the silver negatively. Mr. Davy therefore considers this chemical action as destroying, or at least counteracting, the natural tendency of the electrical fluid to pass from the water to the zinc, and from modifications of this counteraction he explains the effects of galvanic combinations in all cases. Thus, in a circle composed of copper, sulphuret, and iron, the fluid tends to pass from the iron towards the sulphuret, and from the copper to the iron, in one direction; and in the opposite direction from the copper to the sulphuret, with a force which must be equal to both the others, since there would otherwise be a continual motion without any mechanical cause, and without any chemical change; but the action of the sulphuret on the copper tends to destroy its electromotive, or rather electrophoric power, of directing the current towards the sulphuret, and its combination with the sulphur makes it either positively electrical, or negatively electrical in a less considerable degree; consequently the fluid passes, according to its natural tendency, from the copper to the iron, and from the iron to the sulphuret. In a third case, when copper, an acid, and water, form a circle, the natural tendency is from the acid to the copper on one side, and from the acid to the water, and from the water to the copper on the other; here we must suppose the first force to be only a little weakened by the chemical action, while the third is destroyed, so that the first overcomes the second, and the circulation is determined, although very feebly, in such a direction that the fluid passes from the acid to the copper. When, in the fourth place, the combination consists of copper, sulphuret, and water, the tendencies are, first, from the copper to the sulphuret, and from the water to the copper; and secondly from the water to the sulphuret: in this instance a chemical action must be supposed between the oxygen of the water and the sulphuret, which lessens the electromotive tendency more than the action that takes place between the sulphuret and the copper, so that the fluid passes from the copper to the sulphuret; and the current has even force enough to prevent any chemical action between the water and the copper, which would tend to counteract that force, if it took place.

Mr. Davy has observed that the decomposition of the substances, employed in the battery of Volta, is of much more consequence to their activity than either their conducting power, or their simple action on the other element of the series: thus, the sulphuric acid, which conducts electricity better, and dissolves the metals more readily than a neutral solution, is, notwithstanding less active in the battery, because it is not easily decomposed. Mr. Davy has also extended his researches, and the application of his discoveries, to a variety of natural as well as artificial phænomena, and there can be no doubt but that he will still make such additions to his experiments, as will be of the greatest importance to this branch of science.

The operation of the most useful electrical machines depends first on the excitation of electricity by the friction of glass on a cushion of leather, covered with a metallic amalgam, usually made of mercury, zinc, and tin, which probably, besides being of use in supplying electricity readily to different parts of the glass, undergoes in general a chemical change, by means of which some electricity is excited. The fluid, thus excited, is received into an insulated conductor by means of points, placed at a small distance from the surface which has lately undergone the effects of friction, and from this conductor it is conveyed by wires or chains to any other parts at pleasure. Sometimes also the cushion, instead of being connected with the earth, is itself fixed to a second conductor, which becomes negatively electrified; and either conductor may contain within it a jar, which may be charged at once by the operation of the machine, when its internal surface is connected either with the earth, or with that of the jar contained in the opposite conductor. The glass may be either in the form of a circular plate or of a cylinder, and it is uncertain which of the arrangements affords the greatest quantity of electricity from the same surface; but the cylinder is cheaper than the plate, and less liable to accidents, and appears to be at least equally powerful.

The plate machine in the Teylerian museum, employed by Van Marum, when worked by two men, excited an electricity, of which the attraction was sensible at the distance of thirty-eight feet, and which made a point luminous at twenty-seven feet, and afforded sparks nearly twenty-four inches long. Mr. Wilson had also a few years ago, in the Pantheon in London, an apparatus of singular extent; the principal conductor was 150 feet long, and sixteen inches in diameter, and he employed a circuit of 4800 feet of wire.

The electrophorus derives its operation from the properties of induced electricity. A cake of a nonconducting substance, commonly of resin or of sulphur, is first excited by friction, and becomes negatively electric: an insulated plate of a conducting substance, being placed on it, does not come sufficiently into contact with it to receive its electricity, but acquires by induction an opposite state at its lower surface, and a similar state at its upper; so that when this upper and negative surface is touched by a substance communicating with the earth, it receives enough of the electric fluid to restore the equilibrium. The plate then being raised, the action of the cake no longer continues, and the electricity, which the plate has received from the earth, is imparted to a conductor or to a jar; and the operation may be continually repeated, until the jar has received a charge, of an intensity equal to that of the plate when raised. Although the quantity of electricity received by the plate, is exactly equal to that which is emitted from it at each alternation, yet the spark is far less sensible; since the effect of the neighbourhood of the cake is to increase the capacity of the plate, while the tension or force impelling the fluid is but weak; and at the same time the quantity received is sufficient, when the capacity of the plate is again diminished, to produce a much greater tension, at a distance from the cake.

The condenser acts in some measure on the same principles with the electrophorus, both instruments deriving their properties from the effects of induction. The use of the condenser is to collect a weak electricity from a large substance into a smaller one, so as to make its density or tension sufficient to be examined. A small plate, connected with the substance, is brought nearly into contact with another plate communicating with the earth; in general a thin stratum of air only is interposed; but sometimes a nonconducting varnish is employed; this method is, however, liable to some uncertainty, from the permanent electricity which the varnish sometimes contracts by friction. The electricity is accumulated by the attraction of the plate communicating with the earth, into the plate of the condenser; and when this plate is first separated from the substance to be examined, and then removed from the opposite plate, its electricity is always of the samo kind with that which originally existed in the substance, but its tension is so much increased as to render it more easily discoverable. This principle has been variously applied by different electricians, and the employment of the instrument has been facilitated by several subordinate arrangements.

Mr. Cavallo's multiplier is a combination of two condensers; the second or auxiliary plate of the first, like the plate of the electrophorus, is moveable, and carries a charge of electricity, contrary to that of the substance to be examined, to the first or insulated plate of the second condenser, which receives it repeatedly, until it has acquired an equal degree of tension; and when the two plates of this condenser are separated, they both exhibit an electricity much more powerful than that of the condenser. The force is, however, still more rapidly augmented by the instruments of Mr. Bennett and Mr. Nicholson; although it has been supposed that these instruments are more liable to inconvenience from the attachment of a greater portion of electricity to the first plate of the instrument, which leaves, ior a very considerable time, a certain quantity of the charge, not easily separable from it. Mr. Bennet employs three varnished plates laid on each other, but Mr. Nicholson has substituted simple metallic plates, approaching only very near together, so that there can be no error from any accidental friction. In both of these instruments, the second plate of a condenser acqnires an electricity contrary and very nearly equal to that of the first, by means of which it brings a third plate very nearly into the same state with the first; and when the first and third plates are connected and insulated, they produce a charge nearly twice as great in the second plate, while the first plate becomes at the same time doubly charged; so that by each repetition of this process, the intensity of the electricity is nearly doubled: it is therefore scarcely possible that any quantity should be so small as to escape detection by its operation.

The immediate intensity of the electricity may be measured, and its character distinguished, by electrical balances, and by electrometers of different constructions. The electrical balance measures the attraction or repulsion exerted by two balls at a given distance, by the magnitude of the force required to counteract it; and the most convenient manner of applying this force is by the torsion of a wire, which has been employed for the purpose by Mr. Coulomb. The quadrant electrometer of Henley expresses the mutual repulsion of a moveable ball and a fixed column, by the divisions of the arch to which the ball rises. These divisions do not exactly denote the proportional strength of the action, but they are still of utility in ascertaining the identity of any two charges, and in informing us how far we may venture to proceed in our experiments with safety; and the same purpose is answered, in a manner somewhat less accurate, by the electrometer, consisting of two pith balls, or of two straws, which are made to diverge by a smaller degree of electricity. Mr. Bennet's electrometer is still more delicate; it consists of two small portions of gold leaf, suspended from a plate, to which the electricity of any substance is communicated by contact: a very weak electricity is sufficient to make them diverge, and it may easily be ascertained whether it is positive or negative, by bringing an excited stick of sealing wax near the plate, since its approach tends to produce by induction a state of negative electricity in the remoter extremities of the leaves, so that their divergence is either increased or diminished, accordingly as it was derived from negative or from positive electricity: a strip of gold leaf or tin foil, fixed within the glass which covers the electrometer, opposite to the extremities of the leaves, prevents the communication of any electricity to the glass, which might interfere with the action of the instrument. When the balls of an electrometer stand at the distance of four degrees, they appear to indicate a charge nearly eight times as great as when they stand at one degree: a charge eight times as great in each ball, producing a mutual action sixty-four times as great at any given distance, and at a quadruple distance a quadruple force; in the same manner a separation of nine degrees is probably derived from an intensity twenty-seven times as great as at one. In Lane's electrometer the magnitude of a shock is determined by the quantity of air through, which it is obliged to pass between two balls, of which the distance may be varied at pleasure; and the power of the machine may be estimated by the frequency of the sparks which pass at any given distance. It appears from Mr. Lane's experiments, that the quantity of electricity required for a discharge is simply as the distance of the surfaces of the balls, the shocks being twice as frequent when this distance is only $\frac{1}{24}$ of an inch as when it is $\frac{1}{12}$. Mr. Volta says, that the indications of Lane's and Henley's electrometer agree immediately with each other; but it seems difficult to reconcile this result with the general theory. Sometimes the force of repulsion between two balls in contact is opposed by a counterpoise of given magnitude, and as soon as this is overcome, they separate and form a circuit which discharges a battery; whence the instrument is called a discharger.

It must be confessed that the whole science of electricity is yet in a very imperfect state: we know little or nothing of the intimate nature of the substances and actions concerned in it: and we can never foresee, without previous experiment, where or how it will be excited. We are wholly ignorant of the constitution of bodies, by which they become possessed of different conducting powers; and we have only been able to draw some general conclusions respecting the distribution and equilibrium of the supposed electric fluid, from the laws of the attractions and repulsions that it appears to exert. There seems to be some reason to suspect, from the phænomena of cohesion and repulsion, that the pressure of an elastic medium is concerned in the origin of these forces; and if such a medium really exists, it appears nearly related to the electric fluid. The identity of the general cause of electrical and galvanic effects is now doubted by few; and in this country the principal phænomena of galvanism are universally considered as depending on chemical changes; perhaps, also, time may shew, that electricity is very materially concerned in the essential properties, which distinguish the different kinds of natural bodies, as well as in those minute mechanical actions and affections which are probably the foundation of all chemical operations; but at present it is scarcely safe to hazard a conjecture on a subject so obscure, although Mr. Davy's experiments have already in some measure justified the boldness of the suggestion.

SECTION IV.

Galvanic, or Voltaic Electricity.

We have already hinted at some of the laws and principles of this peculiar mode of accumalating the electric fluid; for in most parts of Europe, and in our own country more especially, the fine etherial fluid thus produced, or rendered sensible, is regarded as of an electric nature. From the singularity and magnificence, however, of the effects which under this modification it is well known to be capable of evincing, it is necessary to enter a little more at large into the origin and progress of the discovery.

For the earliest insulated facts which paved the way to this science, we are indebted to Professor Galvani; for their explanation and application to purposes of real utility, we are indebted to Professor Volta: and for the grand and simple law of nature by which they operate in the production of effects, we are indebted to Sir Humphry Davy.

About the year 1790, professor Galvani of Bologna discovered accidentally, that the crural nerve of a frog cut up for soup for his wife's dinner, contracted and became convulsed upon the application of a knife wetted with water; as the story is told by other writers, he perceived whilst he was one day dissecting a frog, in a room where some of his friends were amusing themselves with electrical experiments, that the body of the animal was shaken with a violent convulsion, in consequence of a spark being drawn from the conductor of the machine at the time he was touching one of its nerves. Astonished at the phenomenon, and at first imagining that it might be owing to his having wounded the nerve, he pricked it with the point of his knife, to assure himself whether or not this was the case, but no motion of the frog's body was produced. He now touched the nerve with the instrument as at first, and directed a spark to be taken at the same time from the machine, on which the contractions were renewed. Upon a third trial, the animal remained motionless; but observing that he held his knife by the handle, which was made of ivory, he changed it for a metallic one, and immediately the movements took place, which never was the case when he used an electric substance.

After having made a great many similar experiments with the electrical machine, he resolved to prosecute the subject with atmospheric electricity. With this view he raised a conductor on the roof of his house, from which he brought an iron wire into his room. To this he attached metal conductors, connected with the nerves of the animals destined to be the subject of his experiments; and to their legs he fastened wires which reached the floor. These experiments were not confined to frogs alone. Different animals, both of cold and warm blood, were subjected to them; and in all of them considerable movements were excited whenever it lightened. These preceded thunder, and corresponded with its intensity and repetition; and even when no lightning appeared, the movements took place when any stormy cloud passed over the apparatus. That all these appearances were produced by the electric fluid was obvious.

Having soon after this suspended some frogs from the iron palisades which surrounded his garden, by means of metallic hooks fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily, as if from a shock of electricity. Not doubting that the contractions depended on the electric fluid, he at first suspected that they were connected with changes in the state of the atmosphere. He soon found, however, that this was not the case; and having varied, in many different ways, the circumstances in which the frogs were placed, he at length discovered that he could produce the movements at pleasure by touching the animals with two different metals, which at the same time, touched one another either immediately or by the intervention of some other substance capable of conducting electricity.

All the experiments that have been made may be reduced to the following, which will give the otherwise uninformed reader a precise notion of the subject.

Lay bare about an inch of a great nerve, leading to any limb or muscle. Let that end of the bared part which is farthest from the limb be in close contact with a bit of zinc. Touch the zinc with a bit of silver, while another part of the silver touches, either the naked nerve, if not dry, or, whether it be dry or not, the limb or muscle to which it leads. Violent contractions are produced in the limb or muscle, but not in any muscle on the other side of the zinc.

Or, touch the bared nerve with a piece of zinc, and touch, with a piece of silver, either the bared nerve, or the limb; no convulsion is observed, till the zinc and silver are also made to touch each other.

A fact so new, illustrated with so many experiments and much ingenious reasoning, which professor Galvani soon published, could not fail to attract the attention of physiologists all over Europe; and the result of a vast number of experiments, equally cruel and surprising, has been from time to time laid before the public by Valli, Fowler, Monro, Volta, Humbolt, and others.

Frogs, unhappily for themselves, have been found the most convenient subjects for these experiments, as they retain their muscular irritability and susceptibility of the galvanic influence very long. Many hours after they have been decapitated, or have had their brain and spinal marrow destroyed, strong convulsions can be produced in them by the application of the metals. A leg separated from the body will often continue capable of excitement for several days. Nay, very distinct movements have been produced in frogs pretty far advanced in the process of putrefaction. Different kinds of fishes, and many other animals, both of cold and warm blood, have been subjected to similar experiments, and have exhibited the same phænomena; but the warm blooded animals lose their susceptibility of galvanism, as of every other stimulus, very soon after death.

Almost any two metals will produce the movements; but, it is believed, the most powerful are the following, in the order which they are here placed: 1. Zinc; 2. Tin; 3. Lead; in conjunction with 1. Gold: 2. Silver; 3. Molybdena; 4. Steel; 5. Copper. Upon this point, however, authors are not perfectly agreed.

The process by which these singular phænomena are produced consists in effecting, by the use of the exciting apparatus, a mutual communication between any two points of contact, more or less distant from one another, in a system of nervous and muscular organs. The sphere of this mutual communication may be regarded as a complete circle, divided into two parts. That part of it which consists of the organs of the animal under the experiment has been called the animal arc; that which is formed by the galvanic instruments has been called the excitatory arc. The latter usually consists of more pieces than one; of which some are named stays, braces, &c. others communicators, from their respective uses.

Besides the effects thus produced on the muscles, the impressions made on the organs of sense are equally remarkable. And as the experiments illustrating them may be easily repeated, we shall specify some of the most interesting. For instance, if a thin plate of zinc be placed on the upper surface of the tongue, and both metals after a short space of time be brought into contact, a peculiar sensation, or taste, will be perceived at the moment when the mutual touch happens. If the silver be put beneath, and the zinc upon the tongue, the same sensation will arise, but in a weaker degree, resembling diluted ammoniac, from which it in all probability derives its origin.

If a silver probe be introduced as far as convenient into one of the nostrils, and then be brought into contact with a piece of zinc placed on the tongue, a sensation not unlike a strong flash of light will be produced in the corresponding eye, at the instant of contact. A similar perception will result, both at the moment of contact and that of separation, if one of the metals be applied as high as possible between the gums and upper lip, and the other in a similar situation with the under lip, or even under the tongue. Lastly, when a probe or rod of zinc, and another of silver, are introduced as far back as possible into the roof of the mouth, the irritations produced by bringing the external ends into contact, are very powerful; and that caused by the zinc is similar in taste to the sensation arising from its application to the tongue.

No method has hitherto been discovered of applying the galvanic influence in such a manner as to affect the senses of smell, hearing, and touch; though several eminent philosophers have carefully investigated the subject. Nor are the causes of these phænomena clearly ascertained; Galvani and many of his followers supposing them to depend on the electric fluid, while others attribute them to the influence of various physical agents.

Mr. Creeve, surgeon in Wurtzburg, had an opportunity of observing the irritation on the leg of a boy, which had been amputated far above the knee in the hospital of that city. Immediately after the amputation, Mr. Creeve laid bare the crural nerve (kiekehlnerven), and surrounded it with a slip of tinfoil. He touched at once the tinfoil and the nerve with a French crown-piece. In that instant the most violent convulsions took place in the leg both above and below the knee. The remainder of the thigh bone bent with force toward the calf; the foot was more bent than extended. All these motions were made with much force and rapidity. None were produced when the tinfoil was taken away, or when a steel pincer was used in place of a piece of silver, or when the tin or silver was covered with blood; but they were renewed when these obstacles were removed. These phænomena continued till 38 minutes after the amputation, when the limb became cold.

The principle, however, upon which the electric power acted was misunderstood; nor were any means as yet devised by which the new power could be accumulated to any definite extent, or made applicable to any useful purposes.

Galvani explained the phenomenon by conceiving the muscles to resemble a charged Leyden phial, having electricity accumulated in the inside, while the outside was minus. The nerves he conceived to be connected with the inside: when it was united with the outside by conductors, the surplus electricity was discharged, and hence the motions of the limb.

M. Volta, professor of natural philosophy at Como in the Milanese, soon discovered, however, that the convulsions were produced by a different operation of the electric principle; in reality by merely touching two different parts of the same nerve by two different metals, and thus making a circuit of the three substances, of which the part of the nerve selected for the purpose formed the middle: and pursuing this simple but beautiful law, he soon afterwards perceived that the two distinct metals alone had an action upon each other when brought into contact, but that the action was considerably increased by the interposition of a third substance of a different nature. The hypothesis of Galvani was hereby completely destroyed, and a foundation laid for that wonderful electric column which has been called the galvanic, or more correctly the voltaic pile, which, by the simple means of multiplying plates of two different kinds of metal, with an interposition of a plate of some other substance between each, produces such an accumulation of electric power; and, when the force of the opposite ends is brought into approximation by means of a flexible wire, or other conductor, attached to each end, such an exertion of this power as to become one of the most, if not altogether the most energic agents in chemistry. And we now advance to the second and most important stage of this new branch of natural science; for which the world is entirely indebted to the penetrating genius of M. Volta, and the curious facts and phænomena of which have hence been universally denominated voltaism.

M. Volta commenced his experiments in 1793, and it was seven years before he rendered his pile sufficiently satisfactory and perfect to usher its description and powers before the public. This, however, he accomplished in 1800; at which time he communicated a particular account of it to the Royal Society, through the medium of Sir Joseph Banks, who published this valuable paper in the latter part of their Transactions for that year. His apparatus, as there described, consists of a number of copper or silver plates (which last are preferable), together with an equal number of plates composed of tin, or still better of zinc, and a similar number of pieces of card, leather, or woollen cloth, the last of which substances appears to be the most suitable. These last should be well soaked in water saturated with common salt, muriat of ammonia, or more effectually with nitre. The silver or copper may be pieces of money, and the plates of zinc may be cast of the same size. A pile is then to be formed, by placing a piece of silver on a corresponding one of zinc, and on them a piece of wet cloth or card: which is to be repeated alternately, till the number required be arranged in regular succession. But, as the pieces are apt to tumble down, if their numbers be considerable, unless properly secured, it will be advisable to support them by means of three rods of glass, or baked wood, fixed into a flat wooden pedestal, and touching the pieces of metal at three equi-distant points. Upon these rods may be made to slide a small circular piece of wood, perforated with three holes, which will serve to keep the top of the pile firm, and the different layers in close contact. The moistened pieces should likewise be somewhat smaller than those of metal, and gently squeezed before they are applied, to prevent the superfluous moisture from insinuating itself between the pieces of metal. Thus constructed, the apparatus will afford a perpetual current of the electric fluid, or voltaic influence, through any conductor that communicates between the uppermost and lowest plate; and, if one hand be applied to the latter, and the other to the highest metal, a shock will be perceived, which may be repeated as often as the contact is renewed. This shock greatly resembles that given by the torpedo, or gymnotus electricus: and, according to the larger size of the metallic plates, the shock will be proportionably stronger. The intensity of the charge, however, is so slow, that it cannot penetrate the skin; it will therefore be necessary to wet both hands, and to grasp a piece of metal in each, in order to produce the desired effect: its power may be considerably increased, both by an elevation of temperature, and by augmenting the number of pieces that compose the pile. Thus, 20 pieces of each will emit a shock, that is very perceptible in the arms; if 100 be employed, a very severe but tremulous and continued sensation will extend even to the shoulders; and, if the surface of the skin be broken, the action of the voltaic influence will be uncommonly painful.

The sensation of a flash, or shock with this apparatus, does not materially differ from that produced by two simple plates, but it may be effected in various ways, especially if one or both hands be applied in a wet state to the lowest plate of the pile; or any part of the face be brought in contact with a wire communicating with the top piece. Further, if a wire be held between the teeth, so as to rest upon the tongue, that organ, as well as the lips, will become convulsed, the flash will appear before the eye, and a very pungent taste will be perceived in the mouth.

When a metallic wire, having a bit of well-burnt charcoal at its extremity, is made to connect the two extremities of the pile, a spark will be perceived, or the point of the charcoal will become ignited.

Various other modes of constructing this apparatus have been adopted, some of which are much superior in point of convenience. One mode is by soldering the plates of zinc and copper together, and by cementing them into troughs of baked wood, covered with cement in the regular order, so as to form cells to be filled with the fluid menstruum, each surface of zinc being opposite to a surface of copper; and this combination is very simple and easy of application. Another form is that of introducing plates of copper and zinc, fastened together by a slip of copper, into a trough of porcelain, containing a number of cells corresponding to the number of the series. The different series may be introduced separately into the troughs and taken out without the necessity of changing the fluid; or they may be attached to a piece of baked wood (and when the number is not very large) introduced into the cells, or taken out together.

Similar polar electrical arrangements to those formed by zinc and copper may be made by various alterations of conducting and imperfect conducting substances: but for the accumulation of the power, the series must consist of three substances or more, and one, at least, must be a conductor. Silver or copper when brought in contact with a solution of a compound of sulphur and potash, at one extremity, and in contact with water or a solution of nitre acid at the other extremity, some saline solution being between the sulphuretted and the acid solutions, forms an element of a powerful combination, which will give shocks when fifty are put together. The other is copper, cloth of the same size moistened with solution moistened in the solution of the compound of sulphur copper, and so on: the specific gravities of the solutions should be in the order in which they are arranged, to prevent the mixture of the acid and sulphuretted solution; that is, the heaviest solution should be placed lowest.

For these and various other progressive discoveries we are chiefly indebted to Sir Humphry Davy; as we are altogether for the great discovery respecting the agency of voltaism, which was published in the Philosophical Transactions, in a paper which gained the prize proposed on voltaism by the French Emperor. This discovery may be expressed in the following sentence: "The voltaic energy has the property of decomposing all compound substances (supposing the battery sufficiently powerful) when the constituents range themselves round the wires, passing from the two extremities of the battery, according to the following law: oxygen and acids arrange themselves round the positive wire; hydrogen, alkalies, earths, and metals, round the negative wire." From this very important discovery Sir Humphry drew several very plausible inferences. Oxygen and acids, since they are attracted towards the positive wire, are naturally negative; while, on the other hand, hydrogen, alkalies, and metals, being attracted to the negative wire, are naturally positive. When two substances are chemically combined, they are in different states of electricity; and the more completely opposite these states, the more intimately they are united. To separate the two constituents of bodies from each other, we have only to bring them to the same electrical state; and this is the effect which voltaism produces. Hence, chemical affinity is nothing else than the attraction which exists between bodies in different states of electricity. The decomposition of the fixed alkalies, of the alkaline earths and boracic acid, soon after discovered by the same celebrated chemist, was the natural consequence of his original discovery. These, though very striking and important, are not to be compared, in point of value, to his original discovery of the decomposing power of voltaism, which has made us acquainted with a new energy in nature, and put into our possession a much more efficient chemical agent than any with which we were before acquained. This is the discovery which does so much honour to Sir Humphry Davy, and has put him on a level with the small number of individuals who have been fortunate enough to lay open to the world a new law of nature.

It has been doubted by many persons, whether the voltaic and electrical energy were the same: but thousands of experiments might be offered to prove them to be such. M. de Luc's very simple aerial electroscope, or electrical column, as he calls it, may be adverted to, as sufficient of itself to establish this fact. This column consists of zinc-plates and Dutch gilt-paper, in regular succession, like the metallic plates of the voltaic pile, the groups being from one thousand to ten thousand. When two of these columns are placed horizontally, the one insulated, and the other communicating with the ground, each being terminated with a small bell, and a small brass ball is suspended between the two bells by a silken thread, the ball, by the mere influence of the electricity contained in the atmosphere, will chime, by striking alternately from column to column, and consequently from bell to bell, sometimes more or less rapidly, and sometimes more or less loudly, and sometimes scarcely at all, according to the state and proportion of the electric aura; and the instrument, which is a genuine voltaic pile, not only proves the identity of the electric and voltaic power, but may be conveniently employed as a measurer of the electricity which the atmosphere contains. It should he observed, however, that as there are no fluids known, except such as contain water, that are capable of being made the medium of connexion between the metals, or metal of the voltaic apparatus, the effect in this, and in all similar instances, is resolved by Sir Humphry Davy into some small quantity of moisture, or water still existing in the substances employed, which he asserts will not act if each of the substances be made perfectly dry.

The first distinct experiment upon the igniting powers of large voltaic plates was performed by MM. Fourcroy, Vauquelin, and Thenard; but a much grander combination for exhibiting the effects of extensive surface was constructed by Mr. Children, and consists of a battery of twenty double plates four feet by two; of which the whole surfaces are exposed, in a wooden trough, in cells covered with cement, to the action of diluted acids.

The most powerful combination, however, that exists, in which numbers of alternations is combined with the extent of surface, is that constructed by subscriptions of a few zealous cultivators and patrons of science, in the laboratory of the Royal Institution. It consists of two hundred instruments, connected together in regular order, each composed of ten double plates, arranged in cells of porcelain, and containing in each plate thirty-two square inches; so that the whole number of double plates is 2000, and the whole surface 128,000 square inches. This battery when the cells were filled with sixty parts of water mixed with one part of nitric acid, and one part of the sulphuric acid, afforded a series of brilliant and impressive effects. When pieces of charcoal about an inch long and one-sixth of an inch in diameter were brought near each other (within the thirtieth part or fortieth part of an inch), a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and by withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form in the middle. When any substance was introduced into this arch it instantly became ignited; platina melted as readily in it as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion; fragments of diamond, and points of charcoal and plumbago, rapidly disappeared, and seemed to evaporate in it, even when the connexion was made in a receiver exhausted by the air-pump; but there was no evidence of their having previously undergone fusion.

When the communication between the points positively and negatively electrified was made in air, rarefied in the receiver of the air-pump, the distance at which the discharge took place increased as the exhaustion was made; and when the atmosphere in the vessel supported only one-fourth of an inch of mercury in the barometrical gage, the sparks passed through a space of nearly half an inch; and by withdrawing the points from each other, the discharge was made through six or seven inches, producing a most beautiful coruscation of purple light, the charcoal became intensely ignited, and some platina wire attached to it fused with brilliant scintillations, and fell in large globules upon the plate of the pump. All the phænomena of chemical changes were produced with intense rapidity by this combination. When the points of charcoal were brought near each other in nonconducting fluids, such as oils, ether, and oxymuriate compounds, brilliant sparks occurred, and elastic matter was rapidly generated: and such was the intensity of the electricity, that sparks were produced, even in good imperfect conductors, such as the nitric and sulphuric acids.

[*Editor. Pantologia.*

CHAP. III.

MAGNETISM.

THE theory of magetism bears a very strong resemblance to that of electricity, and it must therefore be placed near it in a system of natural philosophy. We have seen the electric fluid not only exerting attractions and repulsions, and causing a peculiar distribution of neighbouring portions of a fluid similar to itself, but also excited in one body, and transferred to another, in such a manner as to be perceptible to the senses, or at least to cause sensible effects, in its passage. The attraction and repulsion, and the peculiar distribution of the neighbouring fluid, are found in the phænomena of magnetism; but we do not perceive that there is any actual excitation, or any perceptible transfer of the magnetic fluid from one body to another distinct body; and it has also this striking peculiarity, that, metallic iron is very nearly, if not absolutely, the only substance capable of exhibiting any indicatious of its presence or activity.

For explaining the phænomena of magnetism, we suppose the particles of a peculiar fluid to repel each other, and to attract the particles of metallic iron with equal forces, diminishing as the square of the distance increases; and the particles of such iron must also be imagined to repel each other, in a similar manner. Iron and steel, when soft, are conductors of the magnetic fluid, and become less and less pervious to it as their hardness increases. The ground work of this theory is due to Mr. Aepinus, but the forces have been more particularly investigated by Coulomb, and others. There are the same objections to these hypotheses as to those which constitute the theory of electricity, if considered as original and fundamental properties of matter: and it is additionally difficult to imagine, why iron, and iron only, whether apparently magnetic or not, should repel similar particles of iron with a peculiar force, which happens to be precisely a balance to the attraction of the magnetic fluid for iron. This is obviously improbable; but the hypotheses are still of great utility in assisting us to generalise, and to retain in memory a number of particular facts which would otherwise be insulated. The doctrine of the circulation of streams of the magnetic fluid has been justly and universally abandoned; and some other theories, much more ingenious, and more probable, for instance that of Mr.

Prévost, appear to be too complicated, and too little supported by facts, to require much of our attention.

The distinction between conductors and nonconductors is, with respect to the electric fluid, irregular and intricate; but in magnetism, the softness or hardness of the iron or steel constitutes the only difference. Heat, as softening iron, must consequently render it a conductor; even the heat of boiling water affects it, in a certain degree, although it can scarcely be supposed to alter its temper; but the effect of a moderate heat is not so considerable in magnetism as in electricity. A strong degree of heat appears, from the experiments of Gilbert, and of Mr. Cavallo, to destroy completely all magnetic action.

It is perfectly certain that magnetic effects are produced by quantities of iron incapable of being detected either by their weight or by any chemical tests. Mr. Cavallo found that a few particles of steel, adhering to a hone, on which the point of a needle was slightly rubbed, imparted to it magnetic properties; and Mr. Coulomb has observed, that there are scarcely any bodies in nature which do not exhibit some marks of being subjected to the influence of magnetism, although its force is always proportional to the quantity of iron which they contain, as far as that quantity can be ascertained; a single grain being sufficient to make 20 pounds of another metal sensibly magnetic. A combination, with a large proportion of oxygen, deprives iron of the whole or the greater part of its magnetic properties; finery cinder is still considerably magnetic, but the more perfect oxids and the salts of iron only in a slight degree; it is also said that antimony renders iron incapable of being attracted by the magnet. Nickel, when freed from arsenic and from cobalt, is decidedly magnetic, and the more so as it contains less iron. Some of the older chemists supposed nickel to be a compound metal containing iron; and we may still venture to assume this opinion as a magnetical hypothesis. There is indeed no way of demonstrating that it is impossible for two substances to be so united as to be incapable of separation by the art of the chemist; had nickel been as dense as platina, or as light as cork, we could not have supposed that it contained any considerable quantity of iron, but in fact the specific gravity of these metals is very nearly the same, and nickel is never found in nature but in the neighbourhood of iron; we may therefore suspect, with some reason, that the hypothesis of the existence of iron in nickel may be even chemically true. The aurora borealis is certainly in some measure a magnetical phenomenon, and if iron were the only substance capable of exhibiting magnetical effects, it would follow that some ferruginous particles must exist in the upper regions of the atmosphere. The light usually attending this magnetical meteor may possibly be derived from electricity, which may be the immediate cause of a change of the distribution of the magnetic fluid, contained in the ferruginous vapours, that are imagined to float in the air.

We are still less capable of distinguishing with certainty in magnetism, than in electricity, a positive from a negative state, or a real redundancy of the fluid from a deficiency. The north pole of a magnet may be considered as the part in which the magnetic fluid is either redundant or deficient, provided that the south pole be understood in a contrary sense: thus, if the north pole of a magnet be supposed to be positively charged, the south pole must be imagined to be negative; and in hard iron or steel these poles may be considered as unchangeable.

A north pole, therefore, always repels a north pole, and attracts a south pole. And in a neutral piece of soft iron, near to the north pole of a magnet, the fluid becomes so distributed, by induction, as to form a temporary south pole next to the magnet, and the whole piece is of course attracted, from the great proximity of the attracting pole. If the bar is sufficiently soft, and not too long, the remoter end becomes a north pole, and the whole bar a perfect temporary magnet. But when the bar is of hard steel, the state of induction is imperfect, from the resistance opposed to the motion of the fluid; hence the attraction is less powerful, and an opposite pole is formed, at a certain distance, within the bar; and beyond this another pole, similar to the first; the alternation being sometimes repeated more than once. The distribution of the fluid within the magnet is also affected by the neighbourhood of a piece of soft iron, the north pole becoming more powerful by the vicinity of the new south pole, and the south pole being consequently strengthened in a certain degree; so that the attractive power of the whole magnet is increased by the proximity of the iron. A weak magnet is capable of receiving a temporary induction of a contrary magnetism, from the action of a more powerful one, its north pole becoming a south pole on the approach of a stronger north pole; but the original south pole still retains its situation at the opposite end, and restores the magnet nearly to its original condition, after the removal of the disturbing cause.

The polarity of magnets, or their disposition to assume a certain direction, is of still greater importance than their attractive power. If a small magnet, or simply a soft wire, be poised on a centre, it will arrange itself in such a direction, as will produce an equilibrium of the attractions and repulsions of the poles of a larger magnet; being a tangent to a certain oval figure, passing through those poles, of which the properties have been calculated by various mathematicians. This polarity may easily be imitated by electricity; a suspended wire being brought near to the ends of a positive and negative conductor, which are placed parallel to each other, as in Nairne's electrical machine, its position is perfectly similar to that of a needle attracted by a magnet, of which those conductors represent the poles.

The same effect is observable in iron filings placed near a magnet, and they adhere to each other in curved lines, by virtue of their induced magnetism, the north pole of each particle being attached to the south pole of the particle next it. This arrangement may be seen by placing the filings either on clean mercury, or on any surface that can be agitated; and it may be imitated by strewing powder on a plate of glass, supported by two balls, which are contrarily electrified.

The polarity of a needle may often be observed when it exhibits no sensible attraction or repulsion as a whole; and this may easily be understood by considering that when one end of a needle is repelled from a given point, and the other is attracted towards it, the two forces, if equal, will tend to turn it round its centre, but will wholly destroy each other's effects with respect to any progressive motion of the whole needle. Thus, when the end of a magnet is placed under a surface on which iron filings are spread, and the surface is shaken, so as to leave the particles for a moment in the air, they are not drawn sensibly towards the magnet, but their ends, which are nearest to the point over the magnet, are turned a little downwards, so that they strike the paper further and further from the magnet, and then fall outwards, as if they were repelled by it.

The magnets, which we have hitherto considered, are such as have a simple and well determined form; but the great compound magnet, which directs the mariner's compass, and which appears to consist principally of the metallic and slightly oxidated iron, contained in the internal parts of the earth, is probably of a far more intricate structure, and we can only judge of its nature from the various phænomena derived from its influence.

The accumulation and the deficiency of the magnetic fluid, which determine the place of the poles of this magnet, are probably in fact considerably diffused, but they may generally be imagined, without much error in the result, to centre in two points, one of them nearer to the north pole of the earth, the other to the south pole. In consequence of their attractions and repulsions, a needle, whether previously magnetic or not, assumes always, if freely poised, the direction necessary for its equilibrium; which, in various parts of the globe, is variously inclined to the meridian and to the horizon. Hence arises the use of the compass in navigation, and in surveying: a needle, which is poised with a liberty of horizontal motion, assuming the direction of the magnetic meridian, which for a certain time remains almost invariable for the same place; and a similar property is also observable in the dipping needle, which is moveable only in a vertical plane; for when this plane is placed in the magnetic meridian, the needle acquires an inclination to the horizon, which varies according to the situation of the place with respect to the magnetic poles.

The natural polarity of the needle may be in some measure illustrated by inclosing an artificial magnet in a globe; the direction of a small needle, suspended over any part of its surface, being determined by the position of the poles of the magnet, in the same manner as the direction of the compass is determined by the magnetical poles of the earth, although with much more regularity. In either case the whole needle is scarcely more or less attracted towards the globe than if the influence of magnetism were removed; except when the small needle is placed very near to one of the poles of the artificial magnet, or, on the other hand, when the dipping needle is employed in the neighbourhood of some strata of ferruginous substances, which, in particular parts of the earth, interfere materially with the more general effects, and alter the direction of the magnetic meridian.

A bar of soft iron, placed in the situation of the dipping needle, acquires from the earth, by induction, a temporary state of magnetism, which may be reversed at pleasure by reversing its direction; but bars of iron which have remained long in or near this direction, assume a permanent polarity; for iron, even when it has been at first quite soft, becomes in time a little harder. A natural magnet is no more than a heavy iron ore, which, in the course of ages, has acquired a strong polarity, from the great primitive magnet. It must have lain in some degree detached, and must possess but little conducting power, in order to have received and to retain its magnetism.

We cannot, from any assumed situation of two or more magnetic poles, calculate the true position of the needle for all places; and even in the same place, its direction is observed to change in the course of years, according to a law which has never yet been generally determined, although the variation which has been observed, at any one place, since the discovery of the compass, may perhaps be comprehended in some very intricate expressions; but the less dependence can be placed on any calculations of this kind, as there is reason to think that the change depends rather on chemical than on physical causes. Dr. Halley indeed conjectured that the earth contained a nucleus, or separate sphere, revolving freely within it, or rather floating in a fluid contained in the intermediate space, and causing the variation of the magnetic meridian; and others have attributed the effect to the motions of the celestial bodies: but in either case the changes produced would have been much more regular and universal than those which have been actually observed. Temporary changes of the terrestrial magnetism have certainly been sometimes occasioned by other causes; such causes are, therefore, most likely to be concerned in the more permanent effects. Thus, the eruption of Mount Hecla was found to derange the position of the needle considerably; the aurora borealis have been observed to cause its north pole to move six or seven degrees to the westward of its usual position; and a still more remarkable change occurs continually in the diurnal variation. In these climates the north pole of the needle moves slowly westwards from about eight in the morning till two, and in the evening returns again; a change which has with great probability been attributed to the temporary elevation of the temperature of the earth, eastwards of the place of observation, where the sun's action takes place at an earlier hour in the morning, and to the diminution of the magnetic attraction in consequence of the heat thus communicated. In winter this variation amounts to about seven minutes, in summer to thirteen or fourteen.

Important as the use of the compass is at present to navigation, it would be still more valuable if its declination from the true meridian were constant for the same place, or even if it varied according to any discoverable law: since it would afford a ready mode of determining the longitude of a place by a comparison of an astronomical observation of its latitude with another of the magnitude of the declination. And in some cases it may even now be applied to this purpose, where we have a collection of late and numerous observations. Such observations have from time to time been arranged in charts, furnished with lines indicating the magnitude of the declination or variation at the places through which they pass, beginning from the line of no variation, and proceeding on the opposite sides of this line to show the magnitude of the variation east or west. It is obvious that the intersection of a given parallel of latitude, with the line showing the magnitude of the variation, will indicate the precise situation of the place at which the observations have been made.

The line of no variation passed in 1675 through London, and in 1666 through Paris: its northern extremity appears to have moved continually eastwards, and its southern parts westwards; and it now passes through the middle of Asia. The opposite portion seems to have moved more uniformly westwards; it now runs from North America to the middle of the South Atlantic. On the European side of these lines, the declination is westerly; on the South American side, it is easterly. The variation in London has been for several years a little more than 24°. In the West Indies it changes but slowly; for instance it was 5° near the island of Barbadoes, from 1700 to 1756.

The dip of the north pole of the needle in the neighbourhood of London is 72°. Hence the lower end of a bar standing upright, as a poker, or a lamp-iron, becomes always a north pole, and a temporary south pole of a piece of soft iron being uppermost, it is somewhat more strongly attracted by the north pole of a magnet placed over it, than by its south pole; the distribution of the fluid in the magnet itself being also a little more favourable to the attraction, while its north pole is downwards. It is obvious that the magnetism of the northern magnetic pole of the earth must resemble that of the south pole of a magnet, since it attracts the north pole; so that if we considered the nature of the distribution of the fluid rather than its situation in the earth, we should call it a south pole. Although it is impossible to find any places for two, or even for a greater number of magnetic poles, which will correctly explain the direction of the needle in every part of the earth's surface, yet the dip may be determined with tolerable accuracy, from the supposition of a small magnet placed at the centre of the earth, and directed towards a point in Baffin's Bay, about 75° north latitude, and 70° longitude west of London; and the variation of the dip is so inconsiderable, that a very slow change of the position of this supposed magnet would probably be sufficient to produce it; but the operation of such a magnet, according to the general laws of the forces concerned, could not possibly account for the very irregular disposition of the curves indicating the degree of variation or declination; a general idea of these might perhaps be obtained from the supposition of two magnetic poles situated in a line considerably distant from the centre of the earth; but this hypothesis is by no means sufficiently accurate to allow us to place any dependence on it.

The art of making magnets consists in a proper application of the attractions and repulsions of the magnetic fluid, by means of the different conducting powers of different kinds of iron and steel, to the production and preservation of such a distribution of the fluid in a magnet, as is the best fitted to the exhibition of its peculiar properties.

We may begin with any bar of iron that has long stood in a vertical position; but it is more common to employ an artificial magnet of greater strength. When one pole of such a magnet touches the end of a bar of hard iron or steel; that end assumes in some degree the opposite character, and the opposite end the same character: but in drawing the pole along the bar, the first end becomes neutral, and afterwards has the opposite polarity; while the second end has its force at first a little increased, then becomes neutral, and afterwards is opposite to what it first was. When the operation is repeated, the effect is at first in some measure destroyed, and it is difficult to understand why the repetition adds materially to the inequality of the distribution of the fluid; but the fact is certain, and the strength of the new magnet is for some time increased at each stroke, until it has acquired all that it is capable of receiving. Several magnets, made in this manner, may be placed side by side, and each of them being nearly equal in strength to the first, the whole collection will produce together a much stronger effect; and in this manner we may obtain from a weak magnet others continually stronger, until we arrive at the greatest degree of polarity of which the metal is capable. It is, however, more usual to employ the process called the double touch: placing two magnets, with their opposite poles near to each other, or the opposite poles of a single magnet, bent into the form of a horse-shoe, in contact with the middle of the bar: the opposite actions of these two poles then conspire in their effort to displace the magnetic fluid, and the magnets having been drawn backwards and forwards repeatedly, an equal number of times to and from each end of the bar, with a considerable pressure, they are at last withdrawn in the middle, in order to keep the poles at equal distances.

Iron filings, or the scoriæ from a smith's forge, when finely levigated, and formed into a paste with linseed oil, are also capable of being made collectively magnetic. A bar of steel, placed red-hot between two magnets, and suddenly quenched by cold water, becomes in some degree magnetic, but not so powerfully as it may be rendered by other means. For preserving magnets, it is usual to place their poles in contact with the opposite poles of other magnets, or with pieces of soft iron, which, in consequence of their own induced magnetism, tend to favour the accumulation of the magnetic power in a greater quantity than the metal can retain after they are removed. Hence the ancients imagined that the magnet fed on iron.

A single magnet may be made of two bars of steel, with their ends pressed into close contact; and it might be expected that when these bars are separated, or when a common magnet has been divided in the middle, the portions should possess the properties of the respective poles only. But in fact the ends which have been in contact are found to acquire the properties of the poles opposite to those of their respective pieces, and a certain point in each piece is neutral, which is at first nearer to the newly formed pole than to the other end, but is removed by degrees to a more central situation. In this case we must suppose, contrarily to the general principles of the theory, that the magnetic fluid has actually escaped by degrees from one of the pieces, and has been received from the atmosphere by the other.

There is no reason to imagine any immediate connexion between magnetism and electricity, except that electricity affects the conducting powers of iron or steel for magnetism, in the same manner as heat or agitation. In some cases a blow, an increase of temperature, or a shock of electricity, may expedite a little the acquisition of polarity; but more commonly any one of these causes impairs the magnetic power. Professor Robinson found, that when a good magnet was struck for three quarters of an hour, and allowed in the mean time to ring, its efficacy was destroyed; although the same operation had little effect when the ringing was impeded; so that the continued exertion of the cohesive and repulsive powers appears to favour the transmission of the magnetic as well as of the electric fluid. The internal agitation, produced in bending a magnetic wire round a cylinder, also destroys its polarity, and the operation of a file has the same effect. Mr. Cavallo has found that brass becomes in general much more capable of being attracted when it has been hammered, even between two flints; and that this property is again diminished by fire: in this case it may be conjectured that hammering increases the conducting power of the iron contained in the brass, and thus renders it more susceptible of magnetic action. Mr. Cavallo also observed that a magnetic needle was more powerfully attracted by iron filings during their solution in acids, especially in the sulphuric acid, than either before or after the operation: others have not always succeeded in the experiment; but there is nothing improbable in the circumstance, and there may have been some actual difference in the results, dependent on causes too minute for observation. In subjects so little understood as the theory of magnetism, we are obliged to admit some paradoxical propositions, which are only surprising on account of the imperfect state of our knowledge. Yet, little as we can understand the intimate nature of magnetical actions, they exhibit to us a number of extremely amusing, as well as interesting, phænomena; and the principles of crystallization, and even of vital growth and reproduction, are no where so closely imitated, as in the arrangement of the small particles of iron in the neighbourhood of a magnet, and in the production of a multitude of complete magnets, from the influence of a parent of the same kind.

[*Young's Natural Philosophy.*

CHAP. IV.

AËROSTATION, INCLUDING THE PRINCIPLES, HISTORY, AND MANAGEMENT OF BALLOONS.

SECTION I.

Principles of Aërostation.

THE fundamental principles of this art have been long and generally known, as well as the speculations on the theory of it; but the successful application of them to practice seems to be altogether a modern discovery. These principles chiefly respect the weight or pressure, and elasticity of the air, with its specific gravity, and that of the other bodies to be raised or floated in it; the particular detail of which principles, however, we have not space to enlarge upon. Suffice it therefore, for the present, to observe, that any body which is specifically, or bulk for bulk, lighter than the atmosphere, or air encompassing the earth, will be buoyed up by it, and ascend, like as wood, or a cork, or a blown bladder, ascends in water. And thus the body would continue to ascend to the top of the atmosphere, if the air were every where of the same density as at the surface of the earth. But as the air is compressible and elastic, its density decreases continually in ascending, on account of the diminished pressure of the superincumbent air, at the higher elevations above the earth; and therefore the body will ascend only to such a height where the air is of the same specific gravity with itself; where the body will float, and move along with the wind or current of air, which it may meet with at that height. This body then is an aërostatic machine, of whatever form or nature it may be. And an air-balloon is a body of this kind, the whole mass of which, including its covering and contents, and the weights annexed to it, is of less weight than the same bulk of air in which it rises. We know of no solid bodies, however, that are light enough thus to ascend and float in the atmosphere; and therefore recourse must be had to some fluid or aeriform substance. Among these, that which is called inflammable air, the hydrogen gas of the new nomenclature, is the most proper of any that have hitherto been discovered. It is very elastic, and from six to ten or eleven times lighter than common air; and consequently this compound mass will rise in the atmosphere, and continue to ascend till it attain a height at which the atmosphere is of the same specific gravity as itself; where it will remain or float with the current of air, as long as the inflammable air does not escape through the pores of its covering. And this is an inflammable air-balloon. Another way is to make use of common air, rendered lighter by warming it, instead of the inflammable air. Heat, it is well known, rarefies and expands common air, and consequently lessens its specific gravity; and the diminution of its weight is proportional to the heat applied. If therefore the air, inclosed in any kind of a bag or covering, be heated, and consequently dilated, to such a degree, that the excess of the weight of an equal bulk of common air, above the weight of the heated air, be greater than the weight of the covering and its appendages, the whole compound mass will ascend in the atmosphere, till, by the diminished density of the surrounding air, the whole becomes of the same specific gravity with the air in which it floats; where it will remain, till, by the cooling and condensation of the included air, it shall gradually contract and descend again, unless the heat is renewed or kept up. And such is a heated air-balloon, otherwise called a Montgolfier, from its inventor. Now it has been discovered, by various experiments, that one degree of heat, according to the scale of Fahrenheit's thermometer, expands the air about one five-hundreth part; and, therefore, that it will require about 500°, or nearer 484° of heat, to expand the air to just double its bulk: which is a degree of heat far above what it is practicable to give it on such occasions. And, therefore, in this respect, common air heated is much inferior to inflammable air, in point of levity and usefulness for aerostatic machines. Upon such principles then depends the construction of the two sorts of air-balloons. But before treating of this branch more particularly, it will be proper to give a short historical account of this late-discovered art.

SECTION II.

History of Aerostation.

VARIOUS schemes for rising in the air, and passing through it, have been devised and attempted, both by the ancients and moderns, and that upon different principles, and with various success.

Of these, some attempts have been upon mechanical principles, or by virtue of the powers of mechanism: and such are conceived to be the instances related of the flying pigeon made by Archytas; the flying eagle and fly by Regiomontanus, and various others. Again, other projects have been formed for attaching wings to some part of the body, which were to be moved either by the hands or feet, by the help of mechanical powers; so that striking the air with them, after the manner of the wings of a bird, the person might raise himself in the air, and transport himself through it, in imitation of that animal. The romances of almost every nation have recorded instances of persons being carried through the air, both by the agency of spirits and mechanical inventions; but till the time of the celebrated Lord Bacon, no rational principle appears ever to have been thought of by which this might be accomplished. Friar Bacon, indeed, had written upon the subject; and many had supposed, that, by means of artificial wings, a man might fly as well as a bird: but these opinions were refuted by Borêlli in his treatise De Motu Animalium, where, from a comparison between the power of the muscles which move the wings of a bird, and those which move the arms of a man, he demonstrates that the latter are utterly insufficient to strike the air with such force as to raise him from the ground. In the year 1672, Bishop Wilkins published his "Discovery of the New World," in which he certainly seems to have conceived the idea of raising bodies into the atmosphere by filling them with rarefied air. This, however, he did not by any means pursue; but rested his hopes upon mechanical motions, to be accomplished by human strength, or by springs, &c. which have been proved incapable of answering any useful purpose. The jesuit, Francis Lana, cotemporary with Bishop Wilkins, proposed to exhaust hollow balls of metal of their air, and by that means occasion them to ascend. But though the theory was unexceptionable, the means were certainly insufficient to the end: for a vessel of copper, made sufficiently thin to float in the atmosphere, would be utterly unable to resist the external pressure, which being demonstrated, no attempt was made upon that principle. So that we may reckon nothing to have been particularly concerted towards aerostation, till the experiment of one Gusman, a Portuguese friar, who is reported early in the last century to have launched a paper bag into the air; which, however, soon fell, after attaining the height of 100 feet. Soon after Mr. Cavendish's discovery of the specific gravity of inflammable air, it occurred to the ingenious Dr. Black, of Edinburgh, that if a bladder, sufficiently light and thin, were filled with this air, it would form a mass lighter than the same bulk of atmospheric air, and rise in it. This thought was suggested in his lectures in 1767 or 1768; and he proposed, by means of the allantois of a calf, to try the experiment. Other employments, however, prevented the execution of his design. The possibility of constructing a vessel, which, when filled with inflammable air, would ascend in the atmosphere, had occurred also to Mr. Cavallo about the same time; and to him belongs the honour of having first made experiments on this subject, in the beginning of the year 1782, of which an account was read to the Royal Society, on the 20th of June, in that year. He tried bladders; but the thinnest of these, however scraped and cleaned, were too heavy. In using China-paper, he found that the inflammable air passed through its pores, like water through a sieve; and having failed of success by blowing this air into a thick solution of gum, thick varnishes, and oil paint, he was under a necessity of being satisfied with soap-balls; which, being inflated with inflammable air, by dipping the end of a small glass tube, connected with a bladder containing the air, into a thick solution of soap, and gently compressing the bladder, ascended rapidly in the atmosphere; and these were the first sort of inflammable air-ballons that were ever made.

But while aerostation seemed thus on the point of being made known in Britain, it was all at once announced in France, by two brothers, Stephen and John Montgolfier, natives of Annonay, and masters of a considerable paper-manufactory there, who had turned their thoughts to this project as early as the middle of the year 1782. Their idea was to form an artificial cloud, by inclosing smoke in a bag, and making it carry up the covering along with it. In that year, the experiment was made at Avignon with a fine silk bag; and by applying a burning paper to an aperture at the bottom, the air was rarefied, and the bag ascended to the height of 70 feet.—Various experiments were now tried upon a large scale, which excited the public curiosity very greatly. An immense bag of linen, lined with paper, and containing upwards of 23,000 cubic feet, was found to have a power of lifting about 500 pounds, including its own weight. Burning chopped straw and wool under the aperture of the machine, immediately occasioned it to swell, and afterwards to ascend into the atmosphere. In ten minutes it had risen 6000 feet: and when its force was exhausted, it fell to the ground at the distance of 7668 feet from the place it had left. Soon after this, one of the brothers, invited by the Academy of Sciences to repeat his experiments at their expense, constructed a large balloon of an elliptical form. In a preliminary experiment, this machine lifted from the ground eight persons who held it, and would have carried them all off, if more had not quickly come to their assistance. Next day the machine was filled by the combustion of fifty pounds of straw, and twelve pounds of wool. The machine soon swelled, and sustained itself in the air, together with the charge of between 4 and 500 pounds weight. It was designed to repeat the experiment before the king, at Versailles; but a violent storm of rain and wind happening to damage the machine, it became necessary to prepare a new one; and such expedition was used that this vast balloon, near 60 feet in height, and 43 in diameter, was made, painted within and without, and finely decorated, in no more than four days and four nights. Along with it was sent a wicker cage, containing a sheep, a cock, and a duck, which were the first animals ever sent on such a voyage. The full success of the experiment was, however, prevented by a violent gust of wind, which tore the machine in two places near the top before it ascended. Still it rose 1440 feet; and after remaining in the air about eight minutes, fell to the ground at the distance of 10,200 feet from the place of its setting out. The animals were not in the least hurt.

As the great power of these aerostatic machines, and their very gradual descent, shewed they were capable of transporting people through the air with all imaginable safety, M. Pilatre de Rozier offered himself to be the first aërial adventurer in a new machine, constructed in a garden in the fauxbourg of St. Antoine. It was of an oval shape, 48 feet in diameter, and 74 in height, elegantly painted with the signs of the zodiac, ciphers of the king's name, and other ornaments. A proper gallery, grate, &c. enabled the person who ascended to supply the fire with fuel, and thus keep up the machine as long as he pleased. The weight of the whole apparatus was upwards of 1600 pounds. On the 15th of October, 1783, M. Pilatre placing himself in the gallery, the machine was inflated, and permitted to ascend to the height of 84 feet, where he kept it afloat about four minutes and a half; after which it descended very gently; and such was its tendency to ascend, that it rebounded to a considerable height after touching the ground. On repeating the experiment, he ascended to the height of 210 feet. His next ascent was 262 feet; and in the descent, a gust of wind having blown the machine over some large trees in an adjoining garden, M. Pilatre suddenly extricated himself by throwing straw and wool on the fire, which raised him at once to a sufficient height. On descending again, he once more raised himself to a proper height by the same means. Some time after, he ascended, with M. Girond de Villette, to the height of 330 feet; hovering over Paris at least nine minutes in sight of all the inhabitants, and the machine keeping all the while a steady position. These experiments shewed, that the aërostatic machines might be raised or lowered at the pleasure of the persons who ascended. On the 21st of November, 1783, therefore, M. Pilatre, and the Marquis d'Arlandes, undertook an aërial voyage, which lasted about 25 minutes, and during which time they passed over a space of above five miles. From the account given by the Marquis, they met with several different currents of air, the effect of which was to give a very sensible shock to the machine, and the directions of the motion seemed to be from the upper part downwards. It appears also that they were in some danger of having the balloon burnt altogether; as the Marquis observed several round holes made by the fire in the lower part of it, which alarmed him considerably, and, indeed, not without reason. However, the progress of the fire was easily stopped by the application of a wet sponge, and all appearance of danger ceased.

This voyage of M. Pilatre, and the Marquis, may be said to conclude the history of aerostatic machines which are elevated by means of fire; these having been soon after superseded by balloons, in which inflammable air was enclosed. This gas being considerably lighter than heated atmospheric air, possessed many advantages over the other. The first experiment was made by two brothers, Messrs. Robert and M. Charles, professors of experimental philosophy. The bag was composed of lutestring, varnished over with a solution of the elastic gum, called caoutchouc, and was about thirteen English feet in diameter. Many difficulties occurred in filling it with the inflammable air; but being at last set at liberty, after having been well filled, it was thirty-five pounds lighter than an equal bulk of common air. It remained in the atmosphere only three quarters of an hour, during which it traversed fifteen miles. Its sudden descent was supposed to have been owing to a rupture which had taken place when it ascended into the higher regions of the atmosphere. The event of this experiment, and the aërial voyage made by Messrs. Rosier and Arlandes, naturally suggested the idea of undertaking something of the same kind with a balloon filled with inflammable air. The machine used on this occasion was formed of gores of silk, covered with a varnish of caoutchouc, of a spherical figure, and measuring 27½ feet in diameter. A net was spread over the upper hemisphere, and fastened to a hoop, which passed round the middle of the balloon. To this a sort of car was suspended a few feet below the lower part of the balloon; and in order to prevent the bursting of the machine, a valve was placed in it; by opening of which some of the inflammable air might be occasionally let out. The car was of basket work, covered with linen, and beautifully ornamented; being eight feet long, four broad, and three and a half deep; its weight 130 pounds. Great difficulties again occurred in filling the machine, but these at last being removed, the two adventurers took their seats at three quarters after one in the afternoon of the 1st of December, 1783. At the time the balloon rose, the thermometer stood at of Fahrenheit, and the barometer at 30·18 inches; and, by means of the power of ascent with which they left the ground, the balloon rose till the mercury fell to 27 inches, from which they calculated their height to be about 600 yards. Throwing out ballast occasionally as they found the machine descending by the escape of some of the inflammable air, they found it practicable to keep at pretty near the same distance from the earth, during the rest of their voyage; the quicksilver fluctuating between 27 and 27·65 inches, and the thermometer between 53° and 57°, the whole time. They continued in the air an hour and three quarters, and alighted at the distance of twenty-seven miles from Paris; having suffered no inconvenience during their voyage, nor experienced any contrary currents of air, as had been felt by Messrs. Pilatre and Arlandes. As the balloon still retained a great quantity of inflammable gas, M. Charles determined to take another voyage by himself. M. Robert accordingly got out of the machine; which now being 130 pounds lighter, arose with such velocity, that in twenty minutes he was almost 9000 feet in the air, and entirely out of sight of terrestrial objects. The globe, which had been rather flaccid, soon began to swell, and the inflammable air escaped in great quantity. He also drew the valve, to prevent the balloon from bursting; and the inflammable gas, being considerably warmer than the external air, diffused itself all round, and was felt like a warm atmosphere. In ten minutes, however, the thermometer indicated a great variation of temperature: his fingers were benumbed with cold, and he felt a violent pain in his right ear and jaw, which he ascribed to the expansion of the air in these organs as well as to the external cold. The beauty of the prospect which he now enjoyed, however, made amends for these inconveniencies. At his departure the sun was set on the valleys; but the height to which M. Charles was got into the atmosphere rendered him again visible, though only for a short time. He saw, for a few seconds, vapours rising from the valleys and rivers. The clouds seemed to ascend from the earth, and collect one upon the other, still preserving their usual form; only their colour was grey and monotonous, for want of sufficient light in the atmosphere. By the light of the moon, he perceived that the machine was turning round with him in the air; and he observed that there were contrary currents which brought him back again. He observed also, with surprise, the effects of the wind, and that the streamers of his banners pointed upwards; which, he says, could not be the effect either of his ascent or descent, as he was moving horizontally at the time. At last, recollecting his promise of returning to his friends in half an hour, he pulled the valve, and accelerated his descent. When within 200 feet of the earth, he threw out two or three pounds of ballast, which rendered the balloon again stationary; but, in a little time afterwards, he gently alighted in a field about three miles distance from the place whence he set out; though, by making allowance for all the turnings and windings of the voyage, he supposes that he had gone through nine miles at least. By the calculations made, it appears that he rose at this time not less than 10,500 feet; a height somewhat greater than that of Mount Ætna.

The subsequent aërial voyages differ so little from that just now related, that any particular description of them seems to be superfluous. It had occurred to M. Charles, however, in his last flight, that there might be a possibility of directing the machine in the atmosphere; and this was afterwards attempted by M. Jean-Pierre Blanchard. In one of the aërostatic excursions of the latter, he gives an account of the sensations he felt during his voyage, and which were somewhat different from those of M. Charles; having in one part of it found the atmosphere very warm, in another very cold; and having once found himself very hungry, and at another, time almost overcome by a propensity to sleep. The height to which he arose, as measured by mathematical instruments, was thought to be very little less than 10,000 feet; and he remained in the atmosphere an hour and a quarter. Notwithstanding the rapid progress of aërostation in France, it is remarkable that we have no authentic accounts of any experiments of this kind being attempted in other countries. Even in onr own island, where all arts and sciences find an indulgent nursery, and many their birth, no aërostatic machine was seen before the month of November, 1783. Various speculations have been made on the reasons of this strange neglect of so novel and brilliant an experiment; but none seemed to carry any shew of probability, except that it was said to be discouraged by the leader of a philosophical society, expressly instituted for the improvement of natural knowledge, for the reason, as was said, that it was a discovery of a neighbouring nation. Be this however as it may, it is a fact that the first aërostatic experiment was exhibited in England, by a foreigner unconnected and unsupported. This was a Count Zambeccari, an ingenious Italian, who happened to be in London about that time. He made a balloon of oiled silk, ten feet in diameter, weighing only eleven pounds; it was gilt, both for ornament, and to render it more impermeable to the inflammable air, with which it was to be filled. The balloon after being publicly shewn for several days in London, was carried to the Artillery-ground, and there being filled about three-quarters with inflammable air, and having a direction, inclosed in a tin box, for any person by whom it should afterwards be found, it was launched about one o'clock on the 25th of November, 1783. At half past three it was taken up, near Petworth, in Sussex, forty-eight miles distant from London; so that it travelled at the rate of near twenty miles an hour. Its descent was occasioned by a rent in the silk, which must have been the effect of the rarefaction of the inflammable air when the balloon ascended to a rarer part of the atmosphere. The attempts of M. Blanchard to direct his machine through the atmosphere, were repeated in 1784, by Messrs. Morveau and Bertrand, at Dijon, who raised themselves with an inflammable air-balloon to the height, as it was thought, of 13,000 feet: passing through a space of eighteen miles in an hour and twenty-five minutes. M. Morveau had prepared oars for directing the machine through the air; but they were damaged by the wind, so that only two remained serviceable; by working these, however, they were able to produce a sensible effect on the motion of the machine. In a third aërial voyage performed by M. Blanchard, he seemed to produce some effect by the agitation of his wings, both in ascending, descending, moving sideways, and even in some measure against the wind: however this is supposed, with some probability, to have been a mistake, as, in all his succeeding voyages, the effects of his machinery could not be perceived.

Having said thus much with regard to the conducting aërostatic machines through the atmosphere, we shall now relate the attempts made to lessen their expence, by falling upon some contrivance to ascend without throwing out ballast, and to descend without losing any of the inflammable air. The first attempt of this kind was made by the Duke de Chartres; who, on the 15th of July, 1784, ascended with the two brothers, Charles and Robert, from the park of St. Cloud. The balloon was of an oblong form, made to ascend with its longest diameter horizontally, and measured fifty-five feet in length, and twenty-four in breadth. It contained within it a smaller balloon filled with common air; by blowing into which with a pair of bellows, and thus throwing in a considerable quantity of common air, it was supposed that the machine would become sufficiently heavy to descend; especially as, by the inflation of the internal bag, the inflammable air in the external one would be condensed into a smaller space, and thus become specifically heavier. The voyage, however, was attended with such circumstances as rendered it impossible to know what would have been the event of the scheme. The power of ascent, with which they set out, seems to have been very great; as in three minutes after parting from the ground, they were lost in the clouds, and involved in such a dense vapour that they could see neither the sky nor the earth. In this situation they seemed to be attacked by a whirlwind, which, besides turning the balloon three times round from right to left, shocked, and beat it so about, that they were rendered incapable of using any of the means proposed for directing their course, and the silk stuff of which the helm had been composed was even torn away. No scene can be conceived more terrible than that in which they were now involved. An immense ocean of shapeless clouds rolled one upon another below them, and seemed to prevent any return to the earth, which still continued invisible, while the agitation of the balloon became greater every moment. In this extremity they cut the cords which held the interior balloon, and of consequence it fell down upon the aperture of the tube that came from the large balloon into the boat, and stopped it up. They were then driven upwards by a gust of wind from below, which carried them to the top of that stormy vapour in which they had been involved. They now saw the sun without a cloud; but the heat of his rays, with the diminished density of the atmosphere, had such an effect on the inflammable air, that the balloon seemed every moment ready to burst. To prevent this they introduced a stick through the tube, in order to push away the inner balloon from its aperture; but the expansion of the inflammable air pushed it so close, that all attempts of this kind proved ineffectual. It was now, however, become absolutely necessary to give vent to a very considerable quantity of the inflammable air; for which purpose the Duke de Chartres himself bored too holes in the balloon, which tore open for the length of seven or eight feet. On this they descended with great rapidity; and would have fallen into a lake, had they not hastily thrown out sixty-pounds of ballast, which enabled them just to reach the water's edge. This scheme for raising or lowering aërostatic machines by bags filled with common air being thus rendered dubious, another method was thought of. This was to put a small aërostatic machine, with rarefied air, under an inflammable air-balloon, but at such a distance that the inflammable air of the latter might be perfectly out of the reach of the fire used for inflating the former; and thus, by increasing or diminishing the fire in the small machine, the absolute weight of the whole would be considerably diminished or augmented. This scheme was unhappily put in execution by the celebrated M. Pilatre de Rozier and M. Romaine. Their inflammable air-balloon was about thirty-seven feet in diameter, and the power of the rarefied air one was equivalent to about sixty-pounds. They ascended without any accident; but had not been long in the atmosphere when the inflammable air-balloon was seen to swell very considerably, at the same time that the aeronauts were observed, by means of telescopes, very anxious to get down, and busied in pulling the valve and opening the appendages to the balloon, in order to facilitate the escape of as much inflammable air as possible. Shortly after this the machine took fire, at the height of about three quarters of a mile from the ground. No explosion was heard; and the silk of the balloon seemed to resist the atmosphere for about a minute, after which it collapsed, and descended along with the two unfortunate travellers so rapidly, that both of them were killed. Pilatre seemed to have been dead before he came to the ground; but M. Romaine was alive when some persons came up to him, though he expired immediately after.

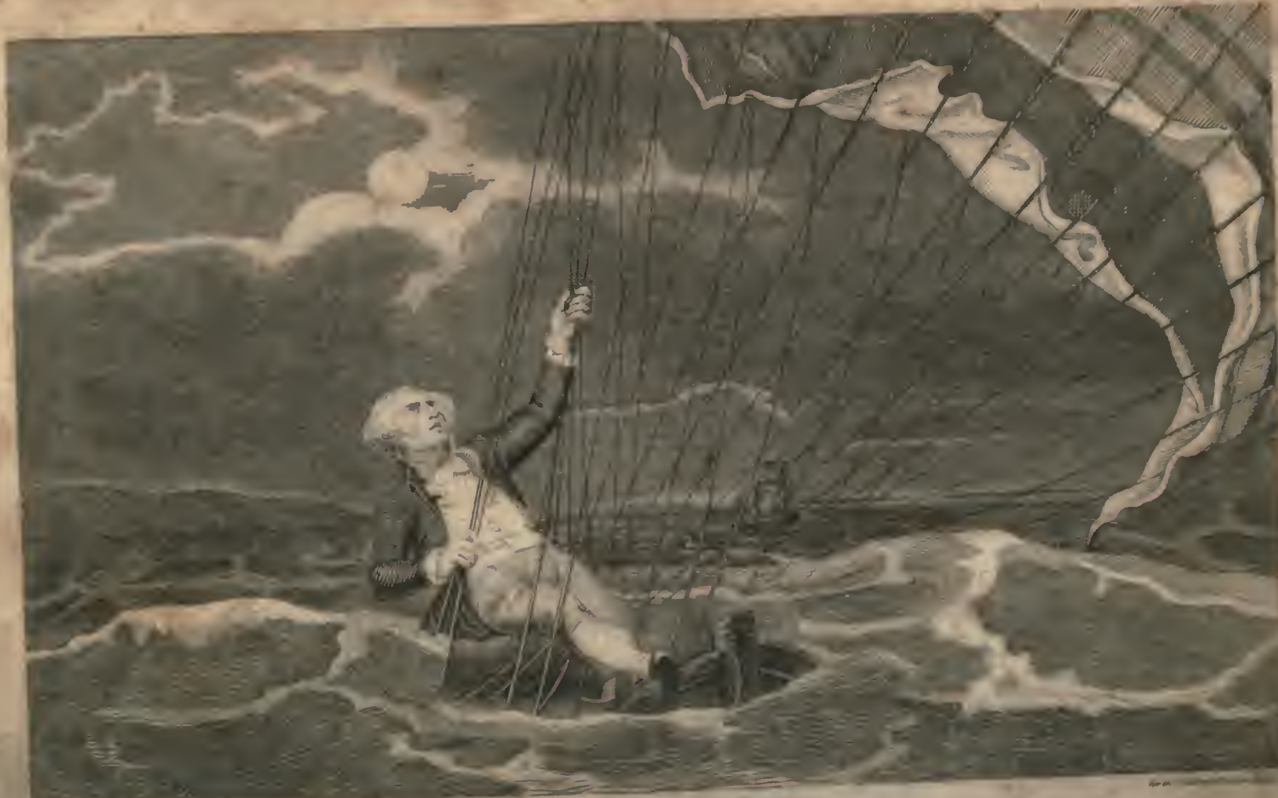
The first aërial voyage in England was performed on the 15th of

September, 1784, by Vincent Lunardi, a native of Italy. His balloon was made of oiled silk, painted in alternate stripes of blue and red. Its diameter was thirty-three feet. From a net which went over about two-thirds of the balloon descended forty-five cords to a hoop hanging below the balloon, and to which the gallery was attached. The balloon had no valve; and its neck, which terminated in the form of a pear, was the aperture through which the inflammable air was introduced, and through which it might be let out. The air for filling the balloon was produced from zinc by means of diluted vitriolic acid. Mr. Lunardi departed from the Artillery-ground at two-o'clock; and with him were a dog, a cat, and a pigeon. After throwing out some sand to clear the houses, he ascended to a great height. The direction of his motion at first was NW by W, but as the balloon rose higher it fell into another current of air, which carried it nearly N. About half after three he descended very near the ground and landed the cat, which was almost dead with cold: then rising, he prosecuted his voyage. He ascribes his descent to the action of an oar; but as he was under a necessity of throwing out ballast in order to re-ascend, his descent was more probably occasioned by the loss of inflammable air. At ten minutes past four he descended on a meadow, near Ware, in Hertfordshire. The only philosophical instrument which he carried with him was a thermometer, which, in the course of his voyage, stood as low as 29°; and he observed that the drops of water collected round the balloon were frozen.

The second aerial voyage, in England, was performed by Mr. Blanchard, and Mr. Sheldon, Professor of Anatomy to the Royal Academy, being the first Englishman who ascended with an aërostatic machine. They ascended at Chelsea, the 16th of October, 1784, at nine minutes past twelve o'clock. Mr. Blanchard having landed Mr. Sheldon, at about fourteen miles from Chelsea, re-ascended alone, and finally landed, near Rumsey, in Hampshire, about seventy-five miles distant from London, having gone nearly at the rate of twenty miles an hour. The wings used on this occasion, it seems, produced no deviation from the direction of the wind. Mr. Blanchard said, that he ascended so high as to feel a great difficulty of breathing: and that a pigeon, which flew away from the boat, laboured, for some time, to sustain itself with its wings in the rarefied air, but after wandering a good while returned, and rested on the side of the boat.

On the 4th of October, Mr. Sadler, an ingenious tradesman, at Oxford, ascended at that place with an inflammable air balloon of his own construction and filling. And again, on the twelfth of the same month, he ascended at Oxford, and floated to the distance of fourteen miles, in seventeen minutes, which is at the rate of near fifty miles an hour. On the 23d of March, count Zambeccari, and Admiral Sir Edward Vernon, ascended at London, and sailed to Horsham, in Sussex, at the distance of thirty-five miles in less than an hour. The voyage proved very dangerous, owing to some of the machinery about the valve being damaged, which obliged them to cut open some part of the balloon when they were about two miles perpendicular height above the earth, the barometer having fallen from 30·4 to 20·8 inches. In descending they passed through a dense cloud, which felt very cold, and covered them with snow. The observations they made were, that the balloon kept perpetually turning round in a vertical axis, sometimes so rapidly as to make each revolution in four or five seconds; that a peculiar noise, like rustling, was heard among the clouds, and that the balloon was greatly agitated in the descent. Perhaps the most daring attempt was that of Mr. Blanchard and Dr. Jeffries across the straits of Dover. This took place on the 7th of January, 1785, being a clear frosty morning, with a wind, barely perceptible, at NNW. The operation of filling the balloon began at ten o'clock, and at three quarters after twelve every thing was ready for their departure. At one o'clock Mr. Blanchard desired the boat to be pushed off, which now stood only two feet distant from that precipice so finely described by Shakspeare, in his tragedy of King Lear. As the balloon was scarcely sufficient to carry two, they were obliged to throw out all their ballast except three bags of ten pounds each; when they at last rose gently, though making very little way on account of there being so little wind. At a quarter after one o'clock, the barometer, which on the cliff stood at 29·7 inches, was now fallen to 27·3, and the weather proved fine and warm. They had now a most beautiful prospect of the south coast of England, and were able to count thirty-seven villages upon it. After passing over several vessels, they found that the balloon, at fifty minutes after one, was descending, on which they threw out a sack and a half of ballast; but as they saw that it still descended, and that with much greater velocity than before, they now threw out all the ballast. This still proving ineffectual, they next threw out a parcel of books they carried along with them, which made the balloon ascend, when they were about midway betwixt France and England. At a quarter past two, finding themselves again descending, they threw away the remainder of their books, and, ten minutes after, they had a most enchanting prospect of the French coast. Still, however, the machine descended; and as they had now no more ballast, they were fain to throw away their provisions for eating, the wings of their boat, and every moveable they could easily spare. "We threw away," says Dr. Jeffries, "our only bottle, which in its descent cast out a steam like smoke, with a rushing noise; and when it struck the water, we heard and felt the shock very perceptibly on our car and balloon." All this proving insufficient to stop the descent of the balloon, they next threw out their anchors and cords, and at last stripped off their clothes, fastening themselves to certain slings, and intending to cut away the boat as their last resource. They had now the satisfaction, however, to find that they were rising; and as they passed over the high lands between Cape Blanc and Calais, the machine rose very fast, and carried them to a greater height than they had been at any former part of their voyage. They descended safely among some trees in the forest of Guiennes, where there was just opening enough to admit them.

In September, 1785, Mr. Baldwin ascended from Chester, in Mr. Lunardi's balloon; and, after traversing in a variety of directions, he first alighted in the neighbourhood of Frodsham; then reascending and pursuing his excursions, he finally landed at Rixton-moss, twenty-five miles from Chester. Mr. Baldwin, who published his observations made during the voyage, and taken from minutes, mentions the following curious particulars. The sensation of ascending he compares to a strong pressure from the bottom of the car upwards against the soles of his feet. At the distance of what appeared to him seven miles from the earth, though by the barometer scarcely a mile and an half, he had a grand and most enchanting view of the city of Chester and its adjacent places below him. The river Dee appeared of a red colour; the city very diminutive; and the town entirely blue. The whole appeared a perfect plane, the highest buildings having no apparent height, but reduced all to the same level, and the whole terrestrial prospect appeared like a coloured map. The perspective appearance of things to him was very remarkable. The lowest bed of vapour that first appeared as cloud, was pure white in detached fleeces, increasing as they rose: they



MAJOR MONEY'S PERILOUS SITUATION

When he fell into the Sea July 23, 1785, off the Coast of Yarmouth.

presently coalesced, and formed, as he expresses it, a sea of cotton, tufting here and there by the action of the air in the undisturbed part of the clouds. The whole became an extended white floor of cloud, the upper surface being smooth and even. Above this white floor he observed, at great and unequal distances, a vast assemblage of thunder clouds, each parcel consisting of whole acres in the densest form: he compares their form and appearance to the smoke of pieces of ordnance, which had consolidated, as it were, into masses of snow, and penetrated through the upper surface, or white floor of common clouds, there remaining visible and at rest. He endeavours to convey some idea of the scene by a sketch, which represents a circular view he had from the car of the balloon, himself being over the centre of the view, looking down on the white floor of clouds, and seeing the city of Chester through an opening, which discovered the landscape below, limited by surrounding vapour to less than two miles in diameter. The breadth of the outer margin defines his apparent height in the balloon (viz. four miles) above the white floor of clouds. The regions in which he was did not feel colder, but rather warmer, than below; and the sun felt hottest, when the balloon was stationary. The discharge of a cannon, when the balloon was at a considerable height, was distinctly heard; and another discharge, when he was at the height of about thirty yards, so disturbed him as to oblige him for safety to lay hold firmly of the cords of the balloon.

Omitting the relation of Mr. Crosbie's attempt to cross the Irish Channel, and of Major Mony's narrow escape from drowning in the German Ocean*, we proceed to remark that, about the latter end of August, 1785, the longest aërial voyage we have yet heard of was performed by Mr. Blanchard: he ascended at Lisle, accompanied by the Chevalier de L'Epinard, and travelled 300 miles in the balloon before it descended. On this occasion, as on some former ones, Mr. Blanchard made trial of a parachute, an instrument like a large umbrella, invented to break the fall, in case of an accident happening to the balloon: with this machine he dropped a dog from the car soon after his ascension, which descended gently and unhurt. The most celebrated aëronaut of modern times was M. Garnerin, a man of an ardent and ingenious mind, but pro-

* We have been induced to give a view of the perilous situation of Major Mony, who fell into the sea with his balloon on the 23d July, 1785, off the coast of Yarmouth, and was most providentially discovered and taken up by the Argus sloop, after having remained in the water during five hours.

bably not very intimately acquainted with the sciences connected with aerostation. We do not remember hearing of this gentleman until August, 1798, on the 28th of which month he made his eleventh ascension from Paris, accompanied by a female friend. His course for a considerable time was near the ground, during which he conversed with the people below. These conversations shewed how much the earth reflected sound; for all his words were repeated five or six times. He thought at first that it might be governed by some local circumstance, which indeed is very probable with regard to the repetition. He descended several times to the same level, at a distance of ten leagues asunder, where he constantly observed the same effect. This great vibration of the air was not sensible to distances exceeding 150 or 200 toises. It decreased with the distance. Having made a number of aërial voyages, M. Garnerin's mechanical acquaintance with the requisites for insuring success was confirmed by frequent experience. This gentleman, availing himself of the short interval of peace, visited England in the summer of 1802; and thus excited the attention of the British public to the almost forgotten subject of aerostation. His voyages made in this country are fresh in the memory of every one; and as they were minutely detailed in several of the daily papers and monthly publications, we shall be the more readily excused giving a full account of them here. On June 29th, this aëronaut, accompanied by a military gentleman (Captain Snowden) rose from Ranelagh, and alighted near Colchester, in less than three quarters of an hour; having, in that short period, travelled full sixty miles! During this voyage the aëronauts did not appear to move with any unpleasant rapidity, until they began to descend, when they were much affected by the boisterousness of the wind: their descent was attended with danger, and occupied some minutes. From this voyage, then, it may fairly be concluded, that the wind often moves with much greater velocity than is commonly assigned to it: on the day this voyage was made, the wind was not thought to be more high and boisterous than it often is, yet it can hardly be doubted that its velocity was more than eighty miles per hour, and this is nearly double the velocity which is commonly assigned to such winds.

The singular experiment of ascending into the atmosphere with an inflammable air-balloon, and of descending with a machine called a parachute, was performed by M. Garnerin on the 21st of September, 1802. He ascended from St. George's Parade, North Audley-street, and descended safe into a field near the Small-pox

Hospital, in Pancras. The balloon was of the usual sort, viz. of oiled silk, with a net, from which ropes proceeded, which terminated in, or were jointed to, a single rope at a few feet below the balloon. To this rope the parachute was fastened in the following manner. The reader may easily form to himself an idea of this parachute, by imagining a large umbrella of canvass of about thirty feet in diameter, but destitute of the ribs and handle. Several ropes of about thirty feet in length, which proceeded from the edge of the parachute, terminated in a common joining, from which basket shorter ropes proceeded, to the extremities of which a circular was fastened, and in this basket M. Garnerin placed himself. Now the single rope, which has been said above to proceed from the balloon, passed through a hole in the centre of the parachute, also through certain tin tubes, which were placed one after the other in the place of the handle or stick of an umbrella, and was lastly fastened to the basket; so that when the balloon was in the air, by cutting the end of this rope next to the basket, the parachute, with the basket, would be separated from the balloon, and, in falling downwards, would be naturally opened by the resistance of the air. The use of the tin tubes was to let the rope slip off with greater certainty, and to prevent its being entangled with any of the other ropes, as also to keep the parachute at a distance from the basket. The balloon began to be filled at about two o'clock. There were thirty-six casks filled with iron filings and diluted sulphuric acid, for the production of the hydrogen gas. These communicated with three other casks or general receivers, to each of which was fixed a tube that emptied itself into the main tube attached to the balloon. At six, the balloon being quite full of gas, and the parachute, &c. being attached to it, M. Garnerin placed himself in the basket, and ascended majestically amidst the acclamations of innumerable spectators. The weather was the clearest and pleasantest imaginable; the wind was gentle and about west by south; in consequence of which M. Garnerin went in the direction of about east by north. In about eight minutes time, the balloon and parachute had ascended to an immense height, and M. Garnerin, in the basket, could scarcely be perceived. While every spectator was contemplating the grand sight before him, M. Garnerin cut the rope, and in an instant he was separated from the balloon, trusting his safety to the parachute. At first, viz. before the parachute opened, he fell with great velocity; but as soon as the parachute was expanded, which took place a few moments after, the descent was very gentle and gradual. In this descent a remarkable circumstance was observed, namely, that the parachute with the appendage of cords and basket, soon began to vibrate like the pendulum of a clock, and the vibrations were so great, that more than once the parachute, and the basket with M. Garnerin, seemed to be on the same level, or quite horizontal, which appeared extremely dangerous: however, the extent of the vibrations diminished as he came pretty near the ground. On coming to the earth, M. Garnerin experienced some pretty strong shocks, and when he came out of the basket, he was much discomposed; but he soon recovered his spirits, and remained without any material hurt.

SECTION III.

Construction of Balloons.

THE shape of the balloon is one of the first objects of consideration in the construction of this machine. As a sphere admits the greatest capacity under the least surface, the spherical figure or that which approaches nearest to it, has been generally preferred. However, since bodies of this form oppose a great surface to the air, and consequently a greater obstruction to the action of the oar or wings than those of some other form; it has been proposed to construct balloons of a conical or oblong figure, and to make them proceed with their narrow end forward. Some have suggested the shape of a fish; others, that of a bird; but either the globular, or the egg-like shape, is, all things considered, certainly the best which can be adopted. The bag or cover of an inflammable-air balloon is best made of the silk stuff called lustring, varnished over. But for a Montgolfier, or heated-air balloon, on account of its great size, linen cloth has been used, lined within or without with paper, and varnished. Small balloons are made either of varnished paper, or simply of paper unvarnished, or of gold-beater's skin, or such-like light substances. The best way to make up the whole coating of the balloon, is by different pieces or slips joined lengthways from end to end, like the pieces composing the surface of a geographical globe, and contained between one meridian and another, or like the slices into which a melon is usually cut, and supposed to be spread flat out. Now the edges of such pieces cannot be exactly described by a pair of compasses, not being circular, but flatter or less rounder than circular arches; but if the slips are sufficiently narrow, or numerous, they will differ the less from circles, and may be described as such. But more accurately, the breadths of the slip, at the several distances from the point, to the middle, where it is broadest, are directly as the sines of those distances, radius being the half length of the slip. After providing the necessary quantity of the stuff, and each piece having been properly prepared with the drying oil, let the corresponding edges be sewed together in such a manner as to leave about half or three quarters of an inch of one piece beyond the edge of the other, in order that this may, in a subsequent row of stitches, be turned over the latter, and both again sewed down together, by so doing, a considerable degree of strength is given to the whole bag at the seams, and the hazard of the gass escaping doubly prevented. Having gone in this manner through all the seams, the following method of Mr. Blanchard is admirably calculated to render them yet more perfectly air tight. The seam being doubly stitched as above, lay beneath it a piece of brown paper, and also another piece over it on the outside; upon this latter pass several times a common fire-iron heated just sufficiently to soften the drying oil in the seam; this done, every interstice will be now closed, and the seam rendered completely air-tight. The neck of the balloon being left a foot in diameter and three in length, and all the seams finished, the bag will be ready to receive the varnish, a single coating of which on the outside is found preferable to the former method of giving an internal as well as external coat.

The compositions for varnishing balloons have been variously modified; but, upon the whole, the most approved appears to be the bird-lime varnish of M. Faujas St. Fond, prepared after Mr. Cavallo's method, as follows: "In order to render linseed oil drying, boil it, with two ounces of sugar of lead and three ounces of litharge for every pint of oil, till they are dissolved, which may be in half an hour. Then put a pound of bird-lime and half a pint of the drying oil into an iron or copper vessel whose capacity should equal about a gallon, and let it boil very gently over a slow charcoal fire till the bird-lime ceases to crackle, which will be in about half or three quarters of an hour: then pour upon it two pints and a half more of the drying oil, and let it boil about an hour longer, stirring it frequently with an iron or wooden spatula. As the varnish whilst boiling, and especially when nearly done, swells very much, care should be taken to remove, in those cases, the pot from the fire, and replace it when the varnish subsides; otherwise it will boil over. Whilst the stuff is boiling the operator should occasionally examine whether it has boiled enough; which may be known by observing whether, when rubbed between two knives and then separated from one another, the varnish forms threads between them, as it must then be removed from the fire; when nearly cool, add about an equal quantity of spirit of turpentine: in using the varnish, the stuff must be stretched and the varnish lukewarm: in twenty-four hours it will be dry." As the elastic resin, known by the name of Indian rubber, has been much extolled for a varnish, the following method of making it, as practised by Mr. Blanchard, may not prove unacceptable: Dissolve elastic resin, cut small, in five times its weight of rectified essential oil of turpentine, (ethereal spirit of turpentine of the shops), by keeping them some days together; then boil one ounce of this solution in eight ounces of drying linseed oil for a few minutes; strain the solution and use it warm.—The car or boat is best made of wicker-work, covered with leather, and painted; and the proper method of suspending it, is by ropes proceeding from the net which goes over the balloon. The net should be formed to the shape of the balloon, and fall down to the middle of it, with various cords proceeding from it to the circumference of a circle about two feet below the balloon; and from that circle other ropes should go to the edge of the boat. This circle may be made of wood, or of several pieces of slender cane bound together. The meshes of the net may be small at top, against which part of the balloon the inflammable air exerts the greatest force; and increase in size as they recede from the top.

With regard to the rarefied-air machines, Mr. Cavallo recommends first to soak the cloth in a solution of sal-ammoniac and common size, using one pound of each to every gallon of water; and when the cloth is quite dry, to paint it over in the inside with some earthy colour, and strong size or glue. When this paint has dried perfectly, it will then be proper to varnish it with oily varnish, which might dry before it could penetrate quite through the cloth. Simple drying linseed oil will answer the purpose as well as any, provided it be not very fluid. If a parachute is required, it should be constructed so as when distended to form but a small segment of a sphere, and not a complete hemisphere; as the weight of this machine is otherwise considerably increased, without gaining much in the opposing surface. The parachute of M. Garnerin is particularly defective in too great extension of its diameter; an unnecessary addition to its weight of a lining of paper both withinside and without;

the too near approximation of the basket to the body of the parachute; and especially in the want of a perpendicular cord passing from the car to the centre of the concave of the umbrella, by the absence of which the velocity of the descent is certain to be very rapid before the machine becomes at all distended; whereas, if a cord were thus disposed, the centre of the parachute would be the portion first drawn downwards by the appended weight, and the machine would be almost immediately at its full extension. Having found, by experiment, the diameter, required for insuring safety, the further the basket or car is from the umbrella, the less fear shall we have of an inversion of the whole from violent oscillations; yet, the longer the space between the car and the head of the machine, the longer will be the space run through in each vibration when once begun, yet by so much the more will they be steadier; and this ought to be attended to, as when by the violence of the oscillations the car became (in Garnerin's experiment) on a line with the horizontal axis of the machine (or, in other words, the point of suspensation,) the force of gravity, or the gravitating power of the weight in the car, on the umbrella, being at that crisis reduced to nothing, the slightest cause might have carried the body of the machine in a lateral direction, reversing the concavity of the umbrella, and M. Garnerin, perhaps, have fallen upon the now convex yet internal portion of the bag, and the whole have descended confusedly together.—It now remains to give some account of the method by which aerostatic machines may be filled; and here we are able to determine with much greater precision concerning the inflammable-air balloons than the other kind. With regard to these, a primary consideration is, the most effectual and cheap method of procuring the inflammable-air. It will be found that the most advantageous methods are, by applying acids to certain metals; by exposing animal, vegetable, and some mineral substances, in a close vessel to a strong fire; or lastly, by transmitting the vapour of certain fluids through red-hot tubes. For obtaining inflammable-air from pit-coal, asphaltum, amber, &c. &c. Mr. Cavallo recommends the following apparatus: let a vessel be made of clay, or rather of iron, in the shape of a Florence flask, somewhat larger, and whose neck is longer and larger. Put the substance to be used into this vessel, so as to fill about four-fifths or less of its cavity. If the substance be of such a nature as to swell much by the action of the fire, lute a tube of brass, or first a brass and then a leaden tube, to the neck of the vessel; and let the end of the tube be so shaped that going into the water it may terminate under a sort of inverted vessel, to the upper aperture of which the balloon is adapted. Things thus prepared, if the part of the vessel is put into the fire, and made red-hot, the inflammable air produced will come out of the tube, and passing through the water will at last enter into the balloon. Previous to the operation, as a considerable quantity of common air remains in the inverted vessel, which it is more proper to expel, the vessel should have a stop-cock, through which the common air may be sucked out, and the water ascend as high as the stop-cock. To procure inflammable air by means of steam, Dr. Priestley used a tube of red-hot brass, upon which the steam of water has no effect, and which he fills with the turnings of iron that are separated in the boring of cannon. By this means he obtained an inflammable air, the specific gravity of which is to that of common air as 1 to 13. In this method, not yet indeed reduced to general practice, a tube about three-quarters of an inch in diameter, and about three feet long, is filled with iron turnings; then the neck of a retort, or close boiler, is luted to one of its ends, and the worm of a refrigeratory is adapted to its other extremity. The middle part of the tube is then surrounded with burning coals, so as to keep about one foot in length of it red-hot, and a fire is always made under the retort or boiler sufficient to make the water boil with vehemence. In this process a considerable quantity of inflammable air comes out of the refrigeratory. It is said that iron yields one half more air by this means than by the action of vitriolic acid.—With regard to the rarefied-air balloons, the method of filling them is by means of a scaffold, the breadth of which is at least two-thirds of the diameter of the machine, and elevated about six or eight feet from the ground. From the middle of it descends a well, rising about two or three feet above it, and reaching to the ground, furnished with a door, through which the fire in the well is supplied with fuel. The well should be constructed of brick, and its diameter somewhat less than that of the machine. On each side of the scaffold are erected two masts, each of which is fixed by ropes, and has a pulley at the top. The machine is to be placed on the scaffold, with its neck round the aperture of the well. The rope passing over the pulleys of the two masts, serves to lift the balloon about fifteen feet above the scaffold; and it is kept steady, and held down, whilst filling, by ropes passing through loops or holes about its equator; and these ropes may easily be disengaged from the machine, by slipping them through the loops when it is able to sustain itself. The proper combustibles, to be lighted in the well, are those which burn quick and clear, rather than such as produce much smoke; because it is hot air, and not smoke, that is required. Small wood and straw are very fit for this purpose. As the current of hot air ascends, the machine will dilate, and lift itself above the scaffold and gallery which was covered by it. The passengers, fuel, instruments, &c. are then placed in the gallery. When the machine makes efforts to ascend, its aperture must be brought, by means of the ropes annexed to it, towards the side of the well a little above the scaffold; the fire-place is then suspended in it, the fire lighted in the grate, and the lateral ropes being slipped off, the machine is let go. It has been determined by accurate experiments, that only one-third of the common air can be expelled from these large machines; and therefore the ascending power of the rarefied air in them can be estimated as only equal to half an ounce avoirdupoise for every cubic foot.

The conduct of balloons, when constructed, filled, and actually ascended in the atmosphere, is an object of great importance in the practice of aërostation. The method generally used for elevating or lowering the balloons with rarefied air, has been the increase or diminution of the fire; and this is entirely at the command of the aeronaut, as long as he has any fuel in the gallery. The inflammable-air balloons have been generally raised or lowered by diminishing their ballast, or by letting out some of the gas through the valve: but the alternate escape of the air in descending, and discharge of the ballast for ascending, will by degrees render the machine incapable of floating; for in the air it is impossible to supply the loss of ballast, and very difficult to supply that of inflammable air. These balloons will also rise or fall by means of the rarefaction or condensation of the inclosed air, occasioned by heat and cold, as has been already observed. Wings or oars are the only means of this sort that have been used with any probable success; and as Mr. Cavallo observes, they seem to be capable of considerable improvement, though much is not to be expected from them, when the machine goes at a great rate. It is a matter of surprise, that the various hints for directing balloons appear to lie dormant with their projectors who seem indisposed to make any attempts to carry their plans into execution: thus the inventions of professor

Daniel (Philosophical Magazine, vol. iv.) also of Martin, and the proposals for performing the same by means of eagles trained for the purpose; or by a reversed parachute to retard the direct progress of the balloon, whereby less power will be necessary to impel it in a lateral direction; all these plans remain obsolete and unpractised from the time of their suggestion. With respect to the probability of directing aërostatic machines, we may infer it to be possible, although the methods hereto tried have been inadequate; perhaps because they were not sufficiently powerful; as, to expect to make so large a body as a balloon to vary from the wind by the impulsion of an oar of six or eight feet in length and one or two in breadth (and that by only endeavouring to draw the car out of the perpendicular) is to expect, by means of a boat's oar, to impel a ship of burthen. Oars are doubtless the most likely means to effect this purpose, if they were of dimensions proportionate to the effects they are wished to produce. The addition of sails, were any variation from the wind is desired, will prove injurious till we have attained a method (perhaps only to be accomplished by oars) of keeping the same point of the balloon continually in a given direction. Yet we doubt not but these also might prove of great service in quick dispatches, by water; as, for instance, where it is required to pass a fortress or fleet for the succour of a besieged town, or convey dispatches thereto: a small balloon, of ten or twelve feet diameter, provided with sails to expose a large surface to the wind, being attached by a long rope to a boat, would outstrip the quickest vessel, and might also be made to deviate from the course of the wind; as the water would form a counter-resisting medium, the want of which in air balloons occasions the difficulty in steering them. A sail balloon similar to the above might also be advantageously attached to a land carriage; namely, by increasing the capacity of the balloon, so that its power of ascension being nearly equal to the weight of the appended carriage, the latter would be drawn along by the impulsion of the wind against the balloon and sails, while the friction over the ground, by the small overplus weight, may be reasonably expected to afford a resistance sufficient to guide the machine, and allow of a deviation in the carriage of at least eight points from the course of the wind. Indeed the uses of the art of aërostation, even in its present incomplete state, may be very considerable. Air balloons may serve the purpose of escaping from ships that cannot safely land, from besieged places, and from other circumstances of danger. They also expedite the communication of important events by signals, and serve for exploring from a great elevation adjacent coasts or regions, fleets and armies. Thus, the French ascribe to the elevation of a balloon, and the information obtained in consequence of thus reconnoitering the army of the enemy, the signal victory gained in the battle of Fleurus, in 1794. Balloons may likewise serve to explore and ascertain the nature of the air in the higher regions of the atmosphere. One of the finest experiments made on this point is that of Gay-Lussac; who, being elevated in a balloon to the height of 6900 metres (nearly eight miles) the greatest ever attained by any person, brought some atmospheric air from those regions, which on being analysed, was found to furnish the principles of oxygen, azote, hydrogen, and carbonic acid gas, in the same proportions as at the surface of the earth. Balloons would also enable us to determine the changes in the direction of the winds at different altitudes, and the law of the diminution of heat at different elevations. In fact, the application of these machines to the advancement of our knowledge of the various phænomena in meteorology stands prominent, as the, perhaps, only means of maturing our acquaintance with causes yet known only by their effects. Their use will also be indicated in many urgent cases where other means of conveyance might fall short. At the same time we conclude with remarking, that the hitherto unsuccessful attempts to render aërial navigation of service to mankind, ought to furnish no argument for causing it to be discouraged by men of sense, or prohibited by civil authority. Many arts and sciences from which commercial nations now derive so much benefit were long in rearing to maturity, and were only at length produced for the public good, in consequence of patient investigation and reiterated experiments.—Much useful information on the theory and practice of aërostation may be obtained from Baldwin's Aeropaidia, Cavallo on Aerostation, and Description des Experiences Aerostatiques, par M. Faujas St. Fond.

[*Pantologia.*

CHAP. V.

GASS LIGHTS.

SECTION I.

Introductory Remarks.

THE term gass or gas (from the German *gheist* or spirit, whence our own *ghost, ghostly, aghast, ghastly*) is used in modern chemistry, to express all those aerial fluids, whether produced by chemical experiments or evolved in natural processes, which are not condensible by the cold of our atmosphere, and which differ from atmospheric air, which is indeed a compound, consisting of three distinct gasses, as we have already observed in a former part of this work.

Of these fluids, some are inflammable, others not. Of the former, the chief are hydrogen, and the gass emitted from phosphorus. It is possible, however, that phosphorus itself is a compound of hydrogen and oxygen, with a peculiar base, and consequently, that hydrogen is the inflammable principle in this instance. Be this as it may, phosphorus, concerning which we shall treat presently, is by no means so easily procured as hydrogen, and hence, it is this last which is ordinarily had recourse to, in processes for the production of light or inflammation from gasseous substances.

We have observed in the preceding chapter on AEROSTATION, that the earlier name for hydrogen was *inflammable air*, a name indeed derived from this very principle of inflammability; its modern name was given it by Lavoisier, from its being found to be the chief constituent part or principle of water, which is now well known to be a compound, consisting of a larger portion of hydrogen, or inflammable air, and a smaller of oxygen, concerning which our readers may turn to the chapter on the constituent principles of WATER.

Hydrogen gass enters very largely into all animal, most vegetable, and a great variety of mineral compositions. It hence frequently set at liberty by fermentations, or spontaneous decompositions, is thrown forth from bogs and marshes, when, from a spark of natural electric fire, or some other accidental cause, it is often seen burning under the form of *ignes fatui*, or *will-o'-the-whisps*; is occasionally kindled by similar causes, in coal or metallic mines, with dreadful explosions and mischief, of which we have already given various examples in the preceding part of this work; and is collected at times from substances that possess it in the largest abundance, for purposes of ECONOMICAL ILLUMINATION.

It is under this last character that we are alone to consider it upon the present occasion. As the general principle of inflammations, all inflammable bodies necessarily contain it in a greater or less degree: such more especially as metals, alkohols, oils, and bitumens or coals of every kind, and it constitutes the fine blue or purest part of the flame emitted from a candle or a fire, when made with good round coals, that melt into pitch. Of these different substances, coals or bitumens may be obtained in the largest abundance, and with the greatest ease; and it is hence by a distillation of these, that the gass is usually procured, which is employed in gass lights. The means by which this is accomplished, the expence attending the process, and the great advantage of having recourse to it in extensive manufactories, or other places where large bodies or lengths of light are absolutely necessary, we shall now proceed to explain from a very valuable paper communicated to the Royal Society, by the ingenious artist and philosopher, who may justly be regarded as the inventor of the practical application of the light of hydrogen gass to useful purposes.

[*Editor.*

SECTION II.

Application of the Gass from Coal to economical Purposes.

By Mr. William Murdoch.

THE facts and results intended to be communicated in this paper, are founded upon observations made, during the present winter, at the cotton manufactory of Messrs. Philips and Lee at Manchester, where the light obtained by the combustion of the gass from coal is used upon a very large scale; the apparatus for its production and application having been prepared by me at the works of Messrs. Boulton, Watt, and Co. at Soho.

The whole of the rooms of this cotton mill, which is, I believe, the most extensive in the united kingdom, as well as its counting-houses and store-rooms, and the adjacent dwelling-houses of Mr. Lee, are lighted with the gass from coal. The total quantity of light used during the hours of burning, has been ascertained, by a comparison of shadows, to be about equal to the lights which 2500 mould candles of six to the pound would give; each of the candles, with which the comparison was made consuming at the rate of 4-10ths of an ounce (175 grains) of tallow per hour.

The quantity of light is necessarily liable to some variation, from the difficulty of adjusting all the flames, so as to be perfectly equal at all times; but the admirable precision and exactness with which the business of this mill is conducted, afforded as excellent an opportunity of making the comparative trials I had in view, as is perhaps likely to be ever obtained in general practice. And the experiments being made upon so large a scale, and for a considerable portion of time, may, I think, be assumed as a sufficiently accurate standard for determining the advantages to be expected from the use of the gass lights under favourable circumstances.

It is not my intention, in the present paper, to enter into a particular description of the apparatus employed for producing the gas; but I may observe generally, that the coal is distilled in large iron retorts, which during the winter season are kept constantly at work, except during the intervals of charging; and that the gass, as it rises from them, is conveyed by iron pipes into large reservoirs, or gazometers, where it is washed and purified, previous to its being conveyed through other pipes, called mains, to the mill. These mains branch off into a variety of ramifications (forming a total length of several miles), and diminish in size, as the quantity of gass required to be passed through them becomes less. The burners, where the gass is consumed, are connected with the above mains, by short tubes, each of which is furnished with a cock to regulate the admission of gass to each burner, and to shut it totally off when requisite. This latter operation may likewise be instantaneously performed, throughout the whole of the burners in each room, by turning a cock, with which each main is provided, near its entrance into the room.

The burners are of two kinds: the one is upon the principle of the Argand lamp, and resembles it in appearance; the other is a small curved tube with a conical end, having three circular apertures or perforations, of about a thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones, through which the gass issues, forming three divergent jets of flames, somewhat like a fleur-de lis. The shape and general appearance of this tube, has procured it among the workmen, the name of the cock-spur burner.

The number of burners employed in all the buildings, amounts to 271 Argands, and 633 cockspurs; each of the former giving alight equal to that of four candles of the description above-mentioned; and each of the latter, a light equal to two and a quarter of the same candles; making therefore the total of the gass light a little more than equal force to that of 2500 candles When thus regulated, the whole of the above burners require an *hourly* supply of 1250 cubic feet of the gass produced from cannel coal; the superior quality and quantity of the gass produced from that material having given it a decided preference in this situation, over every other coal, notwithstanding its higher price.

The time during which the gass light is used, may, upon an average of the whole year, be stated at least two hours per day of twenty-four hours. In some mills, where there is over work; it will be three hours; and in the few where night-work is still continued, nearly twelve hours. But taking two hours per day as the common average throughout the year, the consumption in Messrs. Philips' and Lee's mill, will be $1250 \times 2 = 2500$ cubic feet of gass per day; to produce which, seven hundred weight of cannel coal is required in the retort The price of the best Wigan cannel (the sort used) is 13½d. per cwt. (22s. per ton), delivered at the mill, or say about eight shillings for the seven hundred weight. Multiplying by the number of working days in the year (313), the annual consumption of cannel coal will be 110 tons, and its cost £ 125.

About one-third of the above quantity, or say forty tons of good common coal, value ten shillings per ton, is required for fuel to heat the retorts; the annual amount of which is £20.

The 110 tons of cannel coal when distilled, produce about 70 tons of good coak, which is sold upon the spot at 1s. 4d. per cwt. and will therefore amount annually to the sum of £ 93.

The quantity of tar produced from each ton of cannel coal is from eleven to twelve ale gallons, making a total annual produce of about 1230 ale gallons, which not having been yet sold, I cannot determine its value; but whenever it comes to be manufactured in large quantities, it cannot be such as materially to influence the economical statement, unless indeed new applications of it should be discovered.

The quantity of aqueus fluid which came over in the course of the observations which I am now giving an account of, was not exactly ascertained, from some springs having got into the reservoir; and as it has not been yet applied to any useful purpose, I may omit further notice of it in this statement.

The interest of the capital expended in the necessary apparatus and buildings, together with what is considered as an ample allowance for wear and tear, is stated by Mr. Lee at about £550. per annum: in which some allowance is made for this apparatus being made upon a scale adequate to the supply of a still greater quantity of light, than he has occasion to make use of.

He is of opinion, that the cost of attendance upon candles would be as much, if not more, than upon the gass apparatus; so that in forming the comparison, nothing need be stated upon that score, on either side.

The economical statement for one year then stands thus:

Cost of 110 tons of cannel coal .	£. 125
Ditto of 40 tons of common ditto .	20
	145
Deduct the value of 70 tons of coak .	93
The annual expenditure in coal, after deducting the value of the coak, and without allowing any thing for the tar, is therefore . .	52
And the interest of capital, and wear and tear of apparatus	550

making the total expense of the gass apparatus about £. 600 per annum.

That of candles, to give the same light, would be about £. 2000. For each candle consuming at the rate of 4-10ths of an ounce of tallow per hour, the 2500 candles burning, upon an average of the year, two hours per day, would, at one shilling per pound, the present price, amount to nearly the sum of money above-mentioned.

If the comparison were made upon an average of three hours per day, the advantage would be still more in favour of the gass light; the interest of the capital, and wear and tear of the apparatus, continuing nearly the same as in the former case; thus,

$1250 \times 3 = 3750$ cubic feet of gass per day, which would be produced by 10¾ cwt. of cannel coals; this multiplied by the number of working days, gives 168 tons per annum, which, valued

as before, amounts to . .	£. 188
And 60 tons common coal, for burning under the retorts, will amount to . .	30
	218
Deduct 105 tons of coak, at 26*s.* 8*d.* .	140
Leaving the expenditure in coal, after deduction of the coak, and without allowance for the tar, at	78

Adding to which the interest, and wear and tear of apparatus, as before, the total annual cost will not be more than £. 650; whilst that of tallow, rated as before, will be £. 3000.

It will readily occur, that the greater number of hours the gass is burnt, the greater will be its comparative economy; although, in extending it beyond three hours, an increase of some parts of the apparatus would be necessary.

If the economical comparison were made with oils, the advantages would be less than with tallow.

The introduction of this species of light, into the establishment of Messrs. Philips and Lee, has been gradual; beginning in the year 1805, with two rooms of the mill, the counting-houses, and Mr. Lee's dwelling-house. After which it was extended through the whole manufactory, as expeditiously as the apparatus could be prepared.

At first some inconvenience was experienced from the smell of the unconsumed, or imperfectly purified gas, which may in a great measure be attributed to the introduction of successive improvements in the construction of the apparatus, as the work proceeded. But since its completion, and since the persons to whose care it is confided, have become familiar with its management, this inconvenience has been obviated, not only in the mill, but also in Mr. Lee's house, which is most brilliantly illuminated with it, to the exclusion of every other species of artificial light.

The peculiar softness and clearness of this light, with its almost unvarying intensity, have brought it into great favour with the work-people. And its being free from the inconvenience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, as tending to diminish the hazard of fire, to which cotton mills are known to be much exposed.

The above particulars, it is conceived, contain such information as may tend to illustrate the general advantages attending the use of the gass light; but nevertheless the Royal Society may perhaps not deem it uninteresting to be apprized of the circumstances which originally gave rise in my mind to its application, as an economical substitute for oils and tallow.

It is now nearly sixteen years since, in a course of experiments I was making at Redruth, in Cornwall, upon the quantities and qualities of the gasses produced by distillation, from different mineral and vegetable substances, I was induced, by some observations I had previously made upon the burning of coal, to try the combustible property of the gasses produced from it, as well as from peat, wood, and other inflammable substances. And being struck with the great quantities of gass which they afforded, as well as with the brilliancy of the light, and the facility of its production, I instituted several experiments, with a view of ascertaining the cost at which it might be obtained, compared with that of equal quantities of light yielded by oils and tallow.

My apparatus consisted of an iron retort, with tinned copper and iron tubes, through which the gass was conducted to a considerable distance; and there, as well as at intermediate points, was burned through apertures of varied forms and dimensions. The experiments were made upon coal of different qualities, which I procured from distant parts of the kingdom, for the purpose of ascertaining which would give the most economical results. The gass was also washed with water, and other means were employed to purify it.

In the year 1798 I removed from Cornwall to Messrs. Boulton, Watt, and Co's. works for the manufactory of steam engines, at the Soho foundry, and there I constructed an apparatus, upon a larger scale, which, during many successive nights, was applied to the lighting of their principal building; and various new methods were practised, of washing and purifying the gass.

These experiments were continued, with some interruptions, until the Peace of 1802, when a public display of this light was made by me, in the illumination of Mr. Boulton's manufactory, at Soho, upon that occasion.

Since that period I have, under the sanction of Messrs. Boulton, Watt, and Co., extended the apparatus at Soho foundry, so as to give light to all the principal shops, where it is in regular use, to the exclusion of other artificial light; but I have preferred giving the results from Messrs. Philips' and Lee's apparatus, both on account of its greater extent, and the greater uniformity of the lights, which rendered the comparison with candles less difficult.

At the same time I commenced my experiments, I was certainly unacquainted with the circumstance of the gass from coal having been observed by others to be capable of combustion; but I am since informed, that the current of gass escaping from Lord Dundonald's tar ovens had been frequently fired; and I find that Dr. Clayton, in a paper in volume xli., of the Transactions of the Royal Society, so long ago as the year 1739, gave an account of some observations and experiments made by him, which clearly manifest his knowledge of the inflammable property of the gass, which he denominates "the spirit of coals;" but the idea of applying it as an economical substitute for oils and tallow, does not appear to have occurred to this gentleman; and I believe I may, without presuming too much, claim both the first idea of applying, and the first actual application of this gass to economical purposes. [*Phil. Trans.* 1808.

CHAP. VI.

PHOSPHORUS OF KUNCKEL *.

Phosphoric Bottles and Matches.

PHOSPHORUS is well known to be a peculiar substance capable of inflaming or emitting a luminous aura, when exposed to the air of the atmosphere in a common temperature, and hence the basis of those curious sticks, matches, and bottles, which have of late

* For other kinds of *phosphorus*, see the ensuing ch. vii.

years been devised for giving light instantly and spontaneously, as soon as they are uncovered and come in contact with the air.

This has hitherto been regarded as a simple combustible, and must be so regarded at present; though various experiments with very high degrees of voltaic electricity appear to have detected that it is a compound, possessing hydrogen and oxygen with a peculiar base. In consistence it resembles wax; when pure it is nearly of the transparency of gum opal, of a colour varying from amber red to the faintest straw, highly combustible, and when oxygenated producing a strong and peculiar acid.

It was discovered by a German chemist of the name of Brandt, about a hundred and fifty years ago, and the preparation was long kept a lucrative secret in the hands of a few persons. It was however well known, from various facts that had escaped, that it was procured in some way or other from human urine; and it has at length been found that it is in consequence of this substance containing a peculiar salt, hence denominated phosphoric salt (a mixture of phosphorus and oxygen), that phosphorus can be procured from it; as it has also that it can in like manner be procured from any other animal substance impregnated with the same material; and consequently from the bones and crustaceous integuments of animals, in which it exists in a larger abundance, and which are now therefore usually employed for this purpose.

One of the earliest chemists, next to Brandt, who devoted his attention in a very considerable degree towards obtaining this combustible was Kunckel. This chemist had seen the new product soon after its discovery by Brandt; and strongly desirous of possessing the secret, he associated himself with a friend of Brandt's, whose name was Krafft, through whom he made an offer to purchase the discovery of its inventor. Brandt consented to disclose it; but Krafft, instead of benefiting his colleague by the communication, paid the money, and retained the secret to himself.

Kunckel at this time knew nothing more of the preparation than that it was obtained by a series of processes from urine, through the medium of fire: and with this brief and unsatisfactory outline he set to work, and was at length fortunate enough to discover the method for himself; on which account the substance long went under the name of Kunckel's phosphorus. Mr. Boyle is also considered as one of the discoverers of phosphorus. He communicated the secret of the process of preparing it to the Royal Society of

London in 1680. It is asserted, indeed, by Krafft, that he discovered the secret to Mr. Boyle having in the year 1678, carried a small piece of it to London to show it to the royal family; but there is little probability that a man of such integrity as Mr. Boyle would claim the discovery of the process as his own, and communicate it to the Royal Society, if this had not been the case. Mr. Boyle communicated the process to Godfrey Hankwitz, an apothecary of London, who for many years supplied Europe with phosphorus, and hence it went under the name of English phosphorus. In the year 1774, the Swedish chemists, Gahn and Scheele, made the important discovery, that phosphorus is contained in bones of animals, and they improved the processes for procuring it.

The most convenient process for obtaining phosphorus seems to be that recommended by Fourcroy and Vauquelin, which we shall transcribe. Take a quantity of burnt bones, and reduce them to powder. Put 100 parts of this powder into a porcelain or stoneware bason, and dilute it with four times its weight of water. Forty parts of sulphuric acid are then to be added in small portions, taking care to stir the mixture after the addition of every portion. A violent effervescence takes place, and a great quantity of air is disengaged. Let the mixture remain for twenty-four hours, stirring it occasionally, to expose every part of the powder to the action of the acid. The burnt bones consist of the phosphoric acid and lime; but the sulphuric acid has a greater affinity for the lime than the phosphoric acid. The action of the sulphuric acid uniting with the lime, and the separation of the phosphoric acid, occasion the effervescence. The sulphuric acid and the lime combine together, being insoluble, and fall to the bottom. Pour the whole mixture on a cloth filter, so that the liquid part, which is to be received in a porcelain vessel, may pass through. A white powder, which is the insoluble sulphate of lime, remains on the filter. After this has been repeatedly washed with water, it may be thrown away; but the water is to be added to that part of the liquid which passed through the filter. Take a solution of sugar of lead in water, and pour it gradually into the liquid in the porcelain bason. A white powder falls to the bottom, and the sugar of lead must be added so long as any precipitation takes place. The whole is again to be poured upon a filter, and the white powder which remains is to be well washed and dried. The dried powder is then to be mixed with one-sixth of its weight of charcoal powder. Put this mixture into an earthenware retort, and place it in a sand bath, with the beak plunged into a vessel of water Apply heat, and let it be gradually increased, till the retort becomes red-hot. As the heat increases, air-bubbles rush in abundance through the beak of the retort, some of which are inflamed when they come in contact with the air at the surface of the water. A substance at last drops out similar to melted wax, which congeals under the water. This is phosphorus. To have it quite pure, melt it in warm water, and strain it several times through a piece of shamoy leather under the surface of the water. To mould it into sticks, take a glass funnel with a long tube, which must be stopped with a cork. Fill it with water, and put the phosphorus into it. Immerse the funnel in boiling water, and when the phosphorus is melted, and flows into the tube of the funnel, then plunge it into cold water, and when the phosphorus has become solid, remove the cork, and push the phosphorus from the mould with a piece of wood. Thus prepared, it must be preserved in close vessels, containing pure water. When phosphorus is perfectly pure, it is semi-transparent, and has the consistence of wax. It is so soft, that it may be cut with a knife. Its specific gravity is from 1.77 to 2.03. It has an acrid and disagreeable taste, and a peculiar smell, somewhat resembling garlic.

When a stick of phosphorus is broken, it exhibits some appearance of crystallization. The crystals are needle shaped, or long octahedrons; but to obtain them in their most perfect state, the surface of the phosphorus, just when it becomes solid, should be pierced, that the internal liquid phosphorus may flow out, and leave a cavity for their formation. When phosphorus is exposed to the light it becomes of a reddish colour, which appears to be an incipient combustion. It is therefore necessary to preserve it in a dark place. At the temperature of 99° it becomes liquid, and if air be entirely excluded, evaporates at 219°, and boils at 554. At the temperature of 43° or 44°, it gives out a white smoke, and is luminous in the dark. This is a slow combustion of the phosphorus, which becomes more rapid as the temperature is raised. When phosphorus is heated to the temperature of 148° it takes fire, burns with a bright flame, and gives out a great quantity of white smoke. Phosphorus enters into a combination with oxygen, azote, hydrogen, and carbon. Phosphorus is soluble in oils, and when thus dissolved forms what has been called liquid phosphorus, which may be rubbed on the face and hands without injury. It dissolves too in ether, and a very beautiful experiment consists in pouring this phosphoric ether in small portions, and in a dark place, on the surface of hot water. The phosphoric matches consist of phosphorus extremely dry, minutely divided, and perhaps a little oxygenized. The simplest mode of making them is to put a little phosphorus, dried by blotting paper, into a small phial; heat the phial, and when the phosphorus is melted turn it round, so that the phosphorus may adhere to the sides. Cork the phial closely, and it is prepared. On putting a common sulphur match into the bottle, and stirring it about, the phosphorus will adhere to the match, and will take fire when brought out into the air.

The white smoke given forth by phosphorus when exposed to a heat of 148°, appears when collected and examined to be an acid of a peculiar kind, and it is this which is now denominated phosphoric acid.

[*Pantologia. Aikin's Chem. Dict.*

CHAP. VII.

PNEUMATIC, OR TOUCHWOOD, TINDER-BOX.

THIS is a most useful, simple, yet curious machine, altogether of modern invention, bearing a near analogy to the phosphoric matches we have described in the preceding chapter; and which may consequently be employed for the same purposes.

TOUCHWOOD is the common, and we may say generic, name, given to a variety of substances that easily take fire, as rotten-wood and agaric, some of which occasionally emit spontaneous light in the dark.

The most inflammable touchwoods we are acquainted with are different species of the fungus called Boletus, such as B. igniarius, touchwood-spunk, and B. pini laricis, agaric: and a very curious fact has been lately discovered by the French chemists, in consequence of this combustibility, which may lead to useful and important purposes:- it is, that if a column of the flesh of either of the above species of boletus (spunk or touchwood) be introduced into a syringe, and pressed upon by its common piston, closing with great accuracy, it will catch fire from the mere compression of the column of air forced down upon it, and form a most convenient and ready tinder-box.

These machines, under the name of pneumatic, spunk, or touchwood-tinder-boxes are now common in France; and their origin, principle, and construction, have been so fully investigated and explained by M. Le Bouvier Desmortiers, in vol. lxvii. of the Journal de Physique, that we feel it our duty to copy at some length the paper for the information of our readers.

"The inflammation of spunk in the pneumatic tinder-box, by the compression of air alone, is a phænomenon, with which chance, the father of discovery, has lately enriched natural philosophy. Many have reasoned on its cause; which some consider to be caloric, others electricity; but no one, that I know of, has attempted to support his opinion by experiments. Without bias of any ypothesis, I have made some researches on the construction and effects of the pneumatic tinder-box, the results of which shall be the subject of the present paper. In the first place, I shall consider what relates to the structure of the instrument; in the second, I shall give an account of the experiments that tend to the discovery of the cause of its effects.

"I. The first construction of these tinder-boxes was a little faulty in the piston being commonly eighteen or twenty lines long. This was said to be necessary, that the air might not escape when the piston was in action; for if there were any point not accurately fitted to the inside of the tube, the air escapes, and the spunk does not kindle.

"The goodness of the instrument does not depend on the length of the piston, but on the accuracy with which it fills the bore of the tube; with a tube well bored and a piston of six lines, the air will no more pass than with a piston of twenty. Accordingly, for a tube of six inches I have reduced the piston to six lines, which adds an inch to the column of air, and diminishes the friction two-thirds, so that the effect of the tinder-box is more certain, and is more easily used. With a little dexterity you may kindle the spunk by holding the tube in one hand and pushing the piston with the other, without being obliged to rest it on a table, or any other solid body. Mr. Dumotiez, a skilful maker of philosophical instruments, is so fully convinced of the advantage of short pistons, that he now makes them of these dimensions.

"They should be employed also in the syringes of air-guns, of fountains acting by compressed air, of the apparatus for artificial mineral waters, of fire-engines, which are worked with so much labour, and even of air-pumps. As the shortening the piston is an advantage to the pump, we obtain a greater effect with less labour, and in a shorter time, than with long pistons.

"It is essential too, that the instrument does not leak at the part where the spunk is placed, because there the transient action of inflammation takes place, and a slight emission of air would prevent the effect, but this effect is produced, though the piston does suffer the air in the tube to pass it. To satisfy myself of this, I made the following experiment, at which they who have seen it were greatly surprised.

"In the length of the piston I made a groove a quarter of a line broad. The spunk took fire as before. Three other grooves were added successively opposite one another, so as to divide the piston into four equal parts; and still the spunk took fire. When the grooved piston is moved backwards and forwards in the tube, the air may be heard entering or issuing out; and the friction is so slight, that the effect of the instrument is easily obtained by pushing it with the hand. This kind of piston would be preferable to those that fit accurately, if a solid substance were employed, hard enough to resist the continual friction of the air passing through the grooves, if I may be allowed the expression. The grooves in leather pistons soon alter their shape, and spread so as to allow the air to pass in too large quantity.

"The piston with four grooves acting very well, I made one with a single groove, of dimensions equal to the other four, and what I foresaw actually took place: there was no inflammation. The following are the reasons of this difference.

"The extremity of the grooved pistons exhibits the area of a circle, the periphery of which touches the interior edge of the grooves. The column of air contained in the tube rests almost wholly on this base. There are only the parts corresponding to the grooves, that are continued through the length of the piston, and communicate with the external air. When the piston is pushed with sufficient velocity to kindle the spunk, the parts of the column corresponding to the grooves rush into them with equal velocity; but the friction they experience in passing through such narrow tubes occasions a resistance to their passage, a kind of choking, that suffers only a part to escape, while the column resting on the area of the piston is pushed entirely toward the extremity of the tube, where the spunk to be kindled lies.

"In the piston with a single broad groove, the area of the circle, on which the column of air rests, is much smaller, consequently the column itself is less. The resistance the air experiences in passing through the groove is next to nothing; for we hear no noise on moving the piston backward and forward; and as air expands in all directions, when the piston is moved, the column resting on the area of the circle, resting at the same time laterally on that which answers to the groove, it recedes from all the points of contact, and flows entirely through the channel it finds opens. It is so true, that it wholly flows out, that the piston, when it touches the extremity of the tube, remains there; while with other pistons a sufficient quantity of air is retained to occasion a spring and repel them.

"I think it proper to say a word or two on the quality of the spunk. The driest, softest, and least impregnated with nitre, should be chosen. In that of the best quality a piece will not always be found equally good throughout. Some contains a great deal of nitre, and is kindled with more difficulty*. This may be known by the cold taste it leaves on the tongue; or by kindling it: for when it has taken fire the nitre melts, and sometimes throws out sparks, that may be dangerous when they spirt out of the instrument, particularly if made with a cock. As it is usual to blow on the spunk, to try whether it be kindled, a spark may be thrown from it into the eye. This painful accident once happened to me.

"They who imagine that electricity kindles the spunk, consider these sparks as an incontrovertible proof of their opinion. I think they are mistaken in this case; yet I must not conceal a fact communicated to me by Mr. Veau-Delaunay, which seems to confirm this opinion, of which he is a partisan. Out of twelve times, when he operated with the instrument without any spunk in it, he saw sparks emitted three times. There are strong reasons, however,

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* The common spunk of the shops is prepared from agaric, which is first boiled in water; beaten well when dry; steeped in a strong solution of saltpetre; and lastly dried in an oven. If the solution of nitre be too strong, the agaric is loaded with this salt, which retards its inflammation.

for suspecting, that electricity is not the cause of the inflammation here. These I shall give in the second part of this paper, concluding the present with an important observation on the construction of pistons.

"If we could find an elastic substance sufficiently compact to be turned in a lathe, we should have perfect pistons, that would spring and adapt themselves to the inequalities of the tube, without suffering a bubble of air to escape. I have made some with caoutchouc, softened before the fire, in order to give it a degree of elasticity more obedient to the inequalities of the tube. But on attempting to turn it in a lathe, it bent under the tool. Even the edge of a razor would not take hold it; so that the piston remained uneven and almost ragged, and yielded like soft wax under the fingers. In this imperfect state it so far prevents the air from escaping, that a column of three inches is sufficient to kindle the spunk; but after a few strokes of the piston the heat dilates it to such a degree, that it cannot be moved without considerable force. If a drop of oil be put on it, it moves easily; but this soon spoils the instrument; for the oil dissolves the caoutchouc, and forms a varnish, which, as the piston grows hot, makes it adhere still more strongly to the sides of the tube.

"Might not these inconveniences be avoided, by arming the piston rod with caoutchouc, and covering this with leather? If this process succeeded, it might be applied with advantage to all sorts of pumps.

"To attain, if possible, a knowledge of the principle of inflammation in the pneumatic tinder box, four things are to be considered —the materials of the tube, the matter contained in the tube, the materials of the piston, and the friction. Among the materials of the piston I include the grease, with which it is coated, to make it move more easily, and render it fitter to intercept the passage of the air.

"In examining the question whether the spunk be kindled by electrity, I consider,

"1st, That no part of the instrument is insulated; and that insulation is a necessary condition for producing sensible electricity with any of the machines we know. I say machines that we know, because the animal electricity, that manifests itself without insulation, is an exception to our mechanical means, and cannot here be taken into consideration.

"2dly, The friction of the piston, which is a greasy body, against a metallic substance, is not calculated to produce electricity.

"3dly, Experience demonstrates, that, unless during storms, the atmosphere seldom exhibits any signs of electricity at the height in which we breathe it; and that we must search for them with instruments in a more elevated region, or when electric clouds are passing over our heads. How then shall we estimate the infinitely small quantity of electric matter in a cubic inch of air, or even less, which the instrument contains?

"4thly, It is not without great difficulty, that we can kindle spunk with strong electric sparks. I have discharged a large jar on spunk strewed with powdered resin, and it has remained unkindled, though the resin caught fire, and burned entirely away.

"As long as the instrument was made with metallic substances only, we were obliged to confine ourselves to the exterior marks of inflammation alone, without being able to assign the true cause, or at least furnish proofs of it. For to guess is not sufficient in natural philosophy; we must demonstrate, in order to give to facts that degree of certainty, which befits science; and this we cannot do here, without seeing what passes at the very point of inflammation.

"The means are very simple. Nothing is necessary, but to substitute a glass for a metal tube. Those found in the shops being too slight, I applied to Mr. Laurent, the inventor of glass flutes, requesting him to procure me tubes of a similar quality. This artist, as much distinguished by his civility as by his talents, furnished me with three, which I fitted up. The first eight inches long by eight lines in diameter, did not kindle the spunk. The second, nine inches long by six lines and three quarters in diameter, kindled it completely. This being destroyed by accident, I tried the third, eight inches long by seven lines in diameter, which succeeded equally well.

"When the instrument is made to act, and the spunk kindles, we see a bright flash, that fills the capacity of the tube; and this light is so much the more vivid, in proportion as the compression is more rapid. If the compression be less powerful, the spunk does not kindle, but we perceive in the upper part of the tube a light vapour, that falls in undulations on the piston. When this has disappeared, if we draw back the piston, the vapour will reappear, as long as there is any air in the tube. These effects may be produced several times in succession, merely by pushing the piston with the hand. This vapour is so thin and diaphanous, that it is not perceptible in a strong light. It requires a sort of twilight to see it well.

"But whence arises this vapour, and what is its nature? Assuredly it is not furnished by the materials of the instrument; it can only proceed, therefore, from what it contains, from the atmospheric air. Now, according to the present state of our knowledge, the air contains only nitrogen, oxygen, and a very small portion of carbonic acid; all gassiform substances, which are kept in this state by the great quantity of caloric that penetrates them, and are consequently heavier than it. But in compressing the air contained in the tube, what is the substance that must first give way? Is it not that which is lightest, the caloric, that general solvent, that principle of fluidity and volatilization, which gives wings even to metals to raise themselves in the air? Is then the vapour in question caloric, rendered visible by the approximation of its particles, which are compressed by the surrounding air, as air becomes visible in passing through liquids? This idea, which I am far from presenting as a thing proved, acquires more probability from the following experiments.

"I substituted hydrogen for common air, and the vapour showed itself as before; but the spunk did not take fire. With carbonic acid gass, and with nitrogen, the effects were the same. The latter, which contained a little nitrous gas, gave a somewhat denser vapour. Oxygen, lightly compressed, yielded a vapour more rare and transient than that from common air. It had scarcely fallen on the piston when it rebounded and disappeared. When I compressed oxygen with a proper force for producing inflammation, the spunk, which commonly takes fire only at the anterior part, was almost entirely burned: yet for this experiment I used a copper instrument, the piston of which lost air so much, that it would no longer kindle spunk (with common air).

"Perhaps it will be said, that the vapour came from the greasy matter on the piston, which adheres to the sides of the tube; and that it is expanded by the heat produced by the friction. To this I answer, in this case, 1st. The vapour should not shew itself before the greasy matter is deposited on the sides of the tube; yet it appears at the first stroke of the piston, before the tube becomes greasy. 2dly. It should show itself below the piston, in the part which the piston has left; but, on the contrary, it always shews above. 3dly. There is no vapour, when the piston loses much air, if the friction be ever so rapid. 4thly. The vapour should be more apparent, when the piston exerts its friction throughout the whole length of the tube, than when it is confined to a small part of its upper extremity; yet the reverse frequently happens. 5thly. When the air is entirely decomposed no more vapour appears, but it shows itself again, if ever so little fresh air be introduced.

"As it was essential to ascertain whether the vapour did not contain an acid principle, I fastened to the surface of the piston, with a little green wax, a piece of muslin dipped in infusion of litmus, and afterward dried. After twenty strokes of the piston the colour was not changed. I put on a second piece of muslin larger than the first, and the edges of which were loose. This was burned all round, without the colour of the rest being altered. Lastly, a third piece, which was wet, experienced no change of colour.

"From these experiments it follows, that no acid principle is developed; that all aëriform substances, as well as common air, produce a light vapour; that no other gass, except oxygen and common air, kindles the spunk; that oxygen produces a much more powerful combustion than common air, consequently oxygen acts an important part in the inflammation; that as it can exert its action only when set free by the decomposition of the common air, of which it constitutes a fourth part, it follows, that the air contained in the tube is decomposed by the simple force of compression; that the vapour produced is not owing to the oxygen, since it shows itself equally in gasses that contain no oxygen; that this vapour is the effect of some agent common to all gasses; and that we may presume it is caloric itself, rendered visible by the sudden approximation of its parts in a small space, where it rises to a temperature that is increased in the oxygen so as to kindle the spunk.

"It sometimes happens, that the spunk is turned black without kindling. In this case, as well as when it is kindled, if we draw back the piston in the tube, a dense vapour, that may be smelt, issues out, which is not of the same nature as the former. That shows itself before the inflammation: this always succeeds it. That is the principle of the inflammation: this a product furnished by the combustion of the spunk, of which it has the smell."

[*Le Bouvier. Desmortiers. Journ. de Physique.*

CHAP. VIII.

PHOSPHORESCENCE, OR SPONTANEOUS ILLUMINATION, ANIMAL, VEGETABLE, AND MINERAL.

THIS is a most extraordinary and interesting subject, and a perusal of the three preceding chapters will, in a considerable degree, enable the reader to understand its general principles, though there is much that has hitherto eluded pursuit, and still remains to be developed.

Phosphorescence, in its broadest latitude, imports light thrown forth from substances that at the same time emit little or no heat at the common temperature of the atmosphere, and which are denominated phosphoric.

The phosphorus properly so called, and which is usually understood in chemical books, and employed in chemical processes, is that commonly known by the name of Kunckel's phosphorus, and which we shall describe under that designation. But there are various other substances that possess, in different degrees, the same kind of illuminating power, and which it is hence necessary to take some notice of, as well as of the effects they produce.

Of these kinds the phosphorescent substances there are three leading divisions. The first comprehends those which require a previous exposure to the solar or other light, in order to become luminous; whence they are called solar phosphori: the second includes those which, without any necessary previous exposure to light, become luminous when moderately heated, which are denominated calorized phosphori, or phosphori from heat: the third comprehends those substances belonging to the animal and vegetable kingdoms, which emit light spontaneously at the common temperature, without the necessity of a previous exposure to light, and these are called spontaneous phosphori.

SECTION I.

Solar Phosphori.

A CASUAL discovery by Vincenzio Cascariolo, a shoemaker of Bologna, about 1630, was the first circumstance that attracted the notice of philosophers to this curious subject. This man being in quest of some alchemical secret was induced to calcine a parcel of Bolognian spar (a sub-species of heavy spar or native sulphat of baryte), which he had procured from Monte Paterno, in the neighbourhood of the city; and observed, that whenever this substance, thus prepared, was placed in a dark room, after having been exposed to the sun, it continued to emit faint rays of light for some hours afterwards.

In consequence of this interesting discovery, the Bolognian spar came into considerable demand among natural philosophers, and the curious in general, so that the best way of preparing it was found an object of some pecuniary importance. This seems to have been hit upon by the family of Zagoni, who supplied all Europe with Bolognian phosphorus, till the discovery of more powerful phosphoric put an end to their monopoly. Margraaf, some years afterwards, proved that other species of sulphated baryte might, under particular management, be made to produce a similar effect.

In the year 1677, nearly half a century after the discovery of the Bolognian phosphorus, G. A. Baldwin, a native of Misnia, observed, that if nitrat of lime were evaporated to dryness, and then formed into a compact mass by fusion at a red heat, it would exhibit the same property of imbibing and emitting light as the former, only somewhat inferior in degree: hence this preparation obtained the name of Baldwin's phosphorus.

In 1730, M. du Fay, who is justly celebrated for his electrical researches, directed his attention to this subject, and observed, that all earthy substances, susceptible of calcination, either by mere fire, or when assisted by the previous action of nitrous acid, possessed the property of becoming more or less luminous when calcined and exposed for a short time to the light: that the most perfect of these phosphori were limestones, and other kinds of carbonated lime, gypsum, and particularly the topaz; and that some diamonds were also observed to be luminous by simple exposure to the sun's rays, without being previously ignited; while flint, sand, jasper, agate, and rock crystal, were inphosphorescent.

Not long after, M. Beccaria discovered that a great variety of other bodies were convertible into phosphori, by exposure to the mere light of the sun; not only the varieties of carburet and sulphat of lime, but organic animal remains, and geodes lined with minute crystals of quartz; most compound salts, when clear and crystallized, particularly Glauber's nitre, and borax, were also found to be phosphorescent; of vegetable substances all the farinaceous and oily seeds, all the gums, and several of the resins, the white woods, and vegetable fibre, either in the form of paper or linen; also starch and loaf-sugar proved to be good phosphori, after being made thoroughly dry, and exposed to the direct rays of the sun. Sundry animal matters, by a similar treatment, were also converted into good phosphori, particularly bone, either fresh or calcined, sinew, glew, hair, horn, hooff, feathers, and fish shells. The same property, he observed, might be communicated to rock-chrystal, and some other of the gems, by rubbing them against each other, so as to roughen their surface, and then placing them for some minutes in the focus of a lens, by which the rays of light were concentrated upon them at the same time that they were also moderately heated.

In the year 1768, Mr. Canton contributed some important facts relative to solar phosphori, and communicated a method of preparing a very powerful one, which, after the inventor, is usually called Canton's phosphorus. It is thus made: Calcine oyster-shells in the open fire for half an hour; then select the widest and largest pieces, and mix them with flowers of sulphur in the proportion of one part of the latter to three parts of the former; pack the whole closely in a crucible; lute on a cover, and heat it pretty strongly for one hour; when the crucible has again become quite cold, turn out its contents, and select the whitest pieces for use. Mr. Canton affirms, that his phosphorus, inclosed in a glass flask, and hermetically sealed, retains its property of becoming luminous for at least four years, without any apparent decrease of activity.

Mr. Wilson found that a much greater brilliancy of colour would be produced by letting the oyster-shells come in direct contact with the burning coals, or other inflammable matter, and by being covered with it; and that if the covering matter be iron, the luminousness will be very bright; if steel, still brighter and more iridescent; but if plates of charcoal, most so of all.

If a common box smoothing-iron, heated in the usual manner, be placed for half a minute on a sheet of dry, white paper, and the paper be then exposed to the light, and afterwards examined in a dark closet, it will be found that the whole paper will be luminous, that part however on which the iron had stood being much more shining than the rest.

SECTION II.

Calorized Phosphori.

Besides those substances that are phosphorescent by exposure to the rays of the sun, there are others which give out light when simply heated. These materially differ from the former in this circumstance, that after having been continued at any particular temperature till their luminousness is exhausted, they are incapable of becoming again luminous, except at a greater heat than that to which they were first subjected. The range of temperature at which these bodies become luminous is not very extensive, commencing at about 400° Fahr. and terminating at the lowest visible red heat. The following is a list of substances exhibiting this, properly arranged by Mr. S. Wedgewood, according to the brilliancy of the light.

That variety of the blue fluor spar of Derbyshire, which, when scraped or struck, emits a fetid, bituminous odour, is the most phosphorescent by heat of all the known substances: it glows, when moderately heated, with a pale emerald green light, sufficiently intense to be very visible even in daylight. To the second rank belong the common swine-stone, the common blue fluor, and red fel-spar, all which, as well as the following, exhibit a white or reddish light. The third class includes the diamond, the ruby, carbonated baryte, chalk, colourless calcareous spar, sea-shells, granite, and white fluor. The fourth class comprehends white sand, carbonated magnesia, heavy spar, flint, white marble, quartz, porcelain and earthen ware. The fifth class includes most of the metals, sulphat of potash, borax, white paper, white linen, sawdust, and asbestos. Under the sixth and last class are comprehended oil, wax, spermaceti, and butter when boiling or nearly so. Most of these are also phophorescent by friction.

SECTION III.

Animal and Vegetable Phosphori.

It is a curious fact, and though occasionally noticed, not generally attended to till of late years, that various animal and vegetable substances have a power of throwing forth light under particular circumstances; some of them while living, and others not till after death. We shall first notice the general history of this extraordinary fact, and the observations upon it which first suggested themselves to those who remarked and examined it, and afterwards glance at a few of the numerous modes of which it has of late years been attempted to be accounted for.

General History and earliest Notices.

That light occasionally proceeds from putrescent animal and vegetable substances, as well as from living glow-worms, was noticed by Aristotle. Columba, an industrious naturalist, observed long after, that several insects emitted light, and that such light is not extinguished immediately upon the death of the animal. But the first distinct account that we meet with of light proceeding from putrescent animal flesh, is that which is given by Fabricius ab Aquapendente, (De Visione, p. 45.) who says, that when three Roman youths, residing at Padua, had bought a lamb, and had eaten part of it on Easter-day, 1492, several pieces of the remainder, which they kept till the day followiug, shone like so many candles when they were casually viewed in the dark. Part of this luminous flesh was immediately sent to Aquapendente, who was professor of anatomy in that city. He observed, that both the lean and the fat of this meat shone with a whitish kind of light, and also took notice, that some pieces of kid's flesh, which had happened to have lain in contact with it, were luminous, as well as the fingers and other parts of the bodies of those persons who touched it. Those parts, he observed, shone the most which were soft to the touch, and seemed to be transparent in candle-light; but where the flesh was thick and solid, or where a bone was near the outside, it did not shine.

From this period we must descend to the era of Thomas Bartholin, before we meet with any similar notice. This writer, in a distinct treatise *De luce* animalium (p. 183, 206) mentions four kinds of luminous insects, two of which were possessed of wings, and two wingless, or apterous. He also takes notice of one instance in which it was observed to issue from dead matter. This happened at Montpelier in 1641, when a poor old woman had bought a piece of flesh in the market, intending to make use of it the day following. But happening not to be able to sleep well that night, and her bed and pantry being in the same room, she observed so much light come from the flesh, as to illuminate all the place where it hung. A part of this luminous flesh was carried as a curiosity to Henry Bourbon, duke of Condé, the governor of the place, who viewed it for several hours with the greatest astonishment.

This light was observed to be whitish; and not to cover the whole surface of the flesh, but certain parts only, as if gems of unequal splendour had been scattered over it. This flesh was kept till it began to putrify, when the light vanished; which, as some religious people fancied, it did in the form of a cross.

Boyle tried the effect of his air-pump upon these luminous substances; and found that the light of rotten wood was extinguished in vacuo, and revived again on the admission of the air, even after a long continuance in vacuo; but the extinguishing of this light was not so complete immediately upon exhausting the receiver, as some little time afterwards. He could not perceive, however, that the light of rotten wood was increased in condensed air; but this, he imagined, might arise from his not being able to judge very well of the degree of light, through so thick and cloudy a glass vessel as he then made use of; but we find that the light of a shining fish, which was put into a condensing engine before the Royal Society, in 1668, was rendered more vivid by that means. The principal of Mr. Boyle's experiments were made in October, 1667.

This philosopher attended to a great variety of circumstances relating to this curious phenomenon. Among other things, he observed, that change of air was not necessary to the maintenance of this light; for it continued a long time when a piece of the wood was put into a very small glass hermetically sealed, and it made no difference when this tube which contained the wood was put into an exhausted receiver. This he also observed with respect to a luminous fish, which he put into water, and placed in the same circumstances. He also found, that the light of shining fishes had other properties in common with that of shining wood; but the latter, he says, was presently quenched with water, spirit of wine, a great variety of saline mixtures, and other fluids. Water, however, did not quench all the light of some shining veal on which he tried it, though spirit of wine destroyed its virtue presently.

Mr. Boyle's observation of light proceeding from flesh-meat was quite casual. On the 15th of February, 1662, one of his servants was greatly alarmed with the shining of some veal, which had been kept a few days, but had no bad smell, and was in a state very proper for use. The servant immediately made his master acquainted with this extraordinary appearance; and though he was then in bed, he ordered it to be immediately brought to him, and he examined it with the greatest attention. Suspecting that the state of the atmosphere had some share in the production of this phenomenon, he takes notice, after describing the appearance, that the wind was south-west and blustering, the air hot for the season, the moon was past its last quarter, and the mercury in the barometer was at 29 3-16th inches.

Mr. Boyle was often disappointed in his experiments on shining fishes; finding that they did not always shine in the very same circumstances, as far as he could judge, with others which had shined before. At one time that they failed to shine, according to his expectations, he observed that the weather was variable, and not without some days of frost and snow. In general he made use of whitings, finding them the fittest for his purpose. In a discourse, however, upon this subject at the Royal Society, in 1681, it was asserted, that, of all fishy substances, the eggs of lobsters, after they had been boiled, shone the brightest. Olig. Jacobæus observes*, that, upon opening a sea polype, it was so luminous as to startle several persons who saw it; and he says (but incorrectly according to later experiments) that the more putrid the fish was, the more luminous it grew. The nails also, and the fingers of the persons who touched it, became luminous; and the black liquor which issued from the animal, and which is its bile, shone also, but with a very faint light.

Mr. Boyle draws a minute comparison between the light of burning coals and that of shining wood or fish, showing in what particulars they agree, and in what they differ. Among other things he observes, that extreme cold extinguishes the light of shining wood, as appeared when a piece of it was put into a glass tube, and held in a frigorific mixture, a fact which minutely agrees with Dr. Holmes' more modern experiments upon dead animal matter. He also found that rotten wood did not waste itself by shining, and that the application of a thermometer to it did not discover the least degree of heat.

The shell-fish called pholas, or phloas, which forms for itself holes in various kinds of stone, &c. was one of the earliest subjects

* Act. Hafn. vol. v. p. 282.

of attention. That this fish is luminous was noticed by Pliny; who observes, that it shines in the mouth of the person who eats it, and, if it touch his hands or clothes, makes them luminous. He also says, that the light depends upon its moisture.

Reaumur observes, that, while other fishes give light when they tend to putrescence, this is more luminous in proportion to its being fresh; that when they are dried, their light will revive if they be moistened either with fresh or salt water, but that brandy immediately extinguishes it. He endeavoured to make this light permanent, but none of his schemes succeeded.

The attention of the Bolognian academicians was engaged to this subject by M. F. Marsigli, in 1724, who brought a number of these fishes, and the stones in which they were inclosed, to Bologna, on purpose for their examination.

Beccaria observed, that though this fish ceased to shine when it was putrid, yet that in its most putrid state, it would shine, and make the water in which it was immersed luminous, when they were agitated. Galeati and Monti found, that wine or vinegar extinguished this light: that in common oil it continued some days; but in rectified spirit of wine or urine, hardly a minute.

In order to observe in what manner this light was affected by different degrees of heat, they made use of Reaumur's thermometer, and found that water rendered luminous by these fishes increased in light till the heat arrived to 45 degrees; but that it then became suddenly extinct, and could not be revived.

In the experiments of Beccaria, a solution of sea salt increased the light of the luminous water, a solution of nitre did not increase it quite so much; sal ammoniac diminished it a little; oil of tartar per deliquium nearly extinguished it; and the acids entirely. This water poured upon fresh calcined gypsum, rock crystal, ceruss, or sugar, became more luminous. He also tried the effects of it when poured upon various other substances, but there was nothing very remarkable in them. Afterwards, using luminous milk, he found that oil of vitriol extinguished the light, but that oil of tartar increased it.

This gentleman had the curiosity to try how differently-coloured substances were affected by this kind of light; and having, for this purpose, dipped several ribbons in it, the white came out the brightest, next to this was the yellow, and then the green; the other colours could hardly be perceived. It was not, however, any particular colour, but only light that was perceived in this case. He then dipped boards painted with the different colours, and also glass tubes, filled with substances of different colours, in water rendered luminous by fishes. In both these cases the red was hardly visible, the yellow was the brightest, and the violet the dullest. But on the boards the blue was nearly equal to the yellow, and the green more languid; whereas in the glasses, the blue was inferior to the green.

Of all the liquors into which he put the phloades, milk was rendered the most luminous. A single phloas made seven ounces of milk so luminous, that the faces of persons might be distinguished by it, and it looked as if it was transparent.

Air appeared to be necessary to this light; for when Beccaria put the luminous milk into glass tubes, no agitation would make it shine, unless bubbles of air were mixed with it. Also Monti and Galeati found, that, in an exhausted receiver, the phloas lost its light, but the water was sometimes made more luminous; which they ascribed to the rising of bubbles of air through it.

Beccaria, as well as Reaumur, had many schemes to render the light of these phloades permanent. For this purpose he kneaded the juice into a kind of paste, with flour, and found that it would give light when it was immersed in warm water; but it answered best to preserve the fish in honey. In any other method of preservation, the property of becoming luminous would not continue longer than six months, but in honey it had lasted above a year; and then it would, when plunged in warm water, give as much light as ever it had done.

Similar, in some respects, to those observations on the light of the phloas, was that which was observed to proceed from wood which was moist, but not in a putrid state, which was very conspicuous in the dark.

That the sea is sometimes luminous, especially when it is put in motion by the dashing of oars or the beating of it against a ship, has been observed with admiration by a great number of persons. Mr. Boyle, after reciting all the circumstances of this appearance, as far as he could collect them from the accounts of navigators; as its being extended as far as the eye could reach, and at other times being visible only when the water was dashed against some other body; that, in some seas, this phenomenon is accompanied by some particular winds, but not in others; and that sometimes on part of the sea will be luminous, when another part, not far from it, will not be so; concludes with saying, that he could not help suspecting that these odd phænomena, belonging to great masses of water, were in some measure owing to some cosmical law or custom of the terrestrial globe, or at least of the planetary vortex.

Some curious observations on the shining of some fishes, and the pickle in which in they were immersed, were made by Dr. Beal, in May 1665, and, had they been properly attended to and pursued, might have led to the discovery of the cause of this appearance. Having put some boiled mackarel into water, together with salt and sweet herbs; when the cook was some time after stirring it, in order to take out some of the fishes, she observed, that, at the first motion, the water was very luminous; and that the fish shining through the water added much to the light which the water yielded. The water was of itself thick and blackish, rather than of any other colour; and yet it shined on being stirred, and at the same time the fishes appeared more luminous than the water. Wherever the drops of this water, after it had been stirred, fell to the ground, they shined; and the children in the family diverted themselves with taking the drops, which were as broad as a penny, and running with them about the house. The cook observed, that when she turned up that side of the fish that was lowest, no light came from it; and that, when the water had settled for some time, it did not shine at all. The day following, the water gave but little light, and only after a brisk agitation, though the fishes continued to shine as well from the inside as the outside, and especially about the throat, and such places as seemed to have been a little broken in the boiling.

When, in the light of the sun, he examined with a microscope, a small piece of a fish which had shined very much the night before, he found nothing remakable on its surface, except that he thought he perceived what he calls a steam, rather dark than luminous, arising like a very small dust from the fish, and here and there a very small and almost imperceptible sparkle. Of these sparkles he had no doubt; but he thought it possible that the steam might be a deception of the sight, or some dust in the air.

Finding the fish to be quite dry, he moistened it with his spittle; and then observed that it gave a little light, though but for a short time. The fish at that time was not fetid, nor yet insipid to the best discerning palate. Two of the fishes he kept two or three

three days longer for farther trial; but the weather being very hot, they became fetid; and, contrary to his expectations, there was no more light produced either by the agitation of the water or in the fish.

Father Bourzes, in his voyage to the Indies in 1704, took particular notice of the luminous appearance of the sea. The light was sometimes so great, that he could easily read the title of a book by it, though he was nine or ten feet from the surface of the water. Sometimes he could easily distinguish, in the wake of the ship, the particles that were luminous from those that were not; and they appeared not to be all of the same figure. Some of them were like points of light, and others such as stars appear to the naked eye. Some of them were like globes, of a line or two in diameter; and others as big as one's head. Sometimes they formed themselves into squares of three or four inches long, and one or two broad. Sometimes all these different figures were visible at the same time; and sometimes there were what he calls vortices of light, which at one particular time appeared and disappeared immediately like flashes of lightning.

Nor did only the wake of the ship produce this light, but fishes also, in swimming, left so luminous a track behind them, that both their size and species might be distinguished by it. When he took some of the water out of the sea, and stirred it ever so little with his hand, in the dark, he always saw in it an infinite number of bright particles; and he had the same appearance whenever he dipped a piece of linen in the sea, and wrung it in a dark place, even though it was half dry; and he observed, that when the sparkles fell upon any thing that was solid, it would continue shining for some hours together.

After mentioning several circumstances which did not contribute to this appearance, this Father observes, that it depends very much upon the quality of the water; and he was pretty sure that this light is the greatest when the water is fattest, and fullest of foam. For in the main sea, he says, the water is not every where equally pure; and that sometimes, if linen be dipped in the sea, it is clammy when it is drawn up again: and he often observed, that when the wake of the ship was the brightest, the water was the most fat and glutinous, and that linen moistened with it produced a great deal of light, if it was stirred or moved briskly. Besides, in some parts of the sea, he saw a substance like saw-dust, sometimes red and sometimes yellow; and when he drew up the water in those places, it was always viscous and glutinous. The sailors told him, that it was the spawn of whales: that there are great quantities of it in the north, and that sometimes, in the night, they appeared all over of a bright light, without being put in motion by any vessel or fish passing by them.

As a confirmation of this conjecture, that the more glutinous the sea water is, the more it is disposed to become luminous, he observes, that one day they took a fish that was called a bonite, the inside of the mouth of which was so luminous, that, without any other light, he could read the same characters which he had before read by the light in the wake of the ship; and the mouth of this fish was full of a viscous matter, which, when it was rubbed upon a piece of wood, made it immediately all over luminous; though, when the moisture was dried up, the light was extinguished.

The abbé Nollet was much struck with the luminousness of the sea when he was at Venice in 1749; and after taking a great deal of pains to ascertain the circumstances of it, concluded that it was occasioned by a shining insect; and having examined the water very often, he at length did find a small insect, which he particularly describes, and to which he attributes the light. The same hypothesis had also occurred to M. Vianelli, professor of medicine in Chioggia, near Venice; and both he and M. Grizellini, a physician in Venice, have given drawings of the insects from which they imagined this light to proceed.

The abbé was the more confirmed in this hypothesis, by observing, some time after, the motion of some luminous particles in the sea. For, going into the water, and keeping his head just above the surface, he saw them dart from the bottom, which was covered with weeds, to the top, in a manner which he thought very much resembled the motions of insects; though, when he endeavoured to catch them, he only found some luminous spots upon his handkerchief, which were enlarged when he pressed them with his finger.

M. Le Roi, making a voyage on the Mediterranean, presently after the abbé Nollet made his observations at Venice, took notice, that in the day-time the prow of the ship in motion threw up many small particles, which, falling upon the water, rolled upon the surface of the sea for a few seconds before they mixed with it; and in the night the same particles, as he concluded, had the appearance of fire. Taking a quantity of the water, the same small sparks appeared whenever it was agitated; but, as was observed with respect to Dr. Beal's experiments, every successive agitation produced a less effect than the preceding, except after being suffered to rest awhile; for then a fresh agitation would make it almost as luminous as the first. This water, he observed, would retain its property of shining by agitation a day or two; but it disappeared immediately on being set on the fire, though it was not made to boil.

M. Ant. Martin made many experiments on the light of fishes, with a view to discover the cause of the light of the sea. He thought that he had reason to conclude, from a great variety of experiments, that all sea-fishes have this property; but that it is not to be found in any that are produced in fresh water. Nothing in his opinion depended upon the colour of the fishes, except that he thought that the white ones, and especially those that had white scales, were a little more luminous than others. This light, he found, was increased by a small quantity of salt; and also by a small degree of warmth, though a greater degree extinguished it. This agrees with another observation of his, that it depends entirely upon a kind of moisture which they had about them, and which a small degree of heat would expel, when an oiliness remained which did not give this light, but would burn in the fire. Light from the flesh of birds or beasts is not so bright, he says, as that which proceeds from fishes. Human bodies, he says, have sometimes emitted light about the time that they began to putrify, and the walls and roof of a place in which dead bodies had often been exposed, had a kind of dew or clamminess upon it, which was sometimes luminous; and he imagined that the lights which are said to be seen in burying-grounds may be owing to this cause.

From some experiments made by Mr. Canton, he concludes, that the luminousness of sea-water is owing to the slimy and other putrescent substances it contains. On the evening of the 14th of June 1768, he put a small fresh whiting into a gallon of sea-water, in a pan which was about fourteen inches in diameter, and took notice that neither the whiting nor the water, when agitated, gave any light. A Fahrenheit's thermometer, in the cellar where the pan was placed, stood at 54°. The 15th, at night, that part of the fish which was even with the surface of the water was luminous, but the water itself was dark. He drew the end of the stick through it, from one side of the pan to the other, and the water appeared luminous behind the stick all the way, but gave light only where it was disturbed. When all the water was stirred, the whole became luminous, and appeared like milk, giving a considerable degree of light to the side of the pan; and it continued to do so for some time after it was at rest. The water was most luminous when the fish had been in it about twenty-eight hours; but would not give any light by being stirred, after it had been in it three days.

He then put a gallon of fresh water into one pan, and an equal quantity of sea-water into another, and into each pan he put a fresh herring of about three ounces. The next night the whole surface of the sea-water was luminous, without being stirred: but it was much more so when it was put into motion; and the upper part of the herring, which was considerably below the surface of the water, was also very bright; while at the same time the fresh water, and the fish that was in it, were quite dark. There were several very bright luminous spots on different parts of the surface of the sea-water; and the whole, when viewed by the light of a candle, seemed covered with a greasy scum. The third night, the light of the sea-water, while at rest, was very little, if at all, less than before; but when stirred its light was so great as to discover the time by a watch, and the fish in it appeared as a dark substance. After this its light was evidently decreasing, but was not quite gone before the 7th night. The fresh water and the fish in it were perfectly dark during the whole time. The thermometer was generally above 60°.

The preceding experiments were made with sea-water; but he now made use of other water, into which he put common or sea-salt, till he found by an hydrometer that it was of the same specific gravity with the sea-water; and, at the same time, in another gallon of water, he dissolved two pounds of salt, and into each of these waters he put a small fresh herring. The next evening the whole surface of the artificial sea-water was luminous without being stirred; but gave much more light when it was disturbed. It appeared exactly like the real sea-water in the preceding experiment; its light lasted about the same time, and went off in the same manner: while the other water, which was almost as salt as it could be made, never gave any light. The herring which was taken out of it the seventh night, and washed from its salt, was found firm and sweet; but the other herring was very soft and putrid, much more so than that which had been kept as long in fresh water. If a herring, in warm weather, be put into ten gallons of artificial sea-water, instead of one, the water, he says, will still become luminous, but its light will not be so strong.

It appeared by some of the first observations on this subject, that heat extinguishes the light of putrescent substances. Mr. Canton also attended to this circumstance; and observes, that though the greatest summer heat is well known to promote putrefaction, yet twenty degrees more than that of the human blood seems to hinder it. For putting a small piece of a lumious fish into a thin glass ball, he found, that water of the heat of 118 degrees would extinguish its light in less than half a minute; but that, on taking it out of the water, it would begin to recover its light in about ten seconds; but it was never afterwards so bright as before.

Mr. Canton made the same observation that Mr. Ant. Martin had done, viz. that several kinds of river fishes could not be made to give light, in the same circumstances in which any sea-fish became luminous. He says, however, that a piece of carp made the water very luminous, though the outside, or scaly part of it, did not shine at all.

For the sake of those persons who may choose to repeat his experiments, he observes, that artificial sea-water may be made without the use of an hydrometer, by the proportion of four ounces avoirdupois of salt, to seven pints of water, wine-measure.

From undoubted observations, however, it appears, that in many places of the ocean it is covered with luminous insects to a very considerable extent. Mr. Dagelet, a French astronomer, who returned from the Terra Australis, in the year 1774, brought with him several kinds of worms, which shine in water when it is set in motion; and M. Rigaud, in a paper inserted (if we are not mistaken) in the Journal des Sçavans, for the month of March, 1770, affirms, that the luminous surface of the sea, from the port of Brest, to the Antilles, contains an immense quantity of little, round, shining polypuses, of about a quarter of a line in a diameter. Other learned men, who acknowledge the existence of these luminous animals, cannot, however, be persuaded to consider them as the cause of all that light and scintillation that appear on the surface of the ocean: they think that some substance of the phosphorus kind, arising from putrefaction, must be admitted as one of the causes of this phenomenon. M. Godhou has published curious observations on a kind of fish called, in French, *bonite*, already mentioned; and though he has observed, and accurately described, several of the luminous insects that are found in sea-water, he is, nevertheless, of opinion, that the scintillation and flaming light of the sea proceed from the oily and greasy substances with which it impregnated.

The abbé Nollet was long of opinion, that the light of the sea proceeded from electricity, though he afterwards seemed inclined to think, that this phenomenon was caused by small animals, either by their luminous aspect, or at least by some liquor or effluvia which they emitted. He did not, however, exclude other causes; among these, the spawn or fry of fish deserves to be noticed. M. Dagelet, sailing into the bay of Antogil, in the island of Madagascar, observed a prodigious quantity of fry, which covered the surface of the sea above a mile in length, and which he at first took for banks of sand, on account of their colour; they exhaled a disagreeable odour, and the sea had appeared with uncommon splendor some days before. The same accurate observer, perceiving the sea remarkably luminous, in the road to the Cape of Good Hope, during a perfect calm, remarked, that the oars of the canoes produced a whitish and pearly kind of lustre; when he took in his hand the water which contained this phosphorus, he discerned in it, for some minutes, globules of light as large as the heads of pins. When he pressed these globules, they appeared to his touch like a soft and thin pulp; and some days after the sea was covered, near the coasts, with whole banks of these little fish, in innumerable multitudes.

To putrefaction, also, some are willing to attribute that luminous appearance which goes by the name of Ignis Fatuus. It is most frequently observed in boggy places, and near rivers, though sometimes also in dry places. By its appearance, benighted travellers are said to have been sometimes misled into marshy places, taking the light which they saw before them for a candle at a distance; from which seemingly mischievous property it has been thought, by the vulgar, to be a spirit of a malignant nature, and been named accordingly Will-with-a-wisp, or Jack-with-a-lanthorn; for the same reason also it probably had its Latin name ignis fatuus.

This kind of light is said to be frequent about burying places and dung-hills. Some countries are also remarkable for it, as about Bologna, in Italy; and some parts of Spain and Ethiopia. We have noticed and endeavoured to account for this phenomenon already: but as the following curious example of it has escaped us, we will notice it now. It is given by Doctor Shaw, in his Travels to the Holy Land.

It appeared in the valleys of mount Ephraim, and attended him and his company for more than an hour. Sometimes it would appear globular, or in the shape of the flame of a candle; at others it would spread to such a degree as to involve the whole company in a pale inoffensive light, then contract itself, and suddenly disappear; but in less than a minute would appear again; sometimes running swiftly along, it would expand itself at certain intervals, over more than two or three acres of the adjacent mountains. The atmosphere, from the beginning of the evening, had been remarkably thick and hazy; and the dew, as they felt it on the bridles of their horses, was very clammy and unctuous.

We have also already observed that lights resembling the ignis fatuus are sometimes to be met with at sea, skipping about the masts and rigging of ships; and Dr. Shaw informs us, that he has seen these in such weather as that just mentioned, when he saw the ignis fatuus in Palestine. Similar appearances have been observed in various other situations; and we are told of one which appeared about the bed of a woman in Milan, surrounding it, as well as her body, entirely. This light fled from the hand which approached it; but was at length entirely dispersed by the motion of the air.

Philosophy of Spontaneous Illumination.

It is a fact now fully ascertained and rendered incontestable, that light has a considerable influence upon all animal and vegetable living substances, exposed to its influence: that all imbibe it in some degree, and many rapidly and voraciously. Most of the discous flowers, by some power unknown to us, follow the sun in his course. They attend him to his evening retreat, and meet his rising lustre in the morning with the same unerring law. If a plant also is shut up in a dark room, and a small hole is afterwards opened by which the light of the sun may enter, the plant will turn towards that hole, and even alter its own shape in order to get near it; so that though it was straight before, it will in time become crooked, that it may get near the light. It is not the heat, but the light of the sun, which it thus covets; for, though a fire be kept in the room, capable of giving a much stronger heat than the sun, the plant will turn away from the fire in order to enjoy the sun's light. The green colour of plants also depends on the sun's light being allowed to shine upon them; for without this they are always white.

With the various secretions, and even solid parts of many of these substances, the matter of light unites most intimately; in other classes of animals and vegetables it exists more loosely, and consequently is more easily separated from them.

This separation appears to take place in two ways: first during life, by a peculiar set of organs, which have a power of secreting it from the general fluids of the rest of the body; and secondly, by the tendency to decomposition, which uniformly takes place upon death; in consequence of which, agreeably to the universal law of chemical affinity, homogeneous particles unite themselves with homogeneous particles, and escape in a more sensible, because in a more aggregate and concentrated form.

Upon this simple view of the subject we may easily account for all the phænomena noticed by successive observers, and narrated in the preceding part of this article, as well as for a variety of others of a similar character. The light thus thrown forth was till very lately regarded as phosphorescent, especially by Spallanzani and Fourcroy; while Caradin believed it to be innate, and formed by some chemical process of the organs of the animal exhibiting it. That it is not of a phosphoric nature is clearly proved, because it is in no instance, and in no respect inflammable; and hence we have preferred to treat upon this subject under the present title, rather than under that of *phosphorescent substances*, the title generally selected by which to characterize them. But whether it be not in some instances generated internally, instead of being derived ab extra, is by no means equally well ascertained. Many luminous animals appear to shun the light of the day, and seem scarcely to expose themselves sufficiently to its influence, to be able to throw forth such a quantity as we see issue from their bodies. Yet, on the other hand, it should not be forgotten that almost all substances whatever, mineral as well as animal and vegetable, and gasseous and liquid as well as solid, absorb and contain a great quantity of latent light, a part of which may enter into the bodies of luminous animals, in the form of food, and may be separated from its respective combinations by its luminous organs.

Living luminous Substances.

These are very numerous, though they have never hitherto been arranged into any distinct classification, or tabular form. They consist chiefly, and almost exclusively, of *insects and zoophytes; molluscous worms;* though instances are occasionally met with among other worms. Insects furnish nearly a dozen distinct genera, of which almost all the species are luminous. The chief are the lampyris, or glow-worm, and fire-fly tribes; the fulgora, or lantern-fly; the scolopendra, or centipede; the fausus spœrocenus; the elater noctilucus, and the cancer fulgens. Among the worm-class the principal are the phloas, or pholas, as it is now generally, but erroneously denominated, the pyrosoma, the medusa phosphorea, the nereis noctiluca, the pennatula, or sea-pen, and various species of the sepia or cuttle-fish. The atmosphere in some parts of Italy appears occasionally to be on fire, in the evening, from the great quantities of one species of the lampyris that throng together. A single individual of the South-American fulgora, fixed upon the top of a cane, or other staff, will afford light enough to read by. The streams of light that issue from the elater noctilucus are so strong in the night, that even the smallest print may be read by their lustre. The pyrosoma, when at rest, emits a pale blue lustre; but when in motion a much stronger light, variegated by all the colours of the rainbow. The phloas secretes a luminous juice, every drop of which illuminates, for a length of time, whatever substance it falls upon, or even touches; and the animal, after death, may be preserved so as to retain its luminous power for at least a twelvemonth. The noctilucent nereis often illuminates, by its numbers, the waters it inhabits, to a very considerable extent; and gives so bright a splendour to the waves that, like the atmosphere when lighted up by the lampyris italica, they appear as though they were in a full flame. The organ from which the luminous matter is thrown forth, in these different animals, is of a very different character, and placed in very different parts of the body; sometimes in the head, sometimes in the tail, sometimes in the antennas, sometimes over the surface generally.

Dead luminous Substances.

Light, as we have already observed, being more or less absorbed by bodies of all kinds, may be expected, under circumstances which tend to unite or aggregate its particles, to flow off in a percipient form from all those which have absorbed it in a greater degree, or retain it after absorption in a looser manner than others. Thus it exists in the shells of marine-fishes, or testaceous worms, and is set at liberty and flows off in a visible form after calcination. It exists in the dead trunks of various vegetables; and hence, on the commencement of a putrefactive decomposition, the particles unite together agreeably to the laws of chemical affinity, and flow off in like manner: whence the luminous appearance exhibited in various species of rotten-wood. It exists largely in the bodies of many kinds of animals, and more largely in some animal organs than in others; hence we see it issuing sometimes from putrescent flesh, sometimes from bones, teeth, bezoars, nephritic, and urinary calculi, and egg-shells that have been exposed to the sun.

In marine fishes it appears to be more accumulated than in the bodies of any animals, though for want of appropriate luminous organs these are not found to secrete it (at least not aggregately and palpably) during life.

For the best experiments we possess upon this subject we are indebted to Dr. Hulme, who, while he has rectified many errors of the analysts, has confirmed the more important and more valuable. Dr. Hulme found that light is one of the first, perhaps the first elementary substance that flies off during decomposition: hence it can only be obtained from putrescent fishes, or pieces of fishes in a putrescent state or stage of incipient putrefaction; for after putrefaction is completed, light escapes no longer in a visible form, either forming new combinations with the other gasses that are now escaping, or perhaps having entirely escaped already. He found, also, that it was in a considerable degree adhesive, and would continue attached to the surface of the body that had emitted it, or to the fingers or any other substance to which it was transferred by scraping. Thus pieces of herring were observed to continue luminous for about forty-eight, and thence to sixty hours after they first discovered light, and then ceased to be luminous any longer. Having scraped off the luminous body, he mixed it with solutions of Epsom and other salts, and found that in slight solutions it shone brighter: but that in strong solutions it became apparently extinguished, though it again revived by mixing more water, and reducing the solution to its proper debility; and thus by alternately adding fresh salt, and new supplies of water, he has sometimes revived the same light after ten extinctions. Great cold and heat are also found to extinguish it; yet a moderate heat renders it more brilliant: it begins to be extinguished at 96°; and when the thermometer is raised to 100 it can be no more revived. It is however capable of being revived, after being frozen by frigorific mixtures.

It is therefore an anomalous fact, that the light of dead glow-worms continues to augment in heated water, increased to 114 degrees.

Luminous appearance of the Sea.

From what has already been observed, this beautiful and brilliant phenomenon is not difficult to be accounted for in most cases: for the vast mass of the ocean contains in itself whatever has the greatest tendency to the production of such a phenomenon. It is the natural province of the greater number of those animals that secrete light from peculiar organs with which they are endowed for this purpose, of phloades, nereids, medusas, and luminous cancers; it holds in its immense bosom, at all times, an enormous quantity of that kind of animal matter, (marine fishes) which is most disposed to throw forth its latent light, in an aggregate and visible form, during its first progress of decomposition; and unites the different circumstances which chiefly favour such an evolution; such, for instance, as a fluid menstruum, temperate warmth, and a solution of muriat of soda or common salt.

If then we see occasionally, in vegetable matter undergoing a slow decomposition, as in rotten wood, a certain portion of light poured forth in a visible form; if we see it issuing in a still greater degree from bones and shells that have undergone the process of calcination; if we see it still more freely at times, and under circumstances, thrown forth from the animal exuvia of church-yards, and adhering to the surface of the spot from which it issues, in like manner as the light scraped off from the scales of pieces of putrescent fishes, immersed in salt water, adheres to the knife or the fingers that are employed for this purpose; how much more easily may we expect to see it thrown forth, and in how much larger quantities, from different parts of the ocean, under circumstances that may favour its escape; often adhering to the sides of vessels, or of their oars as they are alternately raised from the water, and producing a long line, or an extended sheet, of wonderful brilliancy, not unfrequently variegated by every playfulness of colour.

It appears obvious, moreover, that it is not to one cause only, but to many, that such phænomena are to be ascribed, at different periods, and in different parts of the world. Linnæus inclined to confine it chiefly to vast flocks of the nereis tribe: but we have already observed, that even at sea, and among living animals, medusas, sapias, pennatulas, pyrosomas, and phloades equally concur: while, on other occasions, the waves appear brilliantly illuminated, and through a very extensive range, without a trace of any living substance whatever, possessed of a luminous power; and can only acquire their light from the decomposition of dead animal matter. [*Pantologia.*

CHAP. IX.

SPONTANEOUS COMBUSTION.

In the preceding chapter we have confined our remarks to substances which spontaneously emit light with little or no increase of sensible heat. In the present we shall have to notice other substances that spontaneously emit heat, and burn, either in conjunction with light, or, as very frequently happens, without any light whatever: in the course of which we shall have to glance at some very remarkable and interesting effects, which to this hour have never been satisfactorily explained.

Spontaneous combustion, as a general fact, is well known; and the more common causes are too obvious to be enlarged upon; we need only refer to friction and its effects, to the heat produced by the slacking of lime when in contact with combustible matter, to the fermentation of hay, of dunghills, and of similar materials similarly disposed.

But besides these more common causes, experience has shewn that many vegetable substances, highly dried and heaped together, will heat, scorch, and at last burn into flame. Of these the most remarkable is a mixture of the expressed oil of the farinaceous seeds, as rape or linseed oil, with almost any other dry vegetable fibre, such as hemp, cotton, matting, &c. and still more, if also united with lamp-black, or any carbonaceous substance. These mixtures if kept for a time undisturbed, in close bundles, and in a warm temperature, even in small quantities, will often heat, and burn with a mouldering fire for some hours; and if air be admitted freely, will then burst into flame. To this without doubt may be attributed several accidental conflagrations in storehouses, and places where quantities of these substances are kept, as has been proved by direct experiments. The most important of these experiments were made by Mr. George, and a committee of the Royal Academy at Petersburgh, in the year 1781, in consequence of the destruction, by fire, of a frigate in the harbour of Cronstadt; the conflagration of a large hemp magazine, in the same place, in the same year; and a slight fire on board another frigate, in the same port, in the following year.

These accidents led to a very strict examination of the subject, by the Russian government; when it came out, that at the time of the second accident, several parcels of matting, tied with pack-thread, in which the soot of burnt fir-wood had been mixed with oil, for painting the ship, had been lying some time on the floor of the cabin, whence the fire broke out. In consequence of which, the following experiments were made: forty pounds of fir-wood soot were soaked with about thirty-five pounds of hemp oil varnish, and the whole was wrapped up in a mat, and put in a close cabin. In about sixteen hours it was observed to give out a smoke, which rapidly increased, and when the door was opened, and the air freely admitted, the whole burst into a flame. Three pounds of fir-black were mixed with five pounds of hemp-oil varnish, and the whole bound up in linen, and shut up in a chest. In sixteen hours it emitted a very nauseous putrid smell and steam; and two hours afterwards it was actually on fire, and burnt to ashes. In another experiment, the same occurrences took place, but not till the end of forty-one hours after the mixture had been made; and in these and many similar experiments, they all succeeded better, and kindled sooner on bright, than on rainy days. Chimney soot used instead of lamp-black did not answer, nor was any effect produced, when oil of turpentine was substituted for the hemp or rape-oil. In general it was found, that the accension took place more readily with the coarser and more unctuous fir-black, than with the finer sorts; but the proportions of the black to the oil did not appear to be of any great moment. Sometimes, in wet weather, these mixtures only become hot for some hours, and then cooled again, without actually taking fire.

In all these cases the soot or black was from wood, and not coal. The presence of lamp-black, or any other dry carbonaceous matter, is not necessary however; for a spontaneous inflammation will take place in hemp or cotton, simply soaked in any of these expressed oils, when in considerable quantity, or under circumstances favourable to this process, as in very hot weather, or closely shut up. An accident of this sort happened at Gainsborough, in Lincolnshire, in July, 1794, with a bale of yarn of 120lb., accidentally soaked in rape-oil; which, after remaining in a warehouse for several days, began to smoke, to emit a most nauseous smell, and finally to burst out in a most violent flame. A similar accident, with a very small quantity of the materials, happened at Bombay. A bottle of linseed oil had been left standing on a chest; this had been thrown down by accident in the night, the oil ran into a chest which contained some coarse cotton cloth, and in the morning the cloth was found scorching hot, and reduced nearly to tinder, and the wood of the chest charred on the inside. On subsequent trial, a piece of the same cloth was soaked in oil, shut up in a box, and in no longer time than three hours it was found scorching hot, and on opening the cloth it burst into fire. Similar to this is the spontaneous combustion of wool, or woollen yarn, which has occasionally happened when large quantities have been kept, heaped up in rooms little aired, and in hot weather. The oil with which wool is dressed, which is generally rape-oil, appears the chief agent in this combustion. Even high dried, oily, or farinaceous matter of any kind, will alone take fire, when placed in circumstances very favourable to this process. Rye flour roasted till half parched, and of the colour of coffee, and wrapped up in a linen cloth, has been found to heat violently, and to destroy the cloth. Wheat flour, when heated in large quantities, and highly dried, has been known to take fire in hot weather, causing accidents in granaries and bakers' shops. An accident of this kind is related by Count Morrozzo, in the Memoirs of the Turin Academy, to have happened at a flour warehouse at Turin, containing about three hundred sacks of flour. It began by a violent explosion, on a lamp being brought into the warehouse, and the whole was soon after in flames. Charcoal alone also has been known to take fire in powder-mills, when quantities of it in powder have been kept for some time closely packed. Another, and totally different species of spontaneous combustion, is that which occurs during the oxygenation or vitriolization of pyrites, or sulphurets of iron, copper, &c.

A most curious, and, if not well authenticated, a scarcely credible species of spontaneous inflammation, is that in a few rare instances, known to occur in the human body. It is not quite certain indeed, whether the first inflammation has been quite spontaneous, or caused by the approach of a lighted substance; but in these melancholy accidents, the body of the unfortunate sufferers has been brought to a state of such high combustibility, that the flame once kindled, has gone on without other fuel, to the entire destruction of every part, (the bones and extremities excepted) and, as it appears, has been attended with actual flame, of a lambent faint light. This change is the more remarkable, as the human body, in all its usual states, both of health and disease, is scarcely at all of itself combustible, and cannot be reduced to ashes without the assistance of a very large pile of faggots, or other fuel; as universal experience, in the very ancient mode of sepulture, and the history of martyrdoms, abundantly shews. Cases of this human combustion on record, have occurred in different countries. Two of them, well authenticated, are recorded in the Philosophical Transactions, and occurred in England; and a few others in Italy, France, and elsewhere. In all but one, the subjects of them have been females rather advanced in life, of indolent habits, and apparently much addicted to spirituous liquors.

The accident has generally been detected by the penetrating fetid smell of burning and sooty films, which have spread to a great distance; and the sufferers have in every instance been discovered dead, and with the body more or less completely burnt up, leaving in the burnt parts only an oily, crumbly, sooty, and extremely fetid matter. Another circumstance in which these cases all agree, is the comparative weakness of the heat produced by this combustion, notwithstanding the very complete disorganization of the body itself, so that the furniture of the room, wooden chairs, &c.

found within the reach of the burning body, were in many instances absolutely unhurt, and in others only scorched; the heat not having been strong enough to set them on fire. It is impossible to give an adequate reason for this remarkable change; nor does it seem before the very time of the accident to have produced any very sensible alteration in the appearance and functions of the body, which is certainly a most astonishing circumstance. With regard to the effect which the use of ardent spirits is supposed to have in this case, it is impossible not to imagine that this cause may contribute largely to this change; but the instances of the abuse of spirits are so innumerable, and those of this surprising combustion are so extremely rare, that very little satisfaction can be obtained from this explanation. [*Pantologia.*

CHAP. X.

CHEMICAL AFFINITY.

1. ALL the great bodies which constitute the solar system are urged towards each other by a force which preserves them in their orbits, and regulates their motions. This force has received the name of attraction. Its nature is unknown: whether it be inherent in these bodies themselves, or the consequence of some foreign agent, are questions altogether beyond the reach of philosophy, because we have no method of deciding the point. One would be more inclined to the first supposition than to the other, as we can conceive no foreign agent sufficient to explain the planetary motions unless an intelligent one; and, for any thing which we know to the contrary, it was as easy for the Creator to have bestowed on the planets the power of acting on each other at a distance, as the power of being acted on, and receiving motion from other substances.

2. Sir Isaac Newton demonstrated, that this planetary attraction is the same with gravitation, or that force by which a heavy body is urged towards the earth; that it is possessed, not only by the planets as wholes, but by all their component parts also; that

it is mutual; that it extends to indefinite distances; and that all bodies, as far as is known, are possessed of it.

3. When two bodies are brought within a certain distance, they adhere together, and require a considerable force to separate them. This is the case, for instance, with two polished pieces of marble or glass. When a piece of metal, or indeed almost any body whatever, is plunged into water and drawn out again, its surface is moistened, that is to say, part of the water adheres to it. When a rod of gold is plunged into mercury, it comes out stained indelibly with a white colour, because it retains and carries with it a portion of the mercury. Hence it is evident that there is a force which urges these bodies towards each other, and keeps them together; consequently there is an attraction between them. Bodies, therefore, are not only attracted towards the earth and the planetary bodies, but towards each other. The nature of this attraction cannot be assigned any more than that of gravitation; but its existence is equally certain, as far at least as regards by far the greater number of bodies.

4. In all cases we find the particles of matter united together in masses; differing indeed from each other in magnitude, but containing all of them a great number of particles. These particles remain united, and cannot be separated without the application of a considerable force; consequently they are kept together by a force which urges them towards each other, since it opposes their separation. Consequently this force is an attraction.

Thus we see that there is a certain unknown force which urges bodies towards each other; a force which acts not only upon large masses of matter, as the sun and the planets, but upon the smaller component parts of these bodies, and even upon the particles of which these bodies are composed. Attraction, therefore, as far as we know, extends to all matter, and exists mutually between all matter. It is not annihilated at how great a distance soever we may suppose bodies to be placed from each other; neither does it disappear, though they be placed ever so near each other. The nature of this attraction, or the cause which produces it, is altogether unknown; but its existence is demonstrated by all the phænomena of nature.

5. This attraction was long accounted for, by supposing that there existed a certain unknown substance, which impelled all bodies towards each other; a hypothesis to which philosophers

had recourse, from an opinion long admitted as a first principle, "that no body can act where it is not;" as if it were more difficult to conceive why a change is produced in a body by another which is placed at a great distance, than why it is produced by one which is situated at a small distance. It is not only impossible to explain the phænomena of attraction by impulsion, but it is as difficult to conceive how bodies should be urged towards each other by the action of an external substance, as how they should be urged towards each other by a power inherent in themselves. The fact is, that we can neither comprehend the one nor the other; nor can any reason be assigned why the Almighty might not as easily bestow upon matter the power of acting upon matter at a distance, as the power of being acted upon and changed by matter in actual contact.

But farther, we have no reason for supposing that bodies are ever in any case actually in contact. For all bodies are diminished in bulk by cold, that is to say, their particles are brought nearer to each other, which would be impossible, unless they had been at some distance before the application of the cold. Almost all bodies are diminished in bulk by pressure, and consequently their particles are brought nearer each other; and the diminution of bulk is always proportional to the pressure. Newton has shewn, that it required a force of many pounds to bring two glasses within the 800th part of an inch of each other; that a much greater was necessary to diminish that distance; and that no pressure whatever was capable of diminishing it beyond a certain point. Consequently there is a force which opposes the actual contact of bodies; a force which increases inversely as some power or function of the distance, and which no power whatever is capable of overcoming. Boscovich has demonstrated, that a body in motion communicates part of its motion to another body, before it actually reaches it. Hence we may conclude that, as far as we know, there is no such thing as actual contact in nature, and that bodies of course always act upon each other at a distance. Even impulsion, therefore, or pressure, is an instance of bodies acting on each other at a distance; and therefore is no better explanation of attraction than the supposition that it is an inherent power. We must therefore be satisfied with considering attraction as an unknown power, by which all bodies are urged towards each other. It is a power which acts constantly and uniformly, in all times and places, and which is always diminishing the distance between bodies, unless when they are prevented from approaching each other by some other force equally powerful.

6. The change which attraction produces on bodies, is a diminution of their distance. Now the distances of bodies from each other are of two kinds, either too small to be perceived by our senses, or great enough to be easily perceived and estimated. In the first case, the change of distance produced by attraction must be insensible; in the second case it must be visible. Hence the attractions of bodies, as far as regards us, naturally divide themselves into two classes: 1. Those which act at sensible distances; 2. Those which act at insensible distances. The first class obviously applies to bodies in masses of sensible magnitude; the second class must be confined to the particles of bodies, because they alone are at insensible distances from each other.

7. It has been demonstrated, that the intensity of the first class of attractions varies with the mass and the distance of the attracting bodies. It increases with the mass of these bodies, but diminishes as the distance between them increases. Hence we see that in this class of attractions every particle of the attracting bodies act, since the sum of the attracting force is always proportional to the number of particles in the attracting bodies. Why it diminishes as the distance increases, it is impossible to say; but the fact is certain, and is almost incompatible with the supposition of impulsion as the cause of attraction. The rate of variation has been demonstrated to be inversely as the square of the distance, in all cases of attraction belonging to the first class.

8. The attractions belonging to the first class must be as numerous as there are bodies situated at sensible distances; but it has been ascertained that they may be all reduced to three different kinds; namely, 1. Gravitation; 2. Electricity; 3. Magnetism. The first of these has been shewn by Newton to belong to all matter, as far as we have an opportunity of examining, and therefore to be universal. The other two are partial, being confined to certain sets of bodies, while the rest of matter is destitute of them; for it is well known, that all bodies are not electric, and that scarcely any bodies are magnetic, except iron, cobalt, nickel, and chromium.

The intensity of these three attractions increases as the mass of the attracting bodies, and diminishes as the square of the distance increases. The first extends to the greatest distance at which bodies are known to be separated from each other. How far electricity extends has not been ascertained; but magnetism extends at least as far as the semidiameter of the earth. All bodies possess gravity; but it has been supposed that the other two attractions are confined to two or three subtile fluids, which constitute a part of all those bodies which exhibit the attractions of electricity or magnetism. This may be so; but it is not, and scarcely can be demonstrated.

9. The absolute force of these attractions in given bodies can only be measured by the force necessary to counteract the effect of these attractions, or by the space which given bodies, acted on merely by these attractions, traverse in a given time. If we compare the different bodies acted on by gravitation, we shall find that the absolute force of their gravitation towards each other is in all cases the same, provided their distances from each other, and their mass, be the same; but this is by no means the case with electrical and magnetic bodies. In them the forces by which they are attracted towards each other, called electricity and magnetism, are exceedingly various, even when the mass and the distance are the same. Sometimes these forces disappear almost entirely; at other times they are exceedingly intense. Gravity, therefore, is a force inherent in bodies; electricity and magnetism not so: a circumstance which renders the opinion of their depending upon peculiar fluids exceedingly probable. If we compare the absolute force of these three powers with each other, it would appear that the intensity of the two last, every thing else being equal, is greater than that of the first; but their relative intensity cannot be compared, and is therefore unknown. Hence it follows that these different attractions, though they follow the same laws of variation, are not the same in kind.

10. The attractions between bodies at insensible distances, and which of course are confined to the particles of matter, have been distinguished by the name of affinity; while the term attraction has been more commonly confined to cases of sensible distance. Now the particles of matter are two kinds, either homogeneous or heterogeneous. By homogeneous particles, I mean particles which compose the same body; thus all particles of iron are homoge-

neous. By heterogeneous particles are meant those which compose different bodies; thus a particle of iron, and a particle of lead, are heterogeneous.

Homogeneous affinity urges the homogeneous particles towards each other, and keeps them at insensible distances from each other; and consequently is the cause why bodies almost always exist united together, so as to constitute masses of sensible magnitude. This affinity is usually denoted by the term cohesion, and sometimes by adhesion, when the surfaces of bodies are only referred to. Homogeneous affinity is nearly universal; as far as is known, caloric and light only are destitute of it.

Heterogeneous affinity urges heterogeneous particles towards each other, and keeps them at insensible distances from each other, and of course is the cause of the formation of new integrant particles, composed of a certain number of heterogeneous particles. These new integrant particles afterwards unite by cohesion, and form masses of compound bodies. Thus an integrant particle of water is composed of particles of hydrogen and oxygen, urged towards each other, and kept at an insensible distance by heterogeneous affinity; and a mass of water is composed of an indefinite number of integrant particles of that fluid, urged towards each other by homogeneous affinity. Heterogeneous affinity is universal, as far as is known; that is to say, there is no body whose particles are not attracted by the particles of some other body; but whether the particles of all bodies have an affinity for the particles of all other bodies, is a point which we have no means of ascertaining. It is, however, exceedingly probable, and has been generally taken for granted; though it is certainly assuming more than even analogy can warrant.

11. Affinity, like sensible attraction, varies with the mass and the distance of the attracting bodies. That cohesion varies with the mass, cannot indeed be ascertained; because we have no method of varying the mass, without at the same time altering the distance. But in cases of the adhesion of the surfaces of homogeneous bodies, which is undoubtedly an instance of homogeneous affinity, it has been demonstrated, that the force of adhesion increases with the surface, that is to say, with the mass; for the number of adhering particles must increase with the surface.

That heterogeneous affinity increases with the mass, has been observed long ago in particular instances, and has been lately demonstrated by Berthollet to hold in every case: thus a given portion of water is retained more obstinately by a large quantity of sulphuric acid, than by a small quantity. Oxygen is more easily abstracted from those oxides, which are oxidized to a maximum, than from those which are oxidized to a minimum; that is to say, that a large mass of metal retains a given quantity of oxygen more violently than a small mass. Lime deprives potash of only a portion of its carbonic acid; and sulphuric acid deprives phosphoric acid of only a portion of the lime with which it is united in phosphate of lime. In these, and many other instances that might be enumerated, a small portion of one body is retained by a given quantity of another, more strongly than a large quantity. And Berthollet has shewn, that in all cases a large quantity of a body is capable of abstracting a portion of another, from a small portion of a third; how weak soever the affinity between the first and second of these bodies is, and how strong soever the affinity between the second and the third. Thus when equal quantities of the following bodies were boiled together,

1. { Sulphate of barytes, Potash	4. { Oxalate of lime, Potash
2. { Sulphate of potash, Soda	5. { Phosphate of lime, Potash
3. { Sulphate of potash, Lime	6. { Carbonate of lime, Potash

the uncombined base abstracted part of the acid, from the base with which it was previously combined; though in every one of these instances it was retained by that base, by an affinity considered as stronger. The same division of the base took place when equal quantities of oxalate of lime, and nitric acid, were boiled together.

We have seen that sensible attraction, though in all cases the *same kind* of force, is not always the *very same* force; for though the mass and the distance of two bodies be equal, the absolute force by which they are attracted towards each other by gravitation is not equal to the force by which they are attracted towards each other by magnetism. The forces of sensible attraction are three in number, namely, gravitation, magnetism, and electricity; the first is always the same when the mass and distance are the same, but the two last vary even when the mass and distance continue unaltered.

The forces of affinity, though also the same in kind, are still more numerous than those of sensible attraction; for instead of three, they amount to as many as there are heterogeneous bodies. The rate, indeed, at which they vary when the distance of the attracting bodies increases or diminishes, is probably the same in all, and so is also their variations as far as it regards the mass. But even when both of these circumstances, as far as we can estimate them, are the same, the affinity of two bodies for a third is not the same. Thus barytes has a stronger affinity for sulphuric acid than potash has: for if equal quantities of each be mixed with a small portion of sulphuric acid, the barytes seizes a much greater proportion of the acid than the potash does. This difference in intensity extends to particles of all bodies; for there are scarcely any two bodies whose particles have precisely the same affinity for a third; and scarcely any two bodies, the particles of each of which cohere together with exactly the same force.

It is this difference in intensity which constitutes the most important characteristic mark of affinity, and which explains the different decompositions and changes which one body occasions in others.

Thus it appears at first sight, that there are as many different affinities as there are bodies; and that affinity, instead of being one force like gravitation, which is always the same when the circumstances are the same, consists of a variety of different forces, regulated, indeed, by the same kind of laws, but all of them different from each other. These affinities do not vary like magnetism and electricity, though the mass continues the same, but are always of equal intensity when other circumstances are equal. Hence it is reasonable to conclude, that these affinities cannot, like magnetism and electricity, depend upon peculiar fluids, the quantity of which may vary; but that they are permanent forces, inherent in every atom of the attracting bodies.

12. It is very possible that this variation of intensity, which forms so remarkable a distinction between affinity and gravitation, may be only apparent and not real. For even in gravitation the intensity varies with the distance and the mass, and the same variation holds in affinity. But as the attraction of affinity acts upon bodies situated at intensible distances from each other, it is evident that, strictly speaking, we have no means of ascertaining that distance; and consequently that it may vary without our discover-

ing the variation. But every such variation in distance must occasion a corresponding variation in the intensity of the attracting force. It may be, then, that barytes attracts sulphuric acid with greater intensity than potash, because the particles of barytes, when they act upon the acid, are at a smaller distance from it than the particles of the potash are.

But it may be asked, Why, if barytes, potash, and sulphuric acid, are all mixed together in water, the particles of potash do not approach as near the acid as those of the barytes, since they are both at liberty to act? To this it may be answered, that in all probability they do approach each of them to the same *apparent* distance, (if the expression be allowed), but that, notwithstanding, their *real* distance may continue different. The particles of bodies, how minute soever we suppose them to be, cannot be destitute of magnitude. They must have a certain length, breadth, and thickness, and therefore must always possess some particular figure or other. These particles, indeed, are a great deal too minute for us to detect their shape; but still it is certain that they must have some shape. Now it is very conceivable that the particles of every particular body may have a shape peculiar to themselves, and differing from the shape of the particles of every other body. Thus the particles of sulphuric acid may have one shape, those of barytes another, and those of potash a third.

But if the particles of bodies have length, breadth, and thickness, we cannot avoid conceiving them as composed of an indeterminate number of still more minute particles or atoms. Now the affinity of two integrant particles for each other must be the sum of the attractions of all the atoms in each of these particles for all the atoms in the other: but the sum of these attractions must depend upon the number of attracting atoms, and upon the distance of these atoms from each other respectively; and this distance must depend upon the figure of the particles. For it is obvious, that if two particles, one of which is a tetrahedron and the other a cube, and which contain the same number of atoms, be placed at the same relative distance from a third particle, the sum of the distances of all the atoms of the first particle from all the atoms of the third particle, will be less than the sum of the distances of all the atoms of the second particle from those of the third. Consequently, in this case, though the apparent distance of the particles be the same, their real distance is different; and of course the cube will attract the third particle more strongly than the tetrahedron; that is, it will have a greater affinity for it than the tetrahedron.

But if the particles of bodies differ from each other in figure, they may differ also in density and in size: and this must also alter the absolute force of affinity, even when the distances and the figure of the attracting particles are the same. The first of these two circumstances, indeed, may be considered as a difference in the mass of the attracting bodies, and therefore may be detected by the weight of the aggregate; but the second, though also no less a variation in the mass, cannot be detected by any such method, though its effect upon the strength of affinity may be very considerable.

There is no doubt that, upon the supposition that such differences in the figure, density, and size of the attracting particles, really exist, and it is in the highest degree probable that they do exist, the variation in intensity which characterises chemical affinity may be accounted for, without supposing the intensity of affinity, as a force inherent in the ultimate particles or atoms of bodies, is really different. The same thing may be applied to electricity and magnetism. It is certainly possible, therefore, that attraction, both sensible and insensible, may not only vary at the same rate, and according to the same laws, but be absolutely the same force inherent in the atoms of matter, modified merely by the number and situation of the attracting atoms. This is certainly possible; and it must be allowed that it corresponds well with those notions of the simplicity of nature, in which we are accustomed to indulge ourselves. But the truth is, that we are by no means good judges of the simplicity of nature; we have but an imperfect glimpse here and there through the veil with which her operations are covered; and from the few points which we see, we are constantly forming conjectures concerning the whole of the machinery by which these operations are carried on. Superior beings smile at our theories as we smile at the reasonings of an infant; and were the veil which conceals the machine from our view to be suddenly withdrawn, we ourselves, in all probability, would be equally astonished and confounded at the wide difference between our theories and conjectures, and the real powers by which the machinery of the universe is moved. Let us not therefore be too precipitate in drawing general conclusions; but let us rather wait with patience till future discoveries enable us to advance farther; and satisfy ourselves in the mean time with arranging those laws of affinity which have been ascertained, without deciding whether it be the same force with gravitation, or a different one. [*Thomson.*

CHAP. XI.

ON CRYSTALLOGRAPHY.

The word crystal (κρυσταλλος) originally signified ice; but it was afterwards applied by the ancients to crystallized silica, or rock crystal; because, as Pliny informs us, they considered that body as nothing else than water congealed by the action of cold. Chemists afterwards applied the word to all transparent bodies of a regular shape; and at present it is employed to denote, in general, the regular figure which bodies assume when their particles have full liberty to combine according to the laws of cohesion. These regular bodies occur very frequently in the mineral kingdom, and have long attracted attention on account of their great beauty and regularity. By far the greater number of the salts assume likewise a crystalline form; and as these substances are mostly soluble in water, we have it in our power to give the regular shape of crystals in some measure at pleasure.

1. Most solid bodies either occur in the state of crystals, or are capable of being made to assume that form. Now it has long been observed by chemists and mineralogists, that there is a particular form which every individual substance always affects when it crystallizes: this indeed is considered as one of the best marks for distinguishing one substance from another. Thus common salt is observed to assume the shape of a cube, and alum that of octahedron, consisting of two four-sided pyramids, applied base to base. Saltpetre affects the form of a six-sided prism; and sulphate of magnesia that of a four-sided prism; and carbonate of lime is often found in the state of a rhomboid. Not that every individual substance always uniformly crystallizes in the same form; for this

is liable to considerable variations according to the circumstances of the case: but there are a certain number of forms peculiar to every substance, and the crystals of that substance, in every case, adopts one or other of these forms, and no other; and thus common salt, when crystallized, has always either the figure of a cube or octahedron, or some figure reducible to these.

2. As the particles of bodies must be at liberty to move before they crystallize, it is obvious that we cannot reduce any bodies to the state of crystals, except those which we are able to make fluid. Now there are two ways of rendering the bodies fluid, namely, solution in a liquid, and fusion by heat. These of course are the only methods of forming crystals in our power.

Solution is the common method of crystallizing salts. They are dissolved in the 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 phænomena of crystallization. Some salts dissolve in very small proportions in cold water, but are very solable 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. Sulphate 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 could be 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 power 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.

There are many substances, however, neither soluble in water nor other liquids, 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.

3. To obtain large artificial crystals of a regular shape, requires considerable address and much patient attention. This curious branch of practical chemistry has been improved by Mr. Leblanc; who has not only succeeded in obtaining regular crystals of almost any size at pleasure, but has made many interesting observations on crystallization in general*. His method is as follows: The salt to be crystallized is to be dissolved in water, and evaporated to such a consistency that it shall crystallize on cooling. Set it by, and when quite cold pour the liquid part off the mass of crystals at the bottom, and put it into a flat-bottomed vessel. Solitary crystals form at some distance from each other, and these may be observed gradually increasing. Pick out the most regular of these, and put them into a flat-bottomed vessel at some distance from each other, and pour over them a quantity of liquid obtained in the same way, by evaporating a solution of the salt, till it crystallizes on cooling. Alter the position of every crystal once at least every day with a glass rod, that all the faces may be alternately exposed to the action of the liquid; for the face on which the crystal rests never receives any increment. By this process the crystals gradually increase in size. When they have acquired such a magnitude that their form can easily be distinguished, the most regular are to be chosen, or those having the exact shape which we wish to obtain; and each of them is to be put separately in a vessel filled with a portion of the same liquid, and turned in the same manner several times a-day. By this treatment they may be obtained of almost any size we think proper. After the crystal has continued in the liquid for a certain time, the quantity of salt held in solution becomes so much diminished, that the liquid begins to act upon the crystal and redissolve it. This action is first perceptible on the angles and edges of the crystal. They become blunted, and gradually lose their shape altogether. Whenever this begins to be

* Jour. de Phys. lv. 300.

perceived, the liquid must be poured off, and a portion of new liquid put in its place; otherwise the crystal is infallibly destroyed. Mr. Leblanc has observed, that this singular change begins first at the surface of the liquid, and extends gradually to the bottom; so that a crystal, if large, may be often perceived in a state of increase at its lower end, while it is disappearing at its upper extremity. Mr. Leblanc even affirms that saline solutions almost always increase in density according to their depth from the surface.

4. The phænomena 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 phænomena; 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 are 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?

The aggregation is evidently the consequence of that attractive force which has been examined in the last section. But to explain the cause of regular figures is a more difficult task. Newton has remarked, that the particles of bodies, while in a state of solution, are arranged in the solvent in regular order and at regular distances; the consequence of which must be, that when the force of cohesion becomes sufficiently strong to separate them from the solvent, they will naturally combine in groups, composed of those particles which are nearest each other. Now all the particles of the same body must be supposed to have the same figure; and the combination of a determinate number of similar bodies must produce similar figures. Hauy has made it exceedingly probable that these integrant particles always combine in the same body in the same way; that is to say, that the same faces, or the same edges, always attach themselves together; but that these differ in different crystals. This can scarcely be accounted for, without supposing that the particles of bodies are endowed with a certain polarity

* Treatise on the origin of forms and qualities.

which makes them attract one part of another particle and repel the other parts. This polarity would explain the regularity of crystallization; but it is itself inexplicable.

It is remarkable that crystals not only assume regular figures, but are always bounded by plane surfaces. It is very rarely indeed that curve surfaces are observed in these bodies; and when they are, the crystals always give unequivocal proofs of imperfection. But this constant tendency towards plane surfaces is inconceivable, unless the particles of which the crystals are composed are themselves regular figures, and bounded by plane surfaces.

5. If the figure of crystals depends upon the figure of their integrant particles, and upon the manner in which they combine, it is reasonable to suppose that the same particles, when at full liberty, will always combine in the same way, and consequently that the crystals of every particular body will be always the same. Nothing at first sight can appear farther from the truth than this. The different forms which the crystals of the same body assume are often very numerous, and exceedingly different from each other. Carbonate of lime, for instance, has been observed crystallized in no fewer than forty different forms, fluate of lime in eight different forms, and sulphate of lime in nearly an equal number.

But this inconsistency is not so great as might at first sight appear. Romé de Lisle has shewn that every body susceptible of crystallization has a particular form which it most frequently assumes, or at least to which it most frequently approaches. Bergman has demonstrated, that this primitive form, as Hauy has called it, very often lies concealed in those very crystals which appear to deviate farthest from it. And Hauy has demonstrated, that all crystals either have this primitive form, or at least contain it as a nucleus within them; for it may be extracted out of all of them by a skilful mechanical division.

These primitive forms must depend upon the figure of the integrant particles composing these crystals, and upon the manner in which they combine with each other. Now, by continuing the mechanical division of the crystal, by cuting off slices parallel to each of its faces, we must at last reduce it to so small a size that it shall contain only a single integrant particle. Consequently this ultimate figure of the crystal must be the figure of the integrant particles of which it is composed. The mechanical division, indeed, cannot be continued so far; but it may be continued till it can be demonstrated that no subsequent division can alter its figure. Consequently it can be continued till the figure which it assumes is similar to that of its integrant particles.

Hauy has found that the figure of the integrant particles of bodies, as far as experiment has gone, may be reduced to three; namely,

1. The parallelopiped, the simplest of the solids, whose faces are six in number, and parallel two and two.

2. The triangular prism, the simplest of prisms.

3. The tetrahedron, the simplest of pyramids. Even this small number of primitive forms, if we consider the almost endless diversity of size, proportion, and density, to which particles of different bodies, though they have the same figure, may still be liable, will be found fully sufficient to account for all the differences in cohesion and heterogeneous affinity, without having recourse to different absolute forces.

These integrant particles, when they unite to form the primitive crystals, do not always join together in the same way. Sometimes they unite by their faces, and at other times by their edges, leaving considerable vacuities between each. This explains why integrant particles, though they have the same form, may compose primitive crystals of different figures.

Mr. Hauy has ascertained that the primitive forms of crystals are six in number; namely,

1. The parallelopiped, which includes the cube, the rhomboid, and all solids terminated by six faces, parallel two and two.

2. The regular tetrahedron.

3. The octahedron with triangular faces.

4. The six-sided prism.

5. The dodecahedron, terminated by rhombs.

6. The dodecahedron, with isosceles triangular faces.

Each of these may be supposed to occur as the primitive form, or the nucleus in a variety of bodies; but those only which are regular, as the cube and the octahedron, have hitherto been found in any considerable number.

But bodies, when crystallized, do not always appear in the primitive form; some of them indeed very seldom affect that form; and all of them have a certain latitude and a certain number of forms, which they assume occasionally as well as the primitive form.

Thus the primitive form of fluate of lime is the octahedron; but that salt is often found crystallized in cubes, in rhomboidal dodecahedrons, and in other forms. All these different forms which a body assumes, the primitive excepted, have been denominated by Hauy *secondary forms*. Now what is the reason of this latitude in crystallizing? why do bodies assume so often these secondary forms?

7. To this it may be answered:

1st, That these secondary 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.

2d, The secondary forms are sometimes owing to the solvent in which the crystals are formed. Thus if common salt be dissolved in water, and then crystallized, it assumes the form of cubes; but when crystallized in urine, it assumes the form, not of cubes, but of regular octahedrons. On the other hand, muriate of ammonia, when crystallized in water, assumes the octahedral form, but in urine it crystallizes in cubes †.

3d, But even when the solvent is the same, and the proportion of ingredients, as far as can be ascertained, exactly the same, still there are a variety of secondary forms which usually make their appearance. These secondary forms have been happily ex-

* Leblanc, Ann. de Chim. xiv. 149.

† Fourcroy and Vauquelin, ibid. xiv. 149.

plained by the theory of crystallization, for which we are indebted to the sagacity of Mr. Hauy; a theory which, for its ingenuity, clearness, and importance, must ever rank high, and which must be considered as one of the greatest acquisitions which mineralogy, and even chemistry, have hitherto attained.

According to this theory, the additional matter which envelopes the primitive nucleus consists of thin slices or layers of particles laid one above another upon the faces of that nucleus, and each layer decreasing in size, in consequence of the abstraction of one or more rows of integrant particles from its edges or angles.

[*Thomson.*

CHAP. XI.

ON THE NATURE OF THE DIAMOND.

THE diamond is not more an object of attention to the jeweller or lapidary than to the chemist; for it is as singular in its composition among the crystals, as it is valuable, on account of its rarity and lustre, among the gems: having of late been fully ascertained to consist of nothing more than pure charcoal under a peculiar state of crystallization.

Upon this subject we shall copy Mr. Smithson Tenant's interesting paper, as communicated to the Royal Society in 1797.

Sir Isaac Newton having observed that inflammable bodies had a greater refraction, in proportion to their density, than other bodies, and that the diamond resembled them in this property, was induced to conjecture that the diamond itself was of an inflammable nature. The inflammable substances which he employed were camphire, oil of turpentine, oil of olives, and amber; these he called "fat, sulphureous, unctuous bodies;" and using the same expression respecting the diamond, he says, it is probably "an unctuous body coagulated." This remarkable conjecture of Sir Isaac Newton has been since confirmed by repeated experiments. It was found, that though the diamond was capable of resisting the effects of a violent heat when the air was carefully excluded, yet that on being exposed to the action of heat and air, it might be entirely consumed. But as the sole object of these experiments was to ascertain the inflammable nature of the diamond, no attention was paid to the products afforded by its combustion; and it still therefore remained to be determined whether the diamond was a distinct substance, or one of the known inflammable bodies. Nor was any attempt made to decide this question till M. Lavoisier, in 1772, undertook a series of experiments for this purpose. He exposed the diamond to the heat produced by a large lens, and was thus enabled to burn it in close glass vessels. He observed that the air in which the inflammation had taken place had become partly soluble in water, and precipitated from lime-water a white powder which appeared to be chalk, being soluble in acids with effervescence. As M. Lavoisier seems to have had little doubt that this precipitation was occasioned by the production of fixed air, similar to that which is afforded by calcareous substances, he might, as we know at present, have inferred that the diamond contained charcoal; but the relation between that substance and fixed air, was then too imperfectly understood to justify this conclusion. Though he observed the resemblance of charcoal to the diamond, yet he thought that nothing more could be reasonably deduced from their analogy, than that each of these substances belonged to the class of inflammable bodies.

As the nature of the diamond is so extremely singular, it seemed deserving of further examination; and it will appear from the following experiments, that it consists entirely of charcoal, differing from the usual state of that substance only by its crystallized form. From the extreme hardness of the diamond, a stronger degree of heat is required to inflame it, when exposed merely to air, than can easily be applied in close vessels, except by means of a strong burning lens; but with nitre its combustion may be effected in a moderate heat. To expose it to the action of heated nitre free from extraneous matters, a tube of gold was procured, which by having one end closed might serve the purpose of a retort, a glass tube being adapted to the open end for collecting the air produced. To be certain that the gold vessel was perfectly closed, and that it did not contain any unperceived impurities which could occasion the production of fixed air, some nitre was heated in it till it had become alkaline, and afterwards dissolved out by water; but the solution was perfectly free from fixed air, as it did not affect the transparency of lime-water. When the diamond was destroyed in the gold vessel by nitre, the substance which remained precipitated lime from lime-water, and with acids afforded nitrous and fixed air; and it appeared solely to consist of nitre partly decomposed, and of aërated alkali.

In order to estimate the quantity of fixed air which might be obtained from a given weight of diamonds, $2\frac{1}{2}$ grs. of small diamonds were weighed with great accuracy, and being put into the tube with $\frac{1}{4}$ oz. of nitre, were kept in a strong red heat for about an hour and a half. The heat being gradually increased, the nitre was in some degree rendered alkaline before the diamond began to be inflamed, by which means almost all the fixed air was retained by the alkali of the nitre. The air which came over was produced by the decomposition of the nitre, and contained so little fixed air as to occasion only a very slight precipitation from lime-water. After the tube had cooled, the alkaline matter contained in it was dissolved in water, and the whole of the diamonds were found to have been destroyed. As an acid would disengage nitrous air from this solution as well as the fixed air, the quantity of the latter could not in that manner be accurately determined. To obviate this inconvenience, the fixed air was made to unite with calcareous earth, by pouring into the alkaline solution a sufficient quantity of a saturated solution of marble in marine acid. The vessel which contained them being closed, was left undisturbed till the precipitate had fallen to the bottom, the solution having been previously heated that it might subside more perfectly. The clear liquor being found, by means of lime-water, to be quite free from fixed air, was carefully poured off from the calcareous precipitate*. The vessel used on this occasion was a glass globe, having a tube annexed to it, that the quantity of the fixed air might be more accurately measured. After as much quicksilver had been poured into the glass globe containing calcareous precipitate as was necessary to fill it, it was inverted in a vessel of the same fluid. Some marine acid being then made to pass up into it, the fixed air was expelled from the calcareous earth; and in this experiment, in which $2\frac{1}{2}$ grs. of diamonds had been employed, occupied the space

* If much water had remained, a considerable portion of the fixed air would have been absorbed by it. But by the same method as that described above, I observed, that as much fixed air might be obtained from a solution of mineral alkali, as by adding an acid to an equal quantity of the same kind of alkali.—Orig.

of a little more than 10.1 oz. of water. The temperature of the room when the air was measured, was at 55°, and the barometer stood at about 29.8 inches.

From another experiment made in a similar manner with 1 gr. and a half of diamonds, the air obtained occupied the space of 6.18 oz. of water, according to which proportion the bulk of the fixed air from 2 and ½ gr. would have been equal to 10.3 oz.

The quantity of fixed air thus produced by the diamond, does not differ much from that which, according to M. Lavoisier, might be obtained from an equal weight of charcoal. In the Memoirs of the French Academy of Sciences, for the year 1781, he has related the various experiments which he made to ascertain the proportion of charcoal and oxygen in fixed air. From those which he considered as most accurate, he concluded that 100 parts of fixed air contain nearly 28 parts of charcoal and 72 of oxygen. He estimates the weight of a cubic inch of fixed air, under the pressure and in the temperature above-mentioned, to be .695 parts of a grain. If we reduce the French weights and measures to English, and them compute how much fixed air, according to this proportion, 2½ grs. of charcoal would produce, we shall find that it ought to occupy very nearly the bulk of 10 oz. of water.

M. Lavoisier seems to have thought that the aërial fluid produced by the combustion of the diamond was not so soluble in water as that procured from calcareous substances. From its resemblance however, in various properties, hardly any doubt could remain that it consisted of the same ingredients; and I found, on combining it with lime, and exposing it to heat with phosphorus, that it afforded charcoal in the same manner as any other calcareous substance. [*Phil. Trans.* 1797.

Since the above account, M. Guyton de Morveau having burnt the diamond in oxygen gas, by the solar rays, and thereby obtained carbonic acid without residue, presumed that he had ascertained the diamond to consist of pure carbon, or the pure principle of charcoal, that which yields the pure acidifiable basis of the carbonic acid. But it was Clouet who proposed the conclusive experiment of making soft iron pass to the state of steel, by cementation with the diamond. To this end he secured a diamond with some filings of iron, in a cavity bored in a block of soft iron, filling up the cavity with a stopper of iron. The whole properly inclosed in a crucible, was exposed to the heat of a blast furnace, by which the diamond disappeared, and the metal was fused, and converted into a small mass or bottom of cast steel. [*Editor.*

CHAP. XII.

MANUFACTURE OF GLASS.

GLASS is a strictly chemical substance, and well entitled to our attention as to its history, properties, and manufacture.

SECTION I.

History of the discovery.

THE word *glass* is formed of the Latin *glastum*, a plant, called by the Greeks, *isatis;* by the Romans, *vitrum;* by the ancient Britons, *guadum;* by the English, *woad.* We find frequent mention of this plant in ancient writers, particularly Cæsar, Vitruvius, Pliny, &c. who relate, that the ancient Britons painted or dyed their bodies with glastum, guadum, vitrum, &c. i. e. with the blue colour procured from this plant. And hence the factitious matter we are speaking of came to be called glass, as having always somewhat of this blueishness in it.

At what time the art of glass-making was first invented is altogether uncertain. Some imagine it to have been invented before the flood: but of this we have no direct proof, though there is no improbability in the supposition; for we know, that it is almost impossible to excite a very violent fire, such as is necessary in metallurgic operations, without vitrifying part of the bricks or stones wherewith the furnace is built. This, indeed, might furnish the first hints of glass-making; though it is also very probable, that such imperfect vitrifications would be observed a long time before people thought of making any use of them.

The Egyptians boast, that this art was taught them by their great Hermes. Aristophanes, Aristotle, Alexander, Aphrodiseus, Lucretius, and St. John the divine, put it out of all doubt that glass was used in their days. Pliny relates, that it was first discovered accidentally in Syria, at the mouth of the river Belus, by certain merchants driven thither by a storm at sea; who being obliged to continue there, and dress their victuals by making a fire on the ground, where there was great plenty of the herb kali; that plant burning to ashes, its salts mixed and incorporated with the sand, or stones fit for vitrification, and thus produced glass; and that, this accident being known, the people of Sidon in that neighbourhood essayed the work, and brought glass into use; since which time the art has been continually improving. Be this as it may, however, the first glass-houses mentioned in history were erected in the city of Tyre, and here was the only staple of the manufacture for many ages. The sand which lay on the shore for about half a mile round the mouth of the river Belus was peculiarly adapted to the making of glass, as being neat and glittering; and the wide range of Tyrian commerce gave an ample vent for the productions of the furnace.

Mr. Nixon, in his observations on a plate of glass found at Herculaneum, which was destroyed A. D. 80, on which occasion Pliny lost his life, offers several probable conjectures as to the uses to which such plates might be applied. Such plates, he supposes, might serve for specula, or looking-glasses; for Pliny, in speaking of Sidon, adds, Siquidem etiam specula excogitaverat: the reflection of images from these ancient specula being effected by besmearing them behind, or tinging them through with some dark colour. Another use in which they might be employed was for adorning the walls of their apartments, by way of wainscot, to which Pliny is supposed to refer by his vitreæ cameræ, lib. xxxvi. cap. 25. s. 64. Mr. Nixon farther conjectures, that these glass plates might be used for windows, as well as the lamina of lapis specularis and phengites, which were improvements in luxury mentioned by Seneca, and introduced in his time, Ep. xc. However, there is no positive authority relating to the using of glass-windows earlier than the close of the third century: Manifestius est (says Lactantius), mentem esse, quæ per oculos ea quæ sunt opposita, transpiciat, quasi per fenestras lucente vitro aut speculari lapide obductas.

The first time we hear of glass made among the Romans was in the reign of Tiberius, when Pliny relates that an artist had his house demolished for making glass malleable, or rather flexible;

though Petronius Arbiter and some others assure us, that the emperor ordered the artist to be beheaded for his invention.

It appears, however, that before the conquest of Britain by the Romans, glass-houses had been erected in this island, as well as in Gaul, Spain, and Italy. Hence in many parts of the country are to be found annulets of glass, having a narrow perforation and thick rim, denominated by the remaining Britons gleineu naigreedh, or glass adders, and which were probably in former times used as annulets by the druids. It can scarcely be questioned that the Britons were sufficiently well versed in the manufacture of glass, to form out of it many more useful instruments than the glass beads. History indeed assures us, that they did manufacture a considerable quantity of glass vessels. These, like their annulets, were most probably green, blue, yellow, or black, and many of them curiously streaked with other colours. The process in the manufacture would be nearly the same with that of the Gauls and Spaniards. The sand of their shores, being reduced to a sufficient degree of fineness by art, was mixed with three-fourths of its weight of their nitre (much the same with our kelp), and both were melted together. The metal was then poured into other vessels, where it was left to harden into a mass, and afterwards replaced in the furnace, where it became transparent in the boiling, and was afterwards figured by blowing or modelling in the lathe into such vessels as they wanted.

It is not probable that the arrival of the Romans would improve the glass manufacture among the Britons. The taste of the Romans at that time was just the reverse of that of the inhabitants of this island. The former preferred silver and gold to glass for the composition of their drinking-vessels. They made, indeed, great improvements in their own at Rome, during the government of Nero. The vessels then formed of this metal rivalled the bowls of porcelain in their dearness, and equalled the cups of crystal in their clearness. But these were by far too costly for common use; and therefore, in all probability, were never attempted in Britain. The glass commonly made use of by the Romans was of a quality greatly inferior; and from the fragments which have been discovered, at the stations or towns of either, appear to have consisted of a thick, sometimes white, but mostly blue green metal.

According to the venerable Bede, artificers skilled in making glass for windows were brought over into England in the year 674, by abbot Benedict, who were employed in glazing the church and monastery of Weremouth. According to others, they were first brought over by Wilfrid, bishop of Worcester, about the same time. Till this time the art of making such glass was unknown in Britain; though glass windows did not begin to be common before the year 1180: till this period they were very scarce in private houses, and considered as a kind of luxury, and as marks of great magnificence. Italy had them first; next France, from whence they came into England.

Venice for many years excelled all Europe in the fineness of its glasses; and in the thirteenth century the Venetians were the only people that had the secret of making crystal looking-glasses. The great glass-works were at Muran, or Murano, a village near the city, which furnished all Europe with the finest and largest glasses.

The glass manufacture was first begun in England in 1557: the finer sort was made in the place called Crutched Friars, in London; the fine flint glass, little inferior to that of Venice, was first made in the Savoy-house, in the Strand, London. This manufacture appears to have been much improved in 1635, when it was carried on with sea-coal or pit-coal instead of wood; and a monopoly was granted to Sir Robert Mansell, who was allowed to import the fine Venetian flint glasses for drinking, the art of making which was not brought to perfection before the reign of William III. But the first glass plates, for looking-glasses and coach-windows, were made in 1673, at Lambeth, by the encouragement of the Duke of Buckingham; who in 1670 introduced the manufacture of fine glass into England, by means of Venetian artists, with amazing success. So that within a century past, the French and English have not only come up to, but even surpassed, the Venetians; and we are now no longer supplied from abroad.

The French made a considerable improvement in the art of glass, by the invention of a method of casting very large plates, till then unknown, and scarce practised yet by any but themselves and the English. That court applied itself with a laudable industry to cultivate and improve the glass manufacture. A company of glass-men was established by letters patent; and it was provided by an arret, not only that the working in glass should not derogate any thing from nobility, but even that none but nobles should be allowed to work in it.

An extensive manufactory of this elegant and valuable branch of commerce was first established in Lancashire, about the year 1773, through the spirited exertions of a very respectable body of proprietors, who were incorporated by an act of parliament. From those various difficulties constantly attendant upon new undertakings, when they have to contend with powerful foreign establishments, it has not, however, been conducted with any great degree of success.

SECTION II.

Properties of Glass.

The properties of glass are highly interesting and remarkable. The following are among the most curious.

1. Glass is one of the most elastic bodies in nature. If the force with which glass balls strike each other be reckoned sixteen, that wherewith they recede by virtue of their elasticity will be nearly fifteen.

2. When glass is suddenly cooled, it becomes exceedingly brittle; and this brittleness is sometimes attended with very surprising phænomena. Hollow bells made of annealed glass, with a small hole in them, will fly to pieces by the heat of the hand only, if the hole by which the internal and external air communicate be stopped with a finger. Lately, however, some vessels made of such annealed glass have been discovered, which have the remarkable property of resisting very hard strokes given from without, though they shiver to pieces by the shocks received from the fall of very light and minute bodies dropped into their cavities. These glasses may be made of any shape; all that need be observed in making them is, that their bottom be thicker than their sides. The thicker the bottom is, the easier do the glasses break. One whose bottom is three fingers breadth in thickness flies with as much ease at least as the thinnest glass. Some of these vessels have been tried with strokes of a mallet sufficient to drive a nail into wood tolerably hard, and have held good without breaking. They have also resisted the shock of several heavy bodies let fall into their cavities, from the height of two or three feet; as musket-balls, pieces of iron or other metal, pyrites, jasper, wood, bone, &c. But this is not surprising, as other glasses of the same shape and size will do the same: but the wonder is, that taking a shiver of flint of the size of a small pea, and letting it fall into the glass only from the height of three inches, in about two seconds the

glass flies, and sometimes at the very moment of the shock; nay, a bit of flint no larger than a grain dropped into several glasses successively, though it did not immediately break them, yet when set by, they all flew in less than three quarters of an hour. Some other bodies produce this effect as well as flint: as sapphire, diamond, porcelain, hard tempered steel; also marbles such as boys play with, and likewise pearls. These experiments were made before the Royal Society, and succeeded equally when the glasses were held in the hand, when they were rested on a pillow, put in water, or filled with water. It is also remarkable, that the glasses broke upon having their bottoms slightly rubbed with the finger, though some of them did not fly till half an hour after the rubbing. If the glasses are every where extremely thin, they do not break in these circumstances.

Some have pretended to account for these phænomena, by saying, that the bodies dropped into the vessels cause a concussion which is stronger than the cohesive force of the glass, and consequently that a rupture must ensue. But why does not a ball of iron, gold, silver, or copper, which are perhaps a thousand times heavier than flint, produce the same effect? It is because they are not elastic. But surely iron is more elastic than the end of one's finger. Mr. Euler has endeavoured to account for these appearances from his principles of percussion. He thinks that this experiment entirely overthrows the opinion of those who measure the force of percussion by the vis viva, or absolute apparent strength of the stroke. According to his principles, the great hardness and angular figure of the flint, which makes the space of contact with the glass extremely small, ought to cause an impression on the glass vastly greater than lead, or any other metal; and this may account for the flint's breaking the vessel, though the bullet, even falling from a considerable height, does no damage. Hollow cups made of green bottle-glass, some of them three inches thick at the bottom, were instantly broken by a shiver of flint, weighing about two grains, though they had resisted the shock of a musket-ball from the height of three feet.

That Mr. Euler's theory cannot be conclusive any more than the other, must appear evident from a very slight consideration. It is not by angular bodies alone that the glasses are broken. The marbles with which children play are round, and yet they have the same effect with the angular flint. Besides, if it was the mere force of percussion which broke the glasses, undoubtedly the fracture would always take place at the very instant of the stroke; but we have seen, that this did not happen sometimes till a very considerable space of time had elapsed. It is evident, therefore, that this effect is occasioned by the putting in motion some subtile fluid with which the substance of the glass is filled, and that the motions of this fluid, when once excited in a particular part of the glass, soon propagate themselves through the whole or greatest part of it, by which means the cohesive power becomes at last too weak to resist them. There can be little doubt that the fluid just now mentioned is that of electricity. It is known to exist in glass in very great quantity; and it also is known to be capable of breaking glasses, even when annealed with the greatest care, if put into too violent a motion. Probably the cooling of glass hastily may make it more electric than is consistent with its cohesive power, so that it is broken by the least increase of motion in the electric fluid by friction or otherwise. This is evidently the case when it is broken by rubbing with the finger; but why it should also break by the mere contact of flint and the other bodies abovementioned, has not yet been satisfactorily accounted for.

A most remarkable phenomenon also is produced in glass tubes placed in certain circumstances. When these are laid before a fire in an horizontal position, having their extremities properly supported, they acquire a rotatory motion round their axis, and also a progressive motion towards the fire, even when their supports are declining from the fire, so that the tubes will move a little way up hill towards the fire. When the tubes are placed in a nearly upright posture, leaning to the right hand, the motion will be from east to west; but if they lean to the left hand, their motion will be from west to east; and the nearer they are placed to the perfectly upright posture, the less will the motion be either way. If the tube is placed horizontally on a glass plane, the fragment, for instance, of coach window-glass, instead of moving towards the fire, it will move from it, and about its axis in a contrary direction to what it had done before; nay, it will recede from the fire, and move a little up hill when the plane inclines towards the fire. These experiments are recorded in the Philosophical Transactions. They succeeded best with tubes about twenty or twenty-two inches long, which had in each end a pretty strong pin fixed in cork for an axis.

The reason given for these phænomena is the swelling of the tubes towards the fire by the heat, which is known to expand all bodies. For, say the adopters of this hypothesis, granting the existence of such a swelling, gravity must pull the tube down when supported near its extremities; and a fresh part being exposed to the fire, it must also swell out and fall down, and so on. But, without going farther in the explanation of this hypothesis, it may be here remarked, that the fundamental principle on which it proceeds is false: for though fire indeed makes bodies expand, it does not increase them in weight; and therefore the sides of the tube, though one of them is expanded by the fire, must still remain in equilibrio; and hence we must conclude, that the cause of these phænomena remains yet to be discovered.

4. Glass is less dilatable by heat than metalline substances; and solid glass sticks are less dilatable than tubes. This was first discovered by Colonel Roy*, in making experiments in order to reduce barometers to a greater degree of exactness than hath hitherto been found practicable; and since his experiments were made, one of the tubes eighteen inches long, being compared with a solid glass rod of the same length, the former was found by a pyrometer to expand four times as much as the other, in a heat approaching to that of boiling oil. On account of the general quality which glass has of expanding less than metal, M. de Luc recommends it to be used in pendulums: and, he says, it has also this good quality, that its expansions are always equable and proportioned to the degrees of heat; a quality which is not to be found in any other substance yet known.

5. Glass appears to be more fit for the condensation of vapours than metallic substances. An open glass filled with water, in the summer time, will gather drops of water on the outside, just as far as the water in the inside reaches; and a person's breath blown on it manifestly moistens it. Glass also becomes moist with dew, when metals do not.

6. A drinking-glass partly filled with water, and rubbed on the brim with a wet finger, yields musical notes, higher or lower as the glass is more or less full, and will make the liquor frisk and leap about.

7. Glass is possessed of extraordinary electrical virtues.

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* Phil. Trans. vol. lxxii. p. 668.

SECTION III.

Manufacture of Glass.

Drinking, Watch, Window, and Plate-Glass.

Glass is a combination of sand, flint, spar, or some other siliceous substances, with one or other of the fixed alkalies, and in some cases with a metallic oxyd. Of the alkalies, soda is commonly preferred: and of the siliceous substances, white sand is most in repute at present, as it requires no preparation for coarse goods, while mere washing in water is sufficient for those of a finer quality. The metallic oxyd usually employed is litharge, or some other preparation of lead, as being the cheapest metal we can have recourse to.

It is also necessary that the siliceous matter should be fused in contact with something called a flux. The substances proper for this purpose are lead, borax, arsenic, nitre, or any alkaline matter. The lead is used in the state of red-lead; and the alkalies are soda, pearl-ashes, sea-salt, and wood-ashes. When red-lead is used alone, it gives the glass a yellow cast, and requires the addition of nitre to correct it. Arsenic, in the same manner, if used in excess, is apt to render the glass milky. For a perfectly transparent glass, the pearl-ashes are found much superior to lead; perhaps better than any other flux, except it be borax, which is too expensive to be used, except for experiments, or for the best looking-glasses.

The materials for making glass must first be reduced to powder, which is done in mortars or by horse-mills. After sifting out the coarse parts, the proper proportions of silex and flux are mixed together and put into the calcining furnace, where they are kept in a moderate heat for five or six hours, being frequently stirred about during the process. When taken out, the matter is called frit. Frit is easily converted into glass by only pounding it, and vitrifying it in the melting pots of the glass furnace: but in making fine glass, it will sometimes require a small addition of flux to the frit to correct any fault. For, as the flux is the most expensive article, the manufacturer will rather put too little at first than otherwise, as he can remedy this defect in the melting pot. The heat in the furnace must be kept up until the glass is brought to a state of perfect fusion; and during this process any scum which arises must be removed by ladles. When the glass is perfectly melted, the glass blowers commence their operations.

The following compositions of the ingredients for glass are extracted from the Handmaid to the Arts:

"For the best flint-glass, 120lbs. of white sand, 50lbs. of red lead, 40lbs. of the best pearl-ashes, 20lbs. of nitre, and five ounces of magnesia; if a pound or two of arsenic be added, the composition will fuse much quicker, and with a lower temperature.

"For a cheaper flint-glass, 120lbs. of white sand, 35lbs. of pearl-ashes, 40lbs. of red-lead, 13lbs. of nitre, six pounds of arsenic, and four ounces of magnesia.

"This requires a long heating to make clear glass; and the heat should be brought on gradually, or the arsenic is in danger of subliming before the fusion commences. A still cheaper composition is made by omitting the arsenic in the foregoing, and substituting common sea-salt.

"For the best German crystal glass, 120lbs. of calcined flints or white sand, the best pearl-ashes 70lbs., saltpetre 10lbs., arsenic half a pound, and five ounces of magnesia. Or, a cheaper composition for the same purpose is, 120lbs. of sand or flints, 46lbs. of pearl-ashes, seven pounds of nitre, six pounds of arsenic, and five ounces of magnesia. This will require a long continuance in the furnace; as do all others where much of the arsenic is employed.

"For looking-glass plates, washed white sand, 60lbs., purified pearl-ashes 25lbs., nitre 15lbs., and seven pounds of borax. If properly managed, this glass will be colourless. But if it should be tinged by accident, a trifling quantity of arsenic, and an equal quantity of magnesia, will correct it; an ounce of each may be tried first, and the quantity increased if necessary.

"The ingredients for the best crown-glass must be prepared in the same manner as for looking-glasses, and mixed in the following proportions: 60lbs. of white sand, 30lbs. of pearl-ashes, and 15lbs. of nitre, borax a pound, and half a pound of arsenic.

"The composition for common green window glass is 120lbs. of white sand, 30lbs. of unpurified pearl-ashes, wood-ashes well burnt and sifted, 60lbs., common salt 20lbs., and five pounds of arsenic.

"Common green bottle-glass is made from 200lbs. of wood-ashes, and 100lbs. of sand; or 170lbs. of ashes, 100lbs. of sand,

and 50lbs. of the lava of an iron-furnace: these materials must be well mixed."

The materials employed in the manufactory of glass are by chemists reduced to three classes, namely, alkalies, earths, and metallic oxides.

The fixed alkalies may be employed indifferently; but soda is preferred in this country. The soda of commerce is usually mixed with common salt, and combined with carbonic acid. It is proper to purify it from both of these foreign bodies before using it. This, however, is seldom done.

The earths are silicia, (the basis of flints), lime, and sometimes a little alumina, (the basis of clay). Silicia constitutes the basis of glass. It is employed in the state of fine sands or flints; and sometimes, for making very fine glass, rock crystal is employed. When sand is used, it ought if possible to be perfectly white; for when it is coloured with metallic oxides, the transparency of the glass is injured. Such sand can only be employed for very coarse glasses. It is necessary to free the sand from all the loose earthy particles with which it may be mixed, which is done by washing it well with water.

Lime renders glass less brittle, and enables it to withstand better the action of the atmosphere. It ought in no case to exceed the twentieth part of the silicia employed, otherwise it corrodes the glass pots. This indeed may be prevented by throwing a little clay into the melted glass; but in that case a green glass only is obtained.

The metallic oxyds employed are the red oxyd of lead or litharge, and the white oxyd of arsenic. The red oxyd of lead, when added in sufficient quantity, enters into fusion with silicia, and forms a glass without the addition of any other ingredient. Five parts of minium and two of silicia form a glass of an orange-colour and full of striæ. Its specific gravity is five. The red oxyd of lead renders glass less brittle and more fusible; but, when added beyond a certain proportion, it injures the transparency and the whiteness of the glass.

The white oxyd of arsenic answers the same purposes with that of lead; but on account of its poisonous qualities it is seldom used. It is customary to add a little nitre to the white oxyd of arsenic, to prevent the heat from reviving it, and rendering it volatile. When added beyond a certain proportion, it renders glass opaque and milky like the dial-plate of a watch. When any combustible body is present, it is usual in some manufactures to add a little white oxyd of arsenic. This supplying oxygen, the combustible is burnt, and flies off; while the revived arsenic is at the same time volatilized.

There are several kinds of glass adapted to different uses. The best and most beautiful are the flint and the plate glass. These, when well made, are perfectly transparent and colourless, heavy and brilliant. They are composed of fixed alkali, pure siliceous sand, calcined flints, and litharge, in different proportions. The flint-glass contains a large quantity of oxyd of lead, which by certain processes is easily separated. The plate-glass is poured in the melted state upon a table covered with copper. The plate is cast half an inch thick, or more, and is ground down to a proper degree of thinness, and then polished.

Crown-glass, that used for windows, is made without lead, chiefly of fixed alkali fused with silicious sand, to which is added some black oxyd of manganese, which is apt to give the glass a tinge of purple.

Bottle-glass is the coarsest and cheapest kind: into this little or no fixed alkali enters the composition. It consists of an alkaline earth combined with alumina and silica. In this country it is composed of sand and the refuse of the soap-boiler, which consists of the lime employed in rendering his alkali caustic, and of the earthy matters with which the alkali was contaminated. The most fusible is flint glass, and the least fusible is bottle glass.

Flint-glass melts at the temperature of 10° Wedgewood; crown-glass at 30°; and bottle-glass at 47°. The specific gravity varies between 2·48 and 3·38.

Glass is often tinged of various colours by mixing with it, while in fusion, some one or other of the metallic oxyds; and on this process, well conducted depends the formation of pastes or factitious gems.

Blue glass is formed by means of oxyd of cobalt.

Green, by the oxyd of iron or of copper.

Violet, by oxyd of manganese.

Red, by a mixture of the oxyds of copper and iron.

Purple, by the purple oxyd of gold.

White, by the oxyd of arsenic and of zinc.

Yellow, by the oxyd of silver and by combustible bodies.

Opticians, who employ glass for optical instruments, often complain of the many defects under which it labours. The chief of these are the following :

Streaks.—These are waved lines, often visible in glass, which interrupt distinct vision. They are probably owing sometimes to want of complete fusion, which prevents the different materials from combining sufficiently ; but in some cases also they may be produced by the workmen lifting up, at two different times, the glass which is to go to the formation of one vessel or instrument.

Tears.—These are white specks or knots, occasioned by the vitrified clay of the furnaces, or by the presence of some foreign salt.

Bubbles.—These are air-bubbles which have not been allowed to escape. They indicate want of complete fusion, either from too little alkali, or the application of too little heat.

Cords.—These are the asperities on the surface of the glass, in consequence of too little heat.

Glass-blowing.

The art of forming vessels of glass is termed blowing, from its being in a great measure performed by the operator blowing through an iron tube, and by that means inflating a piece of glass which is heated so as to become soft and exceedingly pliable. By a series of the most simple and dexterous operations, this beautiful material is wrought into the various utensils of elegance and utility, by methods which require but very few tools, and those of the most simple construction.

Watch-glasses are made by first blowing a hollow globe, the proper radius for the glasses ; then by touching it with an iron ring. This cracks out a watch-glass in an instant. The same globe will make several glasses.

Window or table-glass is worked nearly in the same manner : the workman blows and manages the metal, so that it extends two or three feet in a cylindrical form. It is then carried to the fire, and the operation of blowing repeated till the metal is stretched to the dimensions required, the side to which the pipe is fixed diminishing gradually till it ends in a pyramidal form ; but, in order to bring both ends nearly to the same diameter, while the glass continues flexible, a small portion of hot metal is added to the pipe ; the whole is drawn out with a pair of iron pincers, and the same end is cut off with a little cold water as above.

The cylinder thus open at one end is returned to the mouth of the furnace, where it is cut by the aid of cold water, and ripped up through its whole length by a pair of iron shears; after which it is gradually heated on an earthern table, in order to unfold its length, while the workman with another iron tool alternately raises and depresses the two halves of the cylinder: by which process, the one half accommodates itself to the same flat form as the other.

Plate-glass is the last and most valuable kind, and is thus called from its being cast in plates or large sheets: it is almost exclusively employed for mirrors or looking-glasses, and for the windows of carriages.

Plate-glass was formerly blown; but that method having been found very inconvenient, casting was invented; namely, the liquid metal is conveyed from the furnace to a large table, on which it is poured, and all excrescences, or bubbles, are immediately removed by a roller that is swiftly passed over it. It is then annealed in the manner already referred to.

SECTION IV.

Rupert's Drops. Batavian Tears. Bolognian Phial.

THESE are peculiar modifications of glass, for the purpose of deception or amusement.

Rupert's Drops, an elegant glass toy, are simply formed by pouring a small solid lump of green bottle glass, when red-hot, into water, by which means the rounded lump assumes gradually a lengthened form, terminating with a fine and nearly capillary tail, at the extremity. This solid lump will bear very considerable violence on the massy end without injury, and is altogether extremely tough; but whenever the smallest portion of the thinner end is broken off, the whole bursts with a smart snap, and instantly crumbles into innumerable fragments as small as fine sand; which, from their very minuteness, and the imperfection of their crystallization, do no other injury to the hand that holds the drop, than that of producing a slight sting from the sudden concussion.

This curious and extraordinary fragility is obviously owing to some permanent and very strong inequality of pressure; for when the Rupert's drops are heated so red as to be soft, and are let to cool gradually of themselves, and, consequently, to become better annealed, this property of bursting is entirely lost, and, at the same time, the specific gravity of the drop is increased.

These drops are also called, on the continent, Larmes Bataviques, or Batavian Tears.

All glass, not regularly annealed, or, in other words, cooled suddenly instead of progressively, has a tendency towards the same frangibility. Thus, in common window glass, if it be properly annealed, the diamond cuts it with moderate ease, making an uniform smooth furrow, at first dark, but gradually opening, and appearing like a bright silver thread: but when the glass is badly annealed, the diamond works with much more difficulty, the cut opens very slowly, and often flies into a different direction, or the glass entirely breaks.

There is another equally curious glass toy, formed upon the same principle, and evincing the same effect, called the Bologna phial. This is simply a phial, of any shape whatever, made of any kind of glass, but much thicker at the bottom than at top, and cooled immediately, without annealing. These being pretty stout, from their thickness will bear a smart blow from a wooden mallet, or any blunt instrument, or the concussion of a leaden bullet dropped from a considerable height, without injury: but if any sharp body, however small, such as a large grain of sand, or which is still better, the shiver of a gun-flint, be dropped in from only a few inches height, the bottom cracks all around, just above the thickest part, and drops off. The same effect takes place, if the bottom be slightly scratched with any hard body. When very brittle, if a hard angular substance, as a cut diamond, be dropt in, it will sometimes pass through the bottom, though very thick, with apparently as little resistance as through a spider's web. These glasses, when they have received the first injury, do not always crack immediately, but remain whole, sometimes for a few minutes, sometimes for hours, and then suddenly give way.

[*Pantologia. Aikin's Chem. Dict.*

CHAP. XIII.

GUNPOWDER.

SECTION I.

Of the time when gunpowder was first discovered.

THE history of the discovery of gunpowder is involved in much obscurity; the most ancient authors differing from each other in their accounts of this matter, and many of them confounding two distinct inquiries; the discovery of the composition of gunpowder; and the discovery of the means of applying it to the purposes of war.

Father Kircher* affirms, that without controversy we ought to attribute the invention of gunpowder to Barthold Schwartz, or Barthold the black, a monk of Goslar in Germany, and a profound alchemist. This man having mixed together, with a medical view, nitre, sulphur, and charcoal, a spark accidentally fell upon the mixture, blew up the pot in which it was contained, and caused a dreadful explosion. The monk, astonished at the event, made several repetitions of his experiment, and thereby fully discovered the nature of gunpowder, in the year 1354. Kircher gives us also, out of a very old German book which he professes to have read, a monkish account of the first use which Schwartz made of his gunpowder; he employed it to frighten some robbers from their haunts in the woods.

Sebastian Munster says, that he was well informed by a very eminent physician, that the Danes used guns in naval engagements in the year 1354, and that a chemist, called Schwartz, was the first inventor of them †. Pontanus, the Danish historian, accedes to this opinion.

Polydore Virgil, who died in the year 1555, attributes the dis-

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* Kirch. Mun. Sub. p. 487.

† Achilles Gassarus, medicinæ doctor, et historiographus, diligentissime scripsit mihi, Bombardas anno Christi 1354, in usu apud mare Danicum fuisse, primumque inventorem et autorem extitisse chymistam quendam nomine Bartholdum Schwartzum monachum. Munster. Cosmogr. Univ. Lib. 3. C. 174.

covery of gunpowder to some very ignoble German, whose name he wishes might never be handed down to posterity. He further informs us, that this German invented also an iron tube, and taught the Venetians the use of guns, in the year 1380 *.

This is the common account of the discovery of gunpowder; its truth however is rendered doubtful by what follows.

The battle of Cressy was fought in the year 1346; and an historian who lived at that time is quoted by Spondanus as affirming, that the English greatly increased the confusion the French had been thrown into, by discharging upon them from their cannon hot iron bullets †. Three years before the battle of Cressy, the Moors were besieged by the Spaniards in the city of Algeziras; and we learn from Mariana, the Spanish historian, "that the besieged did great harm among the Christians with iron bullets they shot:" the same author adds, "this is the first time we find any mention of gunpowder and ball in our histories ‡." The Earls of Derby and Salisbury are mentioned by Mariana as having assisted at the siege of Algeziras; and as they returned to England in the latter end of the year 1343, it is not an improbable conjecture, that, having been witnesses of the havock occasioned by the Moorish fire-arms, they brought the secret from Spain to England, and introduced the use of artillery into the English army at the battle of Cressy. The use of guns in Spain in the year 1343, is proof sufficient either that Schwartz was not the inventor of gunpowder, or that Kircher and others are mistaken in fixing his discovery so late as the year 1354.

There is reason, however, to believe, that both gunpowder and guns were known in Germany at least forty years before the period assigned by the Spanish historian for their first introduction into Spain. In the armory at Amberg, in the Palatinate of Bavaria, there is a piece of ordnance, on which is inscribed the year 1303 §. This is the earliest account I have yet met with of the certain use of gunpowder in war; and it seems probable enough, as the Pope

* Polyd. Virg. de Inven. Rerum, Lib. II. C. XI.

† Spond. Ann. Eccl. ann. 1346.

‡ Mariana's Hist. of Spain, Eng. Trans.

§ Quam opinionem (of Schwartz being the inventor of gunpowder) generosissimus Stettenius refutat, cum ex eo quod Ambergæ Palatinatus Superioris in officina armorum reperiatur tormentum militare, cui sit annus 1303 inscriptus. Acta Erud. 1769, p. 19.

and the Duke of Bavaria are thought to have been the first princes who made saltpetre in Europe*.

It ought not to be concealed from the reader, that Camerarius quotes a Danish historian, as relating that Christopher, king of the Danes, was killed in battle by the stroke of a gun, in the 1280 †. Upon examining the passage quoted by Camerarius ‡, it is only said, that Christopher, the son of King Waldemar, was killed in the beginning of an engagement by a gun, a warlike instrument then lately discovered. Now it appears §, that Waldemar, Christopher's father, did not succeed to the crown of Denmark till the year 1332, and that his son was killed in a naval engagement several years afterwards||, probably about the time assigned by Munster for the first use of gunpowder in Denmark.

But we are able, upon good grounds, to carry the discovery of gunpowder to a period antecedent to the date of the Amberg piece of ordnance; and it is probable enough, that its composition was known long before we read any thing of its use in war.

Roger Bacon died at Oxford in 1292. In the printed copies of the works of this renowned Monk, there are two or three passages, from which it may fairly be inferred, that he knew the composition of gunpowder ¶; and a manuscript copy is said to have been seen**, wherein saltpetre, sulphur, and charcoal, are expressly mentioned, as the ingredients of a composition which would burn at any distance. But though it be allowed, that Bacon was well acquainted with the composition of gunpowder, it will not follow, either that he was the first discoverer of it, or that he knew its application to fire-arms.

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* Clarke's Nat. His. of Saltpetre.

† Cranzius scribit Christophorum Danorum regem in prælio bombardæ ictu occisum anno 1280. Camera. Hor. Subs. Con. p. 3. 312.

‡ Cranzius Vandal. Lib. VIII. C. 23.

§ Cranzius Daniæ. Lib. VII. C. 32.

|| Id. Lib. VII. C. 38.

¶ In omnem distantiam quam volumus, possumus artificialiter componere ignem comburentem ex sale petræ et aliis. R. Bacon de Mirab. Potes. Artis et Naturæ, Epis. C. VI.—sed tamen saliis petræ Luru vopo vir can utriet sulphuris et sic facies tonitrum et coruscationem, si scias artificium. Id. ib. C. XI. It is very probable, that in the first of these passages, Bacon, concealed sulphur and charcoal under the word aliis; and that in the last, having mentioned saltpetre and sulphur, he concealed charcoal and the method of mixing the three ingredients, under the barbarous terms, Luru vopo vir can utriet.

** Plott's Nat. His. of Oxfordshire.

The Moors, we have seen, who had settled in Spain, are esteemed by some to have been the first persons who used gunpowder in the practice of war; they also brought into Europe a great many Arabian books, and introduced a taste for chemistry into different countries, about the time in which Bacon flourished. It is confessed, on all hands, that Bacon was no stranger to Arabian literature; a great part of his optical disquisitions, being evidently borrowed from Alhazen the Arab; and it is not a supposition wholly void of probability, that he derived his knowledge of the composition of gunpowder from the same source. As to his knowledge of the use of it in war, he certainly had some idea of it; for he intimates, that cities and armies might be destroyed by it in various ways: but it is not equally certain that he had any specific notion of the manner of using gunpowder, which unquestionably prevailed soon after his death.

It is one thing to throw out a conjecture concerning the effects which might be produced by the proper application of a known substance; another, to describe the means of applying it. There are substances in nature, from a combination of which it is possible to destroy a ship, or a citadel, or an army, by a shower of liquid fire spontaneously lighted in the air; every person who is aware of the dreadful fiery explosion which attends the mixture of two or three quarts of spirit of turpentine with strong acid of nitre, must acknowledge the truth of the assertion; but the simple knowledge of the possibility of effecting such a destruction, is a very different matter from the knowledge of its practicability; though future ages may, perhaps, invent as many different ways of making these substances unite in the air, so as to fall down in drops of fire, as have been invented of making gunpowder a sa instrument of the destruction of our species since the time of Bacon.

From the accounts given of the attempts of Salmoneus and Caligula to imitate thunder and lightning, some have been of opinion that gunpowder was known to the ancients*; be that as it may, we cannot hesitate in admitting that it has been long known in various parts of Asia. It would be useless to cite a variety of authorities in proof of this point; I will content myself with that of Lord Bacon:—" Certain it is, that ordnance was known in the city of

* See Dutens' Enquiry into the Discoveries of the Moderns, p. 263. English Translation.

the Oxidrakes in India; and was that which the Macedonians called thunder and lightning, and magick. And it is well known that the use of ordnance hath been in China above 2000 years*."

One of the most useful applications of gunpowder, is in the art of mining. The hammer and metallic wedges were probably the first instruments which men used for the splitting of rocks. The application of wooden wedges to the same purpose, seems to have been a more recent discovery: it is the property of dry wood to expand itself, when wetted with water: miners have had ingenuity enough to avail themselves of this property, for it is a practice with them to drive wedges of dry wood into the natural or artificial crevices of rocks, and to moisten the wedges with water. Wood, by imbibing moisture, swells in every dimension; and the force of this expansion is sufficient, in many cases, to detach large pieces from the main body of a rock. But the expansive force of gunpowder is incomparably greater than that of moistened wood. There are different accounts of the time when gunpowder was first applied to the blasting of rocks. Rossler relates that in 1627, the blasting of mines was brought from Hungary, and introduced in the German mines: but Bayer says, that in 1613, it was invented by Martin Freygold, at Freiberg†.

In answer to an inquiry which I made concerning the time when blasting was introduced at the famous copper-mine at Ecton in Staffordshire, I received the following account from a very able and intelligent person. "I can give you a little better information concerning the affair of blasting. I have known that country where the mine is, above fifty years; and have often seen the smith's shop in which, tradition says, the first boring auger that had ever been used in England was made; and that the first shot that was ever fired in Derbyshire or Staffordshire, was fired in this very copper-mine at Ecton. The inhabitants of Wetton (a village adjoining to the mine) tell me the auger was made by some German miners, sent for over by Prince Rupert to work this copper mine at Ecton. The Prince (Rapin says) came into England in 1636, and was ordered by the king to leave the kingdom 1645; and though he was afterwards admiral under Charles the Second, it is most probable the miners came during his first abode in this kingdom. I am

* Bacon's Essay on the Vicissitude of Things.

† See Travels through the Bannat, &c. by Baron Born, Eng. Trans. p. 192.

very well convinced of the truth of the above tradition, because the fathers of my informers might be very well acquainted with the mineries that introduced blasting among them." In addition to this account I would observe, that the manner of splitting rocks by gunpowder, as practised at Liege, was published by the Royal Society, in 1665; and that it was not till about the year 1684, that the miners in Somersetshire began to use gunpowder*. In the year 1668 Prince Rupert was chosen governor of the Society for the Mines Royal †; and as he lived fourteen years after that appointment, it is not improbable that he might send for the German miners in consequence of his connection with that society.

Before the discovery of blasting rocks by gunpowder, it was the custom in our English mines, as well as in Germany, to split them by wood fires. This method is minutely described by Agricola ‡, and it is not yet wholly fallen into disuse §. It is a very ancient mode of mining, being mentioned by Diodorus Siculus, as practised in some Egyptian mines ‖: he gives us, in the place here referred to, such a melancholy account of the condition of the poor slaves who were employed in those mines, as must make the heart of every humane man, who has a rational respect for the natural rights of every individual of our species, swell with indignation, and thrill with horror. Would to God, that the clemency of the task-masters in the mines of Peru, and in other settlements of European Christians, could induce us to believe that Diodorus Siculus had exaggerated the barbarity of Heathen policy! But there is much to be done, much, I fear, to be suffered, by all the states of Christendom, before the Gospel of Christ can be said to be established amongst them as a rule of life influencing their conduct.

It is related of Hannibal, that he opened himself a passage through the Alps, by applying fire and vinegar to the rocks which opposed his route. This mode of splitting rocks was, probably, not invented by Hannibal; he might have had frequent opportunities of observing a similar practice in the silver mines in Spain, which daily afforded him three hundred pounds weight of silver ¶.

* Philos. Trans.

† Account of Mines, p. 20.

‡ De Re Metal.

§ Philos. Trans. 1777, p. 414.

‖ Lib. III.

¶ Mirum adhuc per Hispanias ab Hannibale inchoatos puteos durare, sua ab inventoribus nomina habentes. Ex queis Bebulo appellatur hodieque, qui CCC pondo Hannibali subministerabat indies! Plin. Hist. Nat. L. 33. s. 31.

There is nothing, indeed, said of vinegar in the description of the Egyptian mines before mentioned: but Pliny expressly affirms, that it was the quality of vinegar, when poured upon rocks, to split such as an antecedent fire had not split; and that it was the custom of miners to burst the rocks they met with, by fire and vinegar *. This account of Hannibal's using vinegar in splitting the rocks, is generally looked upon as fabulous: for my part, I can easily conceive, that a few barrels of vinegar might have been of great use, if the rocks were of the limestone kind; and, whether they were so or not, I leave to be settled by those, who have visited the place where this famous attempt was made. Vinegar corrodes all sorts of limestone and marble rocks; and hence, being introduced into the crack made by the fire, it might be very efficacious in widening them, and rendering the separation of large lumps by iron crows and wedges more easy. It is erroneously supposed, that a large quantity of vinegar was requisite, for the vinegar did not reduce the whole mass of rocks into a pulp; since Livy clearly informs us, that after the action of both the fire and vinegar, they were obliged to open their passage by iron instruments, which would have been wholly unnecessary, had the main body of the rocks been dissolved by the vinegar †.

SECTION II.

Composition and Analysis of Gunpowder.

GUNPOWDER is an artificial composition, consisting of saltpetre, sulphur, and charcoal. The principal things to be respected in the making of gunpowder are, the goodness of the ingredients; the manner of mixing them; the proportion in which they are to be combined; and the drying of the powder after it is made.

Saltpetre, in its crude state, whether it be brought from the East Indies, or made in Europe, is generally, if not universally, mixed with a greater or less portion of common salt: now a small portion of common salt injures the goodness of a large quantity of gunpowder; hence it becomes necessary, in making gunpowder, to use the very finest saltpetre. The purest sulphur is that which

* Saxa rumpit infusum (acetum) quæ non ruperit ignis antecedens. Plin. Nat. Hist. L. 23. s. 27. & L. 33. s. 21. where by Silices cannot be understood what we call flints, since vinegar has no action on flints.

† —ardentiaque saxa infuso aceto putrefaciunt. Ita torridam incendio rupem ferro pandunt. Liv. Hist. I. xxi. c. xxxvii.

is sold in shops under the name of flowers of sulphur; but the roll sulphur being much cheaper than the flowers of sulphur, and being also of a great degree of purity, it is the only sort which is used in the manufacturing of gunpowder. With relation to the charcoal, it has been generally believed that the coal from soft and light woods was better adapted to the making of gunpowder, than that from the hard and heavy ones; thus Evelyn says of the hazel, that "it makes one of the best coals used for gunpowder, being very fine and light, till they found alder to be more fit*." And in another place he thinks that lime-tree coal is still better than that from alder †. An eminent French chemist has shewn, from actual experiment, that this opinion in favour of coal from light woods is ill founded; he affirms, that powder made from lime-tree coal, or even from the coal of the pith of alder-tree, is in no respect preferable to that made from the coal of the hardest woods, such as guaiacum and oak ‡. This remark, if it be confirmed by future experience, may be of no small use to the makers of gunpowder; as it is not always an easy matter for them to procure a sufficient quantity of the coal of soft wood.

The mixture of the materials of which gunpowder is made, should be as intimate and as uniform as possible; for, in whatever manner the explosion may be accounted for, it is certain that the three ingredients are necessary to produce it. Saltpetre and sulphur mixed together give no explosion; sulphur and charcoal give no explosion; and though saltpetre and charcoal, when intimately mixed, do give an explosion, yet it is, probably, of far less force than what is produced from a mixture of the three ingredients. I have said *probably,* because this point does not seem to be quite settled at present, as may appear from the following opinions, of two eminent chemists, each of whom appeals to experience.—"Un mêlange de six onces de nitre et d'une once charbon produit une poudre qui a *moitiê moins* de force que toutes celles dans lesquelles on fait entrer du soufre: cette substance est donc absolument essentielle à la composition de la poudre. Dans le temps que je travaillois sur cette matiere, quelques particuliers proposerent de faire de la poudre sans soufre: ils promettoient qu'elle seroit plus forte. La poudre dans laquelle on fait entrer une petite quantité de soufre, augmente de force

* Evelyn's Silva, by Dr. Hunter, p. 223. † Id. p. 946.

‡ Chym. par M. Beaumé, vol. I. p. 455.

du double §."—"The principal ingredients of gunpowder, and those to which it owes its force, are nitre and charcoal; for these two ingredients well mixed together, constitute gunpowder at least equal, if not superior in strength to common gunpowder, (as I found by experience,) and may be seen in the Memoire of Count Saluce, inserted in the Melanges de Philosophie et de Mathematiques, de l'Academie Royale de Turin. The sulphur seems to serve only for the purpose of setting fire to the mass with a less degree of heat*." If I may trust some crude experiments which I have made with a common powder trier, I must accede to the opinion of M. Beaumé, as I repeatedly found that equal bulks of common powder, and of the same sort of powder, freed from its sulphur by a gentle evaporation, differed very much both in the loudness and force of the explosion; the powder which had lost its sulphur being inferior to the other in both particulars. It is not without reason, that equal bulks are here specified, for any definitive measure of common powder weighs more than the same measure of powder which has lost its sulphur; hence the result of experiments made with equal weights of these powders, will be different from that which is derived from the explosion of equal bulks: may not this observation tend to reconcile the opinions before mentioned? But whether sulphur be an absolutely necessary ingredient in the composition of gunpowder or not, it is certain that an accurate mixture of the ingredients is essentially requisite. In order to accomplish this accurate mixture, the ingredients are previously reduced into coarse powders, and afterwards ground and pounded together, till the powder becomes exceeding fine; and when that is done the gunpowder is made. But as gunpowder, in the state of an impalpable dust, would be inconvenient in its use, it has been customary to reduce it into grains, by forcing it, when moistened with water, through sieves of various sizes.

The necessity of a complete mixture of the materials, in order to have good gunpowder, is sensibly felt, in the use of such as has been dried after having been accidentally wetted. There may be the same weight of the powder after it has been dried, that there was before it was wetted; but its strength is greatly diminished on account of the mixture of the ingredients being less perfect. This diminution of strength proceeds from the water having dissolved a

* Chym. par M. Beaumé, vol. 1. p. 461.

† Philos. Trans. 1779, p. 397, where the reader will find several ingenious xperiments relative to the nature of gunpowder, by Dr. Ingenhousz.

portion of the saltpetre (the other two ingredients not being soluble in water ;) for upon drying the powder, the dissolved saltpetre will be crystallized in particles much larger than those were, which entered into the composition of the gunpowder, and thus the mixture will be less intimate and uniform, than it was before the wetting. This wetting of gunpowder is often occasioned by the mere moisture of the atmosphere. Great complaints were made concerning the badness of the gunpowder used by the English in their engagement with the French fleet off Grenada, in July 1779; the French having done much damage to the masts and rigging of the English, when the English shot would not reach them. When this matter was inquired into by the House of Commons, it appeared that the powder had been injured by the moisture of the atmosphere; it had concreted into large lumps, in the middle of which the saltpetre was visible to the naked eye. If the wetting has been considerable, the powder is rendered wholly unfit for use; but if no foreign substance has been mixed with it except fresh water, it may be made into good gunpowder again, by being properly pounded and granulated. If the wetting has been occasioned by salt water, and that to any considerable degree, the sea salt, upon drying the powder, will remain mixed with it, and may so far vitiate its quality, that it can never be used again in the form of gunpowder. However, as by solution in water and subsequent crystallization, the most valuable part of the gunpowder, namely, the saltpetre, may be extracted, and in its original purity, even from powder that has been wetted by sea water, or otherwise spoiled, the saving a damaged powder is a matter of national economy, and deservedly attended to in the elaboratory at Woolwich.

The proportions in which the ingredients of gunpowder are combined together, are not the same in different nations, nor in different works of the same nation, even for powder destined to the same use. It is difficult to obtain from the makers of gunpowder, any information upon this subject; their backwardness in this particular arises, not so much from any of them fancying themselves possessed of the best possible proportion, as from an affectation of mystery common to most manufacturers, and an apprehension of discovering to the world that they do not use so much saltpetre as they ought to do, or as their competitors in trade really do use. Saltpetre is not only a much dearer commodity than either sulphur or charcoal, but it enters also in a much greater proportion into the composition of gunpowder, than both these materials taken together; hence, there is a great temptation to lessen the quantity of the saltpetre, and to augment that of the other ingredients: and the fraud is not easily detected, since gunpowder, which will explode readily and loudly, may be made with very different quantities of saltpetre.

Baptista Porta died in the year 1515; he gives three different portions for making of gunpowder, according as it was required to be of different strength*. I have reduced his proportions, so that the reader may see the quantities of the several ingredients, contained in 100 pounds weight of each sort of powder.

	Weak.	Strong.	Strongest.
Saltpetre	$66\frac{2}{3}$ lb.	75	80
Sulphur	$16\frac{2}{3}$	$12\frac{1}{2}$	10
Charcoal	$16\frac{2}{3}$	$12\frac{1}{2}$	10
	100	100	100

It is somewhat remarkable, that in all these proportions, the sulphur and charcoal are used in equal quantities. Cardan died about sixty years after Baptista Porta, and in that interval, the proportions of the ingredients of gunpowder seem to have undergone a great change. Cardan's proportions for great, middle-sized, and small guns, are expressed in the following table†.

	Gr. Guns.	Mid. sized.	Small.
Saltpetre	50 lb.	$66\frac{2}{3}$	$83\frac{1}{3}$
Sulphur	$16\frac{2}{3}$	$13\frac{1}{3}$	$8\frac{1}{3}$
Charcoal	$33\frac{1}{3}$	20	$8\frac{1}{3}$
	100	100	100

For great and middle-sized guns, we see, a much greater proportion of charcoal than of sulphur was used in Cardan's time; at present, I believe, it is in most places the reverse, or at least the charcoal no where exceeds the sulphur. I have put down the proportions used at present in England, France, Sweden, Poland, and Italy, for the best kind of gunpowder.

* Mag. Nat. L. XII. c. 3.

† Card. Oper. Vol. III. p. 379.

	England.	France.	Sweden.	Poland.	Italy.
Saltpetre	75	75	75	80	$76\frac{1}{2}$
Sulphur	15	$9\frac{1}{2}$	16	12	$12\frac{1}{2}$
Charcoal	10	$15\frac{1}{2}$	9	8	$12\frac{1}{2}$
	*100	100‖	100‡	100‡	$100\frac{1}{2}$†

Several experiments have been lately made in France, in order to determine the exact proportions of the several ingredients which would produce the strongest possible power; these proportions when reduced, as all the rest have been, to the quantity composing one hundred pounds of gunpowder, are

Saltpetre	80 lb.
Charcoal	15
Sulphur	5
	100

From hence it would appear, that in a certain weight of saltpetre, the powder would produce the greatest effect, when the weight of the charcoal was to that of the sulphur, as 3 to 1. On the other hand, experiments are produced from which it is to be concluded, that in a certain weight of saltpetre the best powder is made, when the sulphur is to the charcoal, in the proportion of 2 to 1. From these different accounts, it seems as if the problem of determining the very best possible proportion was not yet solved.

In drying gun-powder, after it is reduced into grains, there are two things to be avoided, too much and too little heat. If the heat is too great, a portion of the sulphur will be driven off, and thus the proportion of the ingredients being changed, the goodness of the powder, so far as it depends on that proportion, will be injured. In order to see what quantity of sulphur might be separated from gun-powder, by a degree of heat not sufficient to explode it, I took 24 grains of the powder marked F F in the shops, and placing

* These are said to be the proportions of government powder.—Pemb. Chem. p. 207.

‖ Chem. Dict. & Baumé's Chem. Vol. I. 466.

‡ Mem. de. Chem. Vol. II. p. 425, where it is said, that two specimens of powder from Holland gave only 71lb. of saltpetre from 100 of powder.

† Comm. Scien. Bonon. Vol. IV. p. 133.

it on a piece of polished copper, I heated the copper by holding it over the flame of a candle; the gun-powder soon sent forth a sulphureous vapour; and when it had been dried so long that no more fume or smell could be distinguished, the remainder weighed nineteen grains, the loss amounting to five grains. The remainder did not explode by a spark like gunpowder, but like a mixture of saltpetre and charcoal, and it really was nothing else, all the sulphur having been dissipated. Gunpowder was formerly dried by being exposed to the heat of the sun, and this method is still in use in France, and in some other countries; afterwards a way was invented of exposing it to a heat equal to that of boiling water; at present it is most generally in England dried in stoves, heated by great iron pots; with any tolerable caution no danger of explosion need be apprehended from this method. All the watery parts of the gunpowder may be evaporated by a degree of heat greatly less than that in which gunpowder explodes; that degree having been ascertained by some late experiments, to be about the 600th degree on Fahrenheit's scale, in which the heat of boiling water is fixed at 212. There is more danger of evaporating a portion of the sulphur in this way of drying gunpowder, than when it is dried by exposure to the sun.

The necessity of freeing gunpowder from all its moisture, is obvious from the following experiment, which was made some years ago before the Royal Society. A quantity of gunpowder was taken out of a barrel, and dried with a heat equal to that in which water boils; a piece of ordnance was charged with a certain weight of this dried powder, and the distance to which it threw a ball was marked. The same piece was charged with an equal weight of the same kind of powder, taken out of the same barrel, but not dried, and it threw an equal ball only to one half the distance. This effect of moisture is so sensible, that some officers have affirmed, that they have seen barrels of gunpowder which was good in the morning, but which became (by attracting, probably, the humidity of the air) good for nothing in the evening*. In order to keep the powder dry, by preventing the access of the air, it has been proposed to line the barrels with tin foil, or with thin sheets of lead, after the manner in which tea boxes are lined†. Would it not be

*—qu'il avoit vu, dans les guerres d'Italie, quelque barrels de poudre qui étoit bonne le matin, et qui ne valoit rien le soir. Hist. Nat. de l'Espagne, p.82.

† Hist. Nat. de l'Espagne.

possible to preserve powder free from moisture, and from the loss of a part of its sulphur in hot climates, by keeping it in glazed earthen bottles, or in bottles made of copper or tin, well corked?

This disposition to attract the humidity of the air, is different in different sorts of powder, it is the least in that which is made from the purest saltpetre; pure saltpetre, which has been dried as gunpowder is dried, does not become heavier by exposure to the atmosphere; at least, its increase of weight is very small, not amounting, as far as my experiments have informed me, to above one 72d part of its weight; I rather think that it does not acquire any increase of weight. But saltpetre mixed with sea salt, attracts the humidity very sensibly; and hence, though there should be the same weight of saline matter in a certain weight of gunpowder, yet the goodness of the powder may be very variable, not only from the foreign saline matter, be it sea salt, or any other salt, injuring the quality of the powder as being an improper ingredient, but from its rendering the powder more liable to become humid.

Saltpetre being the ingredient, in which there is the greatest room for fraud, in the composition of gunpowder, and on the quantity of which its strength chiefly depends, the reader will excuse the minuteness of the following process, to ascertain the quantity of saltpetre contained in any specimen of gunpowder.

Take any quantity of gunpowder, pound it in a glass mortar till all the grains are broken, lay it before a gentle fire till it be quite dry; in that state weigh accurately any quantity of it, suppose four ounces; boil these four ounces in about a quart of water; the boiling need neither be violent nor long continued, for the water will readily dissolve all the saltpetre, or other saline matter, and not a particle of either the sulphur or the charcoal of the powder. In order to separate the water containing the saltpetre, from the sulphur and charcoal, pour the whole into a filter made of brown paper; the water containing the saltpetre will run through the paper, and must be carefully preserved; the charcoal and sulphur will remain upon the paper. But as some particles of saltpetre will stick both to the filtering paper, and to the mass of sulphur and charcoal, these are to be repeatedly washed, by pouring hot water upon them, till the water in running through the filter is quite insipid; then we may be certain, that we have all the saltpetre originally contained in the powder, now dissolved in the water, and all the sulphur and charcoal remaining a fixed mass upon the filter. These respective quantities may be ascertained without much difficulty. The water containing the dissolved saltpetre, must be evaporated by a gentle heat; the saltpetre cannot be evaporated by the same degree of heat which evaporates the water; all the saltpetre then contained in the gunpowder, will remain after the water is dispersed, and being carefully collected and weighed, it will shew the quantity of saline matter contained in the powder. Dry the mass of sulphur and charcoal, by laying the filtering paper containing it before the fire; it should be made as dry as the powder was before it was dissolved in the water: in that state weigh the saltpetre and charcoal; and, when the experiment has been accurately made, the weight of the saltpetre, added to that of the mixture of sulphur and charcoal, will just amount to four ounces, the weight of the powder. The quantity of saline matter contained in any specimen of gunpowder, being thus ascertained, its quality may be known by dissolving it in water, and crystallizing it; if any part of it crystallizes in little cubes, it is a sign that it contains sea-salt; or if any part of it, after being duly evaporated, will not crystallize, it is a sign that it contains another sort of impurity, called by saltpetre makers, the *mother of nitre*, which powerfully attracts the humidity of the air.

The gunpowder marked FF, was analysed in the following manner. Twenty-four grains, by evaporating the sulphur, were reduced to nineteen; these nineteen grains gave, by solution in water and subsequent filtration and crystallization, sixteen grains of saltpetre; the charcoal, when properly dried, weighed three grains. According to these proportions, 100 pounds of this kind of gunpowder consisted of

Saltpetre . . .	$66\frac{2}{3}$
Sulphur . . .	$20\frac{5}{6}$
Charcoal . . .	$12\frac{1}{2}$
	100 lbs.

I tried this gunpowder in two or three other ways by taking larger quantities of it, but the quantity of saltpetre was always 66 lb. together with some fractional part of a pound, from 100 lb. of gunpowder. The powders marked with a single and a double *f*, differ in the size of the grain, but they do not seem to differ, as far as I have tried them, in the quantity of the saltpetre they contain. From some sorts of powder, I have got after the rate of 76lb. of saltpetre, from 100lb. of the gunpowder.

The method of analysing gunpowder, by evaporating the sulphur, is not wholly to be relied upon; I have often observed, that when mixtures of sulphur and charcoal have been exposed to evaporation, on a plate of heated copper, the remainder has weighed less than the charcoal which entered the composition, part of it having been carried off by the violent evaporation of the sulphur: and hence the proportion of sulphur in the above analysis is probably too great. I am aware that this observation is wholly opposite to the conclusion of M. Beaumé, who contends, that one twenty-fourth part of the weight of the sulphur employed in any mixture of sulphur and charcoal, adheres so strongly to the charcoal, that it cannot be separated from it without burning the charcoal.—I can only say, that he separated the sulphur by burning it, and I separated mine by subliming it without suffering it to take fire, and this difference in the manner of making the experiment, may perhaps be sufficient to account for the different results.—But it is unnecessary to pursue this subject further; there are several things to be attended to in forming a complete analysis of gunpowder, which any person tolerably well versed in chemistry, would certainly take notice of, if the analysis of any particular powder was required to be made, and which cannot, in this general view, be minutely described: and, indeed, it is the less necessary to enter into a detail on this subject, as the strength of the powder is not so much affected by small variations in the quantities of the sulphur and charcoal, which enter into its composition; and the method of ascertaining the quantity and quality of the saltpetre, in any particular gunpowder, has been sufficiently explained.

In order to judge with more certainty concerning the effect of sea-salt, when mixed with saltpetre in attracting the humidity of the air, I made the following experiment. Five parts of pure saltpetre in powder, were exposed for a month to a moist atmosphere, but I did not observe that the saltpetre had gained the least increase of weight; for the same length of time, and in the same place, I exposed four parts of saltpetre mixed with one of common salt, and this mixture had attracted so much moisture, that it was in a state of fluidity.

[*Bishop Watson.*

Besides saltpetre or the nitric acid, which is the active ingredient in saltpetre, there are various other acids, as the oxymuriatic, (chlorine of Davy), the hyper oxymuriatic, the arsenic, tungstic, molybdic, and columbic, that are powerful supporters of combustion. Of these the most easy of access is the oxymuriatic; and this has in consequence been tried either instead of, or in conjunction with, the nitric acid, to ascertain whether it be possessed of more power. The best experiments upon the subject are those of Edward Howard, Esq. as communicated to the Royal Society. The effect, according to these, is very singular, in the employment of the oxymuriat of potash, the only form in which the oxymuriatic acid has hitherto been made use of. It acts with considerably more energy so far as its range extends; but this range is far short of that produced by saltpetre, or nitrat of potash. It produces also a much more violent explosion; and an explosion which, in one instance, burst the vessel, and nearly destroyed the eye-sight of the bold and ingenious experimenter. [*Editor.*

CHAP. XIV.

FULMINATING POWDERS.

There are various combinations under this name that possess a near resemblance to gunpowder in their constituent parts, easily inflame, and explode with great violence, but require a certain degree of heat to produce this effect. We shall notice the common and the metallic fulminating powders.

SECTION I.

Common Fulminating Powder.

This is prepared as follows: take three parts of nitre, two of purified pearl-ash, and one of flowers of sulphur, mix the whole very accurately in an earthen mortar, and place it on a tile or plate before the fire, till it is perfectly dry: then transfer it while hot into a ground stopper bottle, and it may be kept without injury for any length of time. In order to experience its effects, pour from ten to forty grains into an iron ladle, and place it over a slow fire:

in a short time the powder becomes brown and acquires a pasty consistence ; a blue lambent flame then appears on the surface, and in an instant after the whole explodes with a stunning noise and a slight momentary flash. If the mass be removed from the fire as soon as it is fused, and kept in a dry well-closed vial, it may at any time be exploded by a spark, in which case it burns like gunpowder, but more rapidly and with greater detonation ; but this effect cannot be produced on the unmelted powder, how accurately soever the ingredients of it are mixed together. When fulminating powder is in fusion, but not heated to the degree necessary to produce the blue flame, a particle of ignited charcoal thrown upon it will occasion immediately a remarkably loud explosion.

It appears that the ingredients of this powder do not acquire their fulminating property till combined by fusion ; in other words, till the pot-ash of sulphur form sulphuret of pot-ash : whence fulminating powder may also be made by mixing sulphuret of pot-ash with nitre, instead of by adding the sulphur and alkali separate.

In all these the cause of the detonation, or fulmination, is not accurately understood. In simple fulminating powder, there is a very large portion of elastic gass evolved ; in fulminating gold or silver, a much smaller ; yet the explosion in the latter case is infinitely greater than that in the former.

Fulminating Gold.

Dissolve pure gold in nitro-muriatic acid to saturation, and dilute the solution with three times its bulk of distilled water, and add to it gradually some pure ammonia ; a yellow precipitate will be obtained, which must be repeatedly washed with distilled water, and dried on a chalk stone, or in a filter. When perfectly dry, it is called fulminating gold, and detonates by heat, as may be shewn by heating a few grains of it on the point of a knife over the candle.

Fulminating Silver.

Dissolve fine silver in pale nitric acid, and precipitate the solution by lime-water ; decant the fluid, mix the precipitate with liquid ammonia, and stir it till it assumes a black colour ; then decant the fluid, and leave it in the open air to dry. This product is fulminating silver, which when once obtained cannot be touched without producing a violent explosion. It is the most dangerous preparation known, for the contact of fire is not necessary to cause it to detonate. It explodes by the mere touch. Its preparation is so hazardous, that it ought not to be attempted without a mask, with strong glass eyes, upon the face. No more than a single grain ought at any time to be tried as an experiment. This was invented by M. Berthollet.

M. Chenevix has invented a fulminating silver, not so dangerous as that just mentioned. It explodes only by a slight friction in contact with combustible bodies. It is thus prepared: diffuse a quantity of alumina through water, and let a current of oxygenated muriatic acid gass pass through it for some time. Then digest some phosphate of silver on the solution of the oxygenated muriate of alumina, and evaporate it slowly. The product obtained will be a hyper-oxygenated muriate of silver, a single grain of which, in contact with two or three of sulphur, will explode violently with the slightest friction.

Fulminating Mercury.

The mercurial preparations which fulminate, when mixed with sulphur, and gradually exposed to a gentle heat, are well known to chemists: they were discovered, and have been fully described, by Mr. Bayen.

MM. Brugnatelli and Van Mons have likewise produced fulminations by concussion, as well by nitrat of mercury and phosphorus, as with phosphorus and most other nitrats. Cinnabar also is amongst the substances which, according to MM. Fourcroy and Vauquelin, detonate by concussion with oxymuriat of potash.

M. Ameilon had, according to M. Berthollet, observed, that the precipitate obtained from nitrat of mercury, by oxalic acid, fuses with a hissing noise.

But mercury, and most, if not all its oxyds, may, by treatment with nitric acid and alcohol, be converted into a whitish crystallized powder, possessing all the inflammable properties of gunpowder, as well as many peculiar to itself.

"I was led to this discovery," says Mr. Howard, the inventor, "by a late assertion, that hydrogen is the basis of the muriatic acid: it induced me to attempt to combine different substances with hydrogen and oxygen. With this view I mixed such substances with alcohol and nitric acid as might (by predisposing affinity) favour as well as attract an acid combination of the hydrogen of the one, and the oxygen of the other. The pure red oxyd of mercury appeared not unfit for this purpose; it was therefore intermixed with alcohol, and upon both nitric acid was affused. The acid did not act upon the alcohol so immediately as when these fluids are alone mixed together, but first gradually dissolved the oxyde: however, after some minutes had elapsed, a smell of ether was perceptible, and a white dense smoke, much resembling that from the liquor fumans of Libavius, was emitted with ebullition. The mixture then threw down a dark-coloured precipitate, which by degrees became nearly white. This precipitate I separated by filtration; and observing it to be crystallized in smaller acicular crystals, of a saline taste, and also finding a part of the mercury volatilized in the white fumes, I must acknowledge, I was not altogether without hopes that muriatic acid had been formed, and united to the mercurial oxide; I therefore, for obvious reasons, poured sulphuric acid upon the dried crystalline mass, when a violent effervescence ensued, and, to my great astonishment, an explosion took place. The singularity of this explosion induced me to repeat the process several times; and finding that I always obtained the same kind of powder, I prepared a quantity of it, and was led to make the series of experiments which I shall have the honour to relate in this paper.

"I first attempted to make the mercurial powder fulminate by concussion; and for that purpose laid about a grain of it upon a cold anvil, and struck it with a hammer, likewise cold. It detonated slightly, not being, as I suppose, struck with a flat blow; for upon using three or four grains, a very stunning disagreeable noise was produced, and the faces both of the hammer and the anvil were much indented.

"Half a grain, or a grain, if quite dry, is as much as ought to be used on such an occasion.

"The shock of an electrical battery, sent through five or six grains of the powder, produces a very similar effect. It seems, indeed, that a strong electrical shock generally acts on fulminating substances like the blow of a hammer. Messrs. Fourcroy and Vauquelin found this to be the case, with all their mixtures of oxymuriate of potass.

"To ascertain at what temperature the mercurial powder explodes, two or three grains of it were floated on oil, in a capsule of leaf tin; the bulb of a Fahrenheit's thermometer was made just to touch the surface of the oil, which was then gradually heated till the powder exploded, as the mercury reached the 368th degree.

"Desirous of comparing the strength of the mercurial compound with that of gunpowder, I made the following experiment in the presence of my friend Mr. Abernethy.

"Finding that the powder could not be fired with flint and steel, without a disagreeable noise, a common gunpowder proof, capable of containing eleven grains of fine gunpowder, was filled with it, and fired in the usual way: the report was sharp, but not loud. The person who held the instrument in his hand felt no recoil; but the explosion laid open the upper part of the barrel, nearly from the touch-hole to the muzzle, and struck off the hand of the register, the surface of which was evenly indented, to the depth of 0.1 of an inch, as if it had received the impression of a punch.

"The instrument used in this experiment being familiarly known, it is therefore scarcely necessary to describe it: suffice it to say, that it was brass, mounted with a spring register, the moveable hand of which closed up the muzzle, to receive and graduate the violence of the explosion. The barrel was half an inch in calibre, and nearly half an inch thick, except where a spring of the lock impaired half its thickness.

"A gun belonging to Mr. Keir, an ingenious artist of Camden-Town, was next charged with seventeen grains of the mercurial powder, and a leaden bullet. A block of wood was placed at about eight yards from the muzzle to receive the ball, and the gun was fired by a fuse. No recoil seemed to have taken place, as the barrel was not moved from its position, although it was in no ways confined. The report was feeble; the bullet, Mr. Keir conceived, from the impression made upon the wood, had been projected with about half the force it would have been by an ordinary charge, or sixty-eight grains, of the best gunpowder. We therefore recharged the gun with thirty-four grains of the mercurial powder; and as the great strength of the piece removed any apprehension of danger, Mr. Keir fired it from his shoulder, aiming at the same block of wood. The report was like the first, sharp, but not louder than might have been expected from a charge of gunpowder. Fortunately Mr. Keir was not hurt; but the gun was burst in an extraordinary manner. The breech was what is called a patent one, of the best forged iron, consisting of a chamber 0.4 of an inch thick all round, and 0.4 of an inch in calibre; it was torn open and flawed in many directions, and the gold touch-hole driven out. The barrel into which the breech was screwed was 0.5 of an inch thick; it was split by a single crack three inches long, but this did not appear to me to be the immediate effect of the explosion. I think the screw of the breech, being suddenly enlarged, acted as a wedge upon the barrel. The ball missed the block of wood, and struck against a wall, which had already been the receptable of so many bullets, that we could not satisfy ourselves about the impression made by this last.

" As it was pretty plain that no gun could confine a quantity of the mercurial powder sufficient to project a bullet with a greater force than an ordinary charge of gunpowder, I determined to try its comparative strength in another way. I procured two blocks of wood, very nearly of the same size and strength, and bored them with the same instrument to the same depth. The one was charged with half an ounce of the best Dartford gunpowder, and the other with half an ounce of the mercurial powder; both were alike buried in sand, and fired by a train communicating with the powders by a small touch-hole. The block containing the gunpowder was simply split into three pieces: that charged with the mercurial powder was burst in every direction, and the parts immediately contiguous to the powder were absolutely pounded, yet the whole hung together, whereas the block split by the gunpowder had its parts fairly separated. The sand surrounding the gunpowder was undoubtedly the most disturbed; in short, the mercurial powder appeared to have acted with the greatest energy, but only within certain limits.

" The effects of the mercurial powder, in the last experiments, made me believe that it might be confined, during its explosion, in the centre of a hollow glass globe. Having therefore provided such a vessel, seven inches in diameter, and nearly half an inch thick, mounted with brass caps, and a stop cock, I placed ten grains of mercurial powder on thin paper, laid on iron wire 149th of an inch thick across the paper, through the midst of the powder, and, closing the paper, tied it fast at both extremities with silk to the wire. As the inclosed powder was now attached to the middle of the wire, each end of which was connected with the brass caps, the packet of powder, became by this disposition, fixed in the centre of the globe. Such a charge of an electrical battery was then sent along the wire, as a preliminary experiment (with Mr. Cuthbertson's electrometer) had shewn me would, by making the wire red hot, inflame the powder. The glass globe withstood the explosion, and of course retained whatever gasses were generated; its interior was thinly coated with quicksilver, in a very divided state. A bent glass tube was now screwed to the stop-cock of the brass cap, which being introduced under a glass jar standing in the mercurial bath, the stop-cock was opened. Three cubical inches of air rushed out, and a fourth was set at liberty when the apparatus was removed to the water tub. The explosion being repeated, and the air all received over water, the quantity did not vary. To avoid an error from change of temperature, the glass globe was, both before and after the explosion, immersed in water of the same temperature. It appears, therefore, that the ten grains of powder produced four cubical inches only of air.

"To continue the comparison between the mercurial powder and gunpowder, ten grains of the best Dartford gunpowder were in a similar manner set fire to in the glass globe; it remained entire. The whole of the powder did not explode, for some complete grains were to be observed adhering to the interior surface of the glass. Little need be said of the nature of the gasses generated during the combustion of the gunpowder: they must have been carbonic acid gass, sulphureous acid gass, nitrogen gass, and (according to Lavoisier) perhaps hydrogen gass. As to the quantity of these, it is obvious that it could not be ascertained: because the two first were, at least in part, speedily absorbed by the alkali of the nitre, left pure after the decomposition of its nitric acid."

The following description will give the experimental philosopher a clear idea of the instrument used in this business.

The ball or globe of glass is nearly half an inch thick, and seven inches in diameter. It has two necks, on which is cemented two brass caps, each being perforated with a female screw, to receive the male ones; through the former a small hole is drilled; the latter is furnished with a perforated stud or shank. By means of a leather collar the neck can be air-tightly closed. When a portion of the powder is to be exploded, it must be placed on a piece of paper, and a small wire laid across the paper, through the midst of the powder; the paper being then closed, is to be tied at each end to the wire with a silken thread. One end of this wire is to be fastened to the end of the shank, and the screw inserted to half its length into the brass cap; the other end of the wire, by means of a needle, is to be drawn through the hole. The screw being now fixed in its place, and the wire drawn tight, is to be secured by pushing the irregular wooden plug into the aperture of the screw, taking care to leave a passage for the air. The stop-cock is now to be screwed on. The glass tube is bent, that it may more conveniently be introduced under the receiver of a pneumatic apparatus.

"From some of the experiments (continues Mr. Howard) in which the gunpowder proof and the gun were burst, it might be inferred, that the astonishing force of the mercurial powder is to be attributed to the rapidity of its combustion; and a train of several inches in length being consumed in a single flash, it is evident that its combustion must be rapid. But from other experiments it is plain that this force is restrained to a narrow limit, both because the block of wood charged with the mercurial powder was more shattered than that charged with the gunpowder, whilst the sand surrounding it was least disturbed, and likewise because the glass globe withstood the explosion of ten grains of the powder fixed in its centre; a charge I had twice found sufficient to destroy old pistol barrels, which were not injured by being fired when full of the best gunpowder. It also appears from the last experiment, that ten grains of the powder produced by ignition four cubical inches only of air; and it is not to be supposed that the generation, however rapid, of four cubical inches of air, will alone account for the described force; neither can it be accounted for by the formation of a little water, which, as will hereafter be shewn, happens at the same moment; the quantity formed from ten grains must be so trifling, that I cannot ascribe much force to the expansion of its vapour. The sudden vaporation of a part of the mercury seems to me a principal cause of this immense yet limited force; because its limitation may then be explained, as it is well known that mercury easily parts with caloric, and requires a temperature of 600° of Fahrenheit, to be maintained in the vaporous state. That the mercury is really converted into vapour, by ignition of the powder, may be inferred from the thin coat of divided quicksilver, which, after the explosion in the glass globe, covered its interior surface; and likewise from the quicksilver with which a tallow candle, or a piece of gold, may be evenly coated, by being held at a small distance from the inflamed powder. These facts certainly render it more than probable, although they do not demonstrate that the mercury is volatilized; because it is not unlikely that many mercurial particles are mechanically impelled against the surface of the glass, the gold, and the tallow.

"As to the force of the dilated mercury, M. Beaumé relates a remarkable instance of it, as follows:

"Un alchymiste se présenta à Mr. Geoffroy, et l'assura qu'il avoit trouvé le moyen de fixer le mercure par une opération fort simple. Il fit construire six boîtes rondes en fer fort épais, qui entroient les unes dans les autres; la dernière étoit assujettie par deux cercles de fer qui se croisoient en angles droits. On avoit mis quelques livres de mercure dans la capacité de la première; on mit cet appareil dans un fourneau assez rempli de charbon pour faire rougir à blanc les boîtes de fer; mais, lorsque la chaleur eut pénétré suffisamment le mercure, les boîtes crevèrent, avec une telle explosion qu'il se fit un bruit épouvantable; des morceaux de boîtes furent lancés avec tant de rapidité qu'il y en eut qui passèrent au travers de deux planchers; d'autres firent sur la muraille des effets semblables a ceux des éclats de bombes*."

"Had the alchemist proposed to fix water by the same apparatus, the nest of boxes must, I suppose, have likewise been ruptured; yet it does not follow that the explosion would have been so tremendous; indeed, it is probable that it would not, for if (as Mr. Kirwan remarked to me) substances which have the greatest specific gravity have likewise the greatest attraction of cohesion, the supposition that the vapour of water, would agree with a position of Sir Isaac Newton, that those particles recede from one another with the greatest force, and are most difficultly brought together, which upon contact cohere most strongly.

"Before I attempt to investigate the constituent principles of this powder, it will be proper to describe the process and manipulations which, from frequent trials, seem to be best calculated to produce it. One hundred grains, or a greater proportional quantity of quicksilver, (not exceeding 500 grains), are to be dissolved, with heat, in a measured ounce and a half of nitric acid. This solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied until an effervescence is excited. A white fume then begins to undulate on the surface of the liquor; and the powder will be gradually precipitated, upon the cessation of action and re-

* Chymie Expérimentale et Raisonné, tom. ii. p. 593.

action. The precipitate is to be immediately collected on a filter, well washed with distilled water, and carefully dried in a heat not much exceeding that of a water-bath. The immediate edulcoration of the powder is material, because it is liable to the reaction of nitric acid; and, whilst any of that acid adheres to it, it is very subject to the influence of light. Let it also be cautiously remembered, that the mercurial solution is to be poured upon the alcohol.

"I have recommended quicksilver to be used in preference to an oxyd, because it seems to answer equally, and is less expensive; otherwise, not only the pure red oxyd, but the red nitrous oxide, and turpeth, may be substituted; neither does it seem essential to attend to the precise specific gravity of the acid, or the alcohol. The rectified spirit of wine, and the nitrous acid of commerce, never failed with me, to produce a fulminating mercury. It is indeed true, that the powder prepared without attention is produced in different quantities, varieties in colour, and probably in strength. From analogy, I am disposed to think the whitest is the strongest; for it is well known that the black precipitates of mercury approach nearest to the metallic state. The variation in quantity is remarkable: the smallest quantity I ever obtained from 100 grains of quicksilver being 120 grains, and the largest 132 grains. Much depends on very minute circumstances. The greatest product seems to be obtained when a vessel is used which condenses and causes most ether to return into the mother liquor; besides which, care is to be had in applying the requisite heat, that a speedy and not a violent action be effected. One hundred grains of an oxide are not so productive as 100 grains of quicksilver.

"As to the colour, it seems to incline to black when the action of the acid of the alcohol is most violent, and *vice versa.*

"I need not observe, that the gasses which were generated during the combustion of the powder in the glass globe, were necessarily mixed with atmospheric air; the facility with which the electric fluid passes through a vacuum, made such a mixture unavoidable.

"The cubical inch of gass received over water was not readily absorbed by it; and, as it soon extinguished a taper without becoming red, or being itself inflamed, barytes water was let up to the three cubical inches received over mercury, when a carbonate of barytes was immediately precipitated.

"The residue of several explosions, after the carbonic acid had been separated, was found, by the test of nitrous gass, to contain nitrogen or azotic gas; which does not proceed from any decomposition of atmospheric air, because the powder may be made to explode under the exhausted receiver of an air-pump. It is therefore manifest that the gasses generated during the combustion of the fulminating mercury, consist of carbonic acid and nitrogen gasses.

"The principal re-agents which decompose the mercurial powder are the nitric, the sulphuric, and the muriatic acids. The nitric changes the whole into nitrous gass, carbonic acid gass, acetous acid, and nitrate of mercury. I resolved it into these different principles, by distilling it pneumatically with nitric acid: this acid upon the application of heat soon dissolved the powder, and extricated a quantity of gass, which was found, by well-known tests, to be nitrous gass mixed with carbonic acid gass. The distillation was carried on until gass no longer came over. The liquor of the retort was then mixed with the liquor collected in the receiver, and the whole saturated with potass; which precipitated the mercury into a yellowish brown powder, nearly as it would have done from a solution of nitrate of mercury. This precipitate was separated by a filter, and the filtrated liquor evaporated to a dry salt, which was washed with alcohol. A portion of the salt being refused by this menstruum, it was separated by filtration, and recognized, by all its properties, to be nitrate of potass. The alcohol liquor was likewise evaporated to a dry salt, which upon the effusion of a little concentrate sulphuric acid, emitted acetous acid, contaminated with a feeble smell of nitrous acid, owing to the solubility of a small portion of the nitre in the alcohol.

"The sulphuric acid acts upon the powder in a remarkable manner, as has already been noticed. A very concentrate acid produced an explosion nearly at the instant of contact, on account, I presume, of the sudden and copious disengagement of caloric from a portion of powder which is decomposed by the acid. An acid somewhat less concentrate likewise extricates a considerable quantity of caloric, with a good deal of gass; but as it effects a complete decomposition, it causes no explosion. An acid diluted with an equal quantity of water, by the aid of a little heat, separates the gass so much less rapidly, that it may with safety be collected in a pneumatic apparatus. But, whatever be the density of the acid (provided no explosion be produced), there remains in the sulphuric liquor, after the separation of the gass, a white uninflammable and uncrystallized powder mixed with some minute globules of quicksilver.

"To estimate the quantity, and observe the nature, of this uninflammable substance, I treated 100 grains of the fulminating mercury with sulphuric acid a little diluted. The gass being separated, I decanted off the liquor as it became clear, and freed the insoluble powder from acid by edulcoration with distilled water; after which I dried it, and found it weighed only eighty-four grains; consequently had lost sixteen-grains of its original weight. Suspecting, from the operation of the nitric acid in the former experiment, that these eighty-four grains (with the exception of the quicksilver globules) were oxalate of mercury, I digested them in nitrate of lime and found my suspicion just. The mercury of the oxalate united to the nitric acid, and the oxalic acid to the lime. A new insoluble compound was formed; it weighed, when washed and dry, 48.5 grains. Carbonate of potass separated the lime, and formed oxalate of potass, capable of precipitating lime-water and muriate of lime; although it had been depurated from excess of alkali, and from carbonate acid, by a previous addition of acetous acid. That the mercury of the oxalate in the eighty-four grains had united to the nitric acid of the nitrate of lime was proved, by dropping muriatic acid into liquor from which the substance demonstrated to be oxalate of lime had separated; for a copious precipitation of calomel instantly ensued.

"The sulphuric liquor, decanted from the oxalate of mercury, was now added to that with which it was edulcorated, and the whole saturated with carbonate of potass. As effervescence ceased, a cloudiness and precipitation followed; and the precipitate being collected, washed and dried, weighed 3.4 grains: it appeared to be a carbonate of mercury. Upon evaporating a portion of the saturated sulphuric liquor, I found nothing but sulphate of potass: nor had it any metallic taste. There then remains, without allowing for the weight of the carbonic united to the 3.4 grains, a deficit from the 100 grains of mercurial powder of 12.6 grains, which I ascribe to the gass separated by the action of the sulphuric acid. To ascertain the quantity, and examine the nature of the gass so separated, I introduced into a very small tubulated retort fifty grains of the mercurial powder, and poured upon it three drachms, by measure, of sulphuric acid, with the assistance of a gentle heat. I first received it over quicksilver; the surface of which, during the operation, partially covered itself with a little black powder.

"The gass, by different trials, amounted to from twenty-eight to thirty-one cubical inches: it first appeared to be nothing but carbonic acid, as it precipitated barytes water, and extinguished a taper, without being itself inflamed, or becoming red. But upon letting up to it liquid caustic ammonia, there was a residue of from five to seven inches, of a peculiar inflammable gass, which burnt with a greenish-blue flame. When I made use of the water-tub, I obtained, from the same materials, from twenty-five to twenty-seven inches only of gass, although the average quantity of the peculiar inflammable gass was likewise from five to seven inches: therefore, the difference of the aggregate product, over the two fluids, must have arisen from the absorption, by the water, of a part of the carbonic acid in its nascent state. The variation of the quantity of the inflammable gass, when powder from the same parcel is used, seems to depend upon the acid being a little more or less dilute.

"With respect to the nature of the peculiar inflammable gass, it is plain to me, from the reasons I shall immediately adduce, that it is no other than the gass (in a pure state) into which the nitrous etherized gass can be resolved, by treatment with dilute sulphuric acid.

"The Dutch chemists have shewn, that the nitrous etherized gass can be resolved into nitrous gass, by exposure to concentrate sulphuric acid; and that, by using a dilute instead of a concentrate acid, a gass is obtained which enlarges the flame of a burning taper, so much like the gasseous oxide of azote, that they mistook it for that substance, until they discovered that it was permanent over water; refused to detonate with hydrogen; and that the fallacious appearance was owing to a mixture of nitrous gass with inflammable gass.

"The inflammable gass, separated from the powder, answers to the description of the gass which at first deceived the Dutch chemists: 1st, in being permanent over water; 2dly, refusing to detonate with hydrogen; and 3dly, having the appearance of the gasseous oxide of azote, when mixed with nitrous gass.

"The gass separable by the same acid, from nitrous etherized gass, and from the mercurial powder, have therefore the same properties. Every chemist would thence conclude, that the nitrous etherized gass is a constituent part of the powder; and the inflammable and nitrous gass, instead of the inflammable and carbonic acid gass, had been the mixed product extricated from it by dilute sulphuric acid.

"It however appears to me, that nitrous gass was really produced by the action of the dilute sulphuric acid; and that, when produced, it united to an excess of oxygen, present in the oxalate of mercury.

"To explain how this change might happen, I must premise, that my experiments have shewn me, that oxalate of mercury can exist in two, if not in three states. 1st. By the discovery of Mr. Ameilon, the precipitate obtained by oxalic acid, from nitrate of mercury, fuses with a hissing noise. The precipitate is an oxalate of mercury, seemingly with excess of oxygen. Mercury dissolved in sulphuric acid, and precipitated by oxalic acid, and also the pure red oxide of mercury, digested with oxalic acid, give oxalates in the same state. 2dly. Acetate of mercury, precipitated by oxalic acid, although a true oxalate is formed, has no kind of inflammability. I consider it as an oxalate, with less oxygen than those above-mentioned. 3dly. A solution of nitrate of mercury, boiled with dulcified spirit of nitre, gives an oxalate more inflammable than any other; perhaps it contains most oxygen.

"The oxalate of mercury, remaining from the powder in the sulphuric liquor, is not only always in the same state as that precipitated from acetate of mercury, entirely devoid of inflammability, but contains globules of quicksilver, consequently it must have parted with even more than its excess of oxygen; and if nitrous gass was present, it would of course seize at least a portion of that oxygen. It is true, that globules of quicksilver may seem incompatible with nitrous acid; but the quantity of the one may not correspond with that of the other, or the dilution of the acid may destroy its action.

"As to the presence of the carbonic acid, it must have arisen either from a complete decomposition of a part of the oxalate, or admitting the nitrous etherized gass to be a constituent principle of the powder, from a portion of the oxygen, not taken up by the nitrous gass, being united with the carbon of the etherized gass.

"The muriatic acid, digested with the mercurial powder, dissolves a portion of it, without extricating any notable quantity of gass. The dissolution, evaporated to a dry salt, tastes like the corrosive sublimate; and the portion which the acid does not take up is left in a state of an inflammable oxalate.

"These effects all tend to establish the existence of the nitrous etherized gass, as a constituent part of the powder; and likewise corroborate the explanation I have ventured to give of the action of the sulphuric acid. Moreover, a measured ounce and a half of nitrous acid, holding 100 grains of mercury in solution, and two measured ounces of alcohol, yield ninety cubical inches only of gass: whereas, without the intervention of mercury, they yield 210 inches. Upon the whole, I trust it will be thought reasonable to conclude, that the mercurial powder is composed of the nitrous etherized gass, and of oxalate of mercury with excess of oxygen. 1st. Because the nitric converts the mercurial powder entirely into nitrous gass, carbonic acid gass, acetous acid, and nitrate of mercury. 2dly. Because the dilute sulphuric acid revolves it into an uninflammable oxalate of mercury, and separates from it a gass resembling that into which the same acid resolves the nitrous etherized gass. 3dly. Because an uninflammable oxalate is likewise left, after the muriatic acid has converted a part of it into sublimate. 4thly. Because it cannot be formed by boiling nitrate of mercury, in dulcified spirits of nitre; although a very inflammable oxalate is by this means produced. 5thly. Because the difference of the product of gass, from the same measures of alcohol and nitrous acid, with and without mercury in solution, is not trifling; and 6thly. Because nitrogen gass was generated during its combustion in the glass globe.

"Should my conclusions be thought warranted by the reasons I have adduced, the theory of the combustion of the mercurial powder will be obvious to every chemist. The hydrogen of the oxalic acid, and of the etherized gass, is first united to the oxygen of the oxalate, forming water; the carbon is saturated with oxygen, forming carbonic acid gass; and a part, if not the whole of the nitrogen of the etherized gass, is separated in the state of nitrogen gass; both which last gasses, it may be recollected, were after the explosion present in the glass globe. The mercury is revived, and, I presume, thrown into vapour, as may well be imagined, from the immense quantity of caloric extricated, by adding concentrate sulphuric acid to the mercurial powder.

"I will not venture to state, with accuracy, in what proportions its constituent principles are combined. The affinities I have brought into play are complicated, and the constitution of the substances I have to deal with not fully known. But to make round numbers, I will resume the statement, that 100 grains of the mercurial powder lost sixteen grains of its original weight, by treatment with dilute sulphuric acid: eighty-four grains of the mercurial oxalate, mixed with a few minute globules of quicksilver, remained undissolved in the acid. The sulphuric liquor was saturated with carbonic of potash, and yielded 3.4 grains of carbonate of mercury. If 1.4 grains should be thought a proper allowance for the weight of carbonic acid in the 3.4 grains, I will make that deduction, and add the remaining two grains to the eighty-four grains of mercurial oxalate and quicksilver; I shall then have,

Of oxalate and mercury	-	86 grains.
And a deficit, to be ascribed to the nitrous etherized gass, and excess of oxygen		14
		100

"It may perhaps be proper to proceed still further, and recur to the 48.5 grains, separated by nitrate of lime from the eighty-four grains of mercurial oxalate, and globules of quicksilver. These 48.5 grains were proved to be oxalate of lime; but they contained a minute inseparable quantity of mercury, almost in the state of quicksilver, formerly part of the eighty-four grains from which they were separated. Had the 48.5 grains been pure calcareous oxalate, the quantity of pure oxalic acid in them would, according to Bergmann, be 23.28 grains. Hence, by omitting the two grains of mercury, in the 3.4 grains of carbonate, 100 grains of the mercurial powder might have been said to contain, of pure oxalic acid, 23.28 grains; of mercury 62.72 grains; and of nitrous etherized gass, and excess of oxygen, fourteen grains. But as the 48.5 grains were not pure oxalate, inasmuch as they contained the mercury they received from the eighty-four grains, from which they were generated by the nitrate of lime, some allowance must be made for the mercury, successively intermixed with the eighty-four grains, and the 48.5 grains. In order to make corresponding numbers, and allow for unavoidable errors, I shall estimate the quantity of that mercury to have amounted to two grains, which I must of course deduct from the 33.28 grains of oxalic acid. I shall then have the following statement:

That 100 grains of fulminating mercury ought to contain, of pure oxalic acid,		21.28 grains.
Of mercury, formerly united to the oxalic acid, -	60.72	
Of mercury, dissolved in the sulphuric liquor, -	2	
And of mercury left in the sulphuric liquor, after the separation of the gasses, -	2	
Total of mercury,		64.72
Of nitrous etherized gass, and excess of oxygen, - - -		14
		100

" Since 100 grains of the powder seem to contain 64.72 grains of mercury, it will be immediately enquired, what becomes of 100 grains of quicksilver, when treated as directed, in the description of the process for preparing the fulminating mercury.

" It has been stated, that 100 grains of quicksilver produce, under different circumstances, from 120 to 132 grains of mercurial powder; and, if 100 grains of this powder contain 64.78 grains, 120 grains, or 132 grains, must, by parity of reasoning, contain 78.06 grains, or 85.47 grains; therefore 13.34 grains, or 20.75 grains, more of the 100 grains are immediately accounted for; because 63.72 grains + 13.34 grains = 78.06, and 64.72 grains + 20.75 grains = 85.47 grains. The remaining deficiency of 21.94 grains, or 14.53 grains, which, with the 78.06 grains, or 85.47 grains, would complete the original 100 of quicksilver, remains partly in the liquor from which the powder is separated, and is partly volatilized in the white dense fumes, which in the beginning of this paper I compared to the liquor fumans of Libavius. The mercury cannot, in either instance, be obtained in a form immediately indicative of its quantity; and a series of experiments, to ascertain the quantities in which many different substances can combine with mercury, is not my present object. After observing that the mercury left in the residuary liquor can be precipitated in a very subtle dark powder, by carbonate of potash, I shall content myself with examining the nature of the white fumes.

"It is clear that these white fumes contain mercury: they may be wholly condensed in a range of Wolfe's apparatus, charged with a solution of muriate of ammonia. When the operation is over, a white powder is seen floating with ether on the saline liquor, which, if the bottles are agitated, is entirely dissolved. After the mixture has been boiled, or for some time exposed to the atmosphere, it yields to caustic ammonia a precipitate, in all respects similar to that which is separated by caustic ammonia, from corrosive sublimate.

"I would infer from these facts, that the white dense fumes consist of mercury, or perhaps oxide of mercury, united to the nitrous etherized gass; and that, when the muriate of ammonia containing them is exposed to the atmosphere, or is boiled, the gass separates from the mercury, and the excess of nitrous acid, which always comes over with nitrous ether, decomposes the ammoniacal muriate of sublimate, and forms corrosive mercurial muriate or sublimate. This theory is corroborated by comparing the quantity of gass estimated to be contained in the fulminating mercury with the quanties of gass yielded from alcohol and nitrous acid, with and without mercury in solution; not to mention that more ether, as well as more gass, is produced without the intervention of mercury; and that, according to the Dutch chemists, the product of ether is always in the inverse ratio to the product of nitrous etherized gass. Should a further proof be thought necessary to the existence of the nitrous etherized gass, in the fulminating mercury, as well as in the white dense fumes, it may be added, that if a mixture of alcohol and nitrous acid, holding mercury in solution, be so dilute, and exposed of a temperature so low, that neither ether nor nitrous etherized gass are produced, the fulminating mercury, or the white fumes, will never be generated; for, under such circumstances, the mercury is precipitated chiefly in the state of an inflammable oxalate. Further, when we consider the different substances formed by an union of nitrous acid and alcohol, we are so far acquainted with all, except the ether and the nitrous etherized gass, as to create a presumption, that no others are capable of volatilizing mercury, at the very low temperature in which the white fumes exist; since, during some minutes, they are permanent over water 40° Fahrenheit.

"Hitherto, as much only has been said of the gass which is separated from the mercurial powder, by dilute sulphuric acid, as was necessary to identify it with that into which the same acid can resolve the nitrous etherized gass: I have further to speak of its peculiarity.

"The characteristic properties of the inflammable gass seem to me to be the following: 1st. It does not diminish in volume, either with oxygen or nitrous gass. 2dly. It will not explode with oxygen, by the electric shock, in a close vessel. 3dly. It burns like hydrocarbonate, but with a blueish-green flame: and 4thly. It is permanent over water.

"It is of course either not formed, or is convertible into nitrous gass by the concentrate nitric and muriatic acids; because, by those acids, no inflammable gass was extricated from the powder.

"Should this inflammable gass prove not to be hydrocarbonate, I shall be disposed to conclude, that it has nitrogen for its basis; indeed, I am at this moment inclined to that opinion, because I find that Dr. Priestley, during his experiments on his dephlogisticated nitrous air, once produced a gass which seems to have resembled this inflammable gass, both in the mode of burning and in the colour of the flame.

"After the termination of the common solution of iron, in spirit of nitre, he used heat, and got, says he, 'such a kind of air as I had brought nitrous air to be, by exposing it to iron, or liver of sulphur; for, on the first trial, a candle burned in it with a much enlarged flame. At another time, the application of a candle to air produced in this manner, was attended with a real, though not a loud explosion; and immediately after this a greenish-coloured flame descended from the top to the bottom of the vessel, in which the air was contained. In the next produce of air, from the same process, the flame descended blue, and very rapidly, from the top to the bottom of the vessel.'

"These greenish and blue-coloured flames, descending from the top to the bottom of the vessel, are precisely descriptive of the inflammable gass separated from the powder. If it can be produced with certainty, by the repetition of Dr. Priestley's experiments, or should it by any means be got pure from the nitrous etherized gass, my curiosity will excite me to make it the object of future research; otherwise, I must confess, I shall feel more disposed to prosecute other chemical subjects: for having reason to think, that the density of the acid made a variation in the product of this gass, and having never found that any acid, however dense, produced an immediate explosion, I once poured six drachms of concentrate acid upon fifty grains of the powder. An explosion, nearly at the instant of contact, was effected: I was wounded severely, and most of my apparatus destroyed. A quantity moreover of the gass I had previously prepared was lost, by the inadvertency of a person who went into my laboratory, whilst I was confined by the consequences of this discouraging accident. But should any one be desirous of giving the gass a further examination, I again repeat, that as far as I am enabled to judge, it may with safety be prepared, by pouring three drachms of sulphuric acid, diluted with the same quantity of water, upon fifty grains of the powder, and then applying the flame of a candle until gass begins to be extricated. The only attempt I have made to decompose it, was by exposing it to copper and ammonia; which, during several weeks, did not effect the least alteration.

"I will now conclude (continues Mr. Howard), by observing, that the fulminating mercury seems to be characterised by the following properties:

"It takes fire at the temperature of 368 Fahrenheit; it explodes by friction, by flint and steel, and by being thrown into concentrate sulphuric acid. It is equally inflammable under the exhausted receiver of an air-pump, as surrounded by atmospheric air; and it detonates loudly, both by the blow of a hammer, and by a strong electrical shock.

"Notwithstanding the compositions of fulminating silver, and of fulminating gold, differ essentially from that of fulminating mercury; all three have similar qualities. In tremendous effects, silver undoubtedly stands first, and gold perhaps the last. The effects of the mercurial powder, and of gunpowder, admit of little comparison. The one exerts, within certain limits, an almost inconceivable force: its agents seem to be gass and caloric, very suddenly set at liberty, and both mercury and water thrown into vapour. The other displays a more extended, but inferior power:

gass and caloric are, comparatively speaking, liberated by degrees; and water, according to count Rumford, is thrown into vapour.

" Hence it seems that the fulminating mercury, from the limitation of its sphere of action, can seldom, if ever, be applied to mining; and, from the immensity of its initial force, cannot be used in fire-arms, unless in cases where it becomes an object to destroy them; and where it is the practice to spike cannon, it may be of service, because I apprehend it may be used in such a manner as to burst cannon, without dispersing any splinters.

" The inflammation of fulminating mercury, by concussion, offers nothing more novel or remarkable than the inflammation, by concussion, of many other substances. The theory of such inflammations has been long since exposed by the celebrated Mr. Berthollet, and confirmed by Messieurs Fourcroy and Vauquelin: yet, I must confess, I am at a loss to understand why a small quantity of mercurial powder, made to detonate by the hammer or the electric shock, should produce a report so much louder than when it is inflamed by a match, or by flint and steel. It might at first be imagined, that the loudness of the report could be accounted for, by supposing the instant of the inflammation, and that of the powder's confinement, between the hammer and anvil, to be precisely the same; but, when the electrical shock is sent through or over a few grains of the powder, merely laid on ivory, and a loud report in consequence, I can form no idea of what causes such a report.

" The operation by which the powder is prepared, is perhaps one of the most beautiful and surprising in chemistry; and it is not a little interesting to consider the affinities which are brought into play. The superabundant nitrous acid, of the mercurial solution, must first act on the alcohol, and generate ether, nitrous etherized gass, and oxalic acid. The mercury unites to the two last, in their nascent state, and relinquishes fresh nitrous acid, to act upon unaltered alcohol. With respect to the oxalic acid, a predisposing affinity seems exerted in favour of its quantity, as it is evidently not formed fast enough to retain all the mercury; otherwise, no white fumes during a considerable period of the operation, but fulminating mercury alone will be produced.

" Should any doubt still be entertained of the existence of the affinities which have been called predisposing or conspiring, a proof that such affinities really exist, will, I think, be afforded, by comparing the quantity of oxalic acid which can be generated from given measures of nitrous acid and alcohol, with the intervention of mercury, and the intervention of other metals. For instance, when two measured ounces of alcohol are treated with a solution of 100 grains of nickel, in a measured ounce and a half of nitrous acid, little or no precipitate is produced; yet, by the addition of oxalic acid to the residuary liquor, a quantity of oxalate of nickel, after some repose, is deposited. Copper affords another illustration; 100 grains of copper, dissolved in a measured ounce and a half of nitrous acid, and treated with alcohol, yielded me about eighteen grains of oxalate, although cupreous oxalate was plentifully generated, by dropping oxalic acid into the residuary liquor. About twenty-one grains of pure oxalic acid seem to be produced from the same materials, when 100 grains of mercury are interposed. Besides, according to the Dutch paper, more than once referred to, acetous acid is the principal residue after the preparations of nitrous ether. How can we explain the formation of a greater quantity of oxalic acid, from the same materials, with the intervention of 100 grains of mercury, than with the intervention of 100 grains of copper, otherwise than by the notion of conspiring affinities, so analogous to what we see in other phænomena of nature?

"I have attempted, without success, to communicate fulminating properties, by means of alcohol, to gold, platina, antimony, tin, copper, iron, lead, zinc, nickel, bismuth, cobalt, arsenic, and manganese; but I have not yet sufficiently varied my experiments to enable me to speak with absolute certainty. Silver, when twenty grains of it were treated with nearly the same proportions of nitrous acid and alcohol, as 100 grains of mercury, yielded, at the end of the operation, about three grains of a grey precipitate, which fulminated with extreme violence. Mr. Cruickshank had the goodness to repeat the experiment: he dissolved forty grains of silver, in two ounces of the strongest nitrous acid, diluted with an equal quantity of water, and obtained (by means of two ounces of alcohol) sixty grains of a very white powder, which fulminated like the grey precipitate above described. It probably combines with the same principles as the mercury, and of course differs from Mr. Berthollet's fulminating silver, before alluded to. I observe, that a white precipitate is always produced in the first instance; and that it may be preserved by adding water as soon as it is formed; otherwise, when the mother liquor is abundant, it often becomes grey, and is re-dissolved."

"Several trials of the mercurial powder were afterwards made at Woolwich, in conjunction with Colonel Bloomfield and Mr. Cruickshank, upon heavy guns, carronades, &c. from which Mr. Howard generally infers, that any piece of ordnance might be destroyed, by employing a quantity of the mercurial powder, equal in weight to one-half of the service-charge of gunpowder; and, from the seventh and last experiment, we may also conclude, that it would be possible so to proportion the charge of mercurial powder, to the size of different cannons, as to burst them without dispersing any splinters. But the great danger attending the use of fulminating mercury, on account of the facility with which it explodes, will probably prevent its being employed for that purpose.

"In addition to the other singular properties of the fulminating mercury (says Mr. Howard), it may be observed, that two ounces, inflamed in the open air, seem to produce a report much louder than when the same quantity is exploded in a gun, capable of resisting its action. Mr. Cruickshank, who made some of the powder by my process, remarked, that it would not inflame gunpowder. In consequence of which, we spread a mixture of coarse and fine-grained gunpowder upon a parcel of the mercurial powder; and after the inflammation of the latter, we collected most, if not all, of the grains of gunpowder. Can this extraordinary fact be explained by the rapidity of the combustion of fulminating mercury? Or is it to be supposed (as gunpowder will not explode at the temperature at which mercury is thrown into vapour) that sufficient caloric is not extricated during this combustion? From the late opportunity I have had of conversing with Mr. Cruickshank, I find that he has made many accurate experiments on gunpowder; and he has permitted me to state, that the matter which remains after the explosion of gunpowder, consists of potass, united with a small proportion of carbonic acid, sulphate of potass, and a very small quantity of sulphuret of potass, and unconsumed charcoal. That 100 grains of good gunpowder yielded about fifty-three grains of this residuum, of which three are charcoal. That it is extremely deliquescent, and when exposed to the air, soon absorbs moisture sufficient to dissolve a part of the alkali; in consequence of which the charcoal becomes exposed, and the whole assumes a black, or very dark colour. Mr. Cruickshanks likewise informs me, that after the combustion of good gunpowder under mercury, no water is ever perceptible."

[*Pantolog. Phil. Trans.*

SECTION III.

Azotane, or the Detonating Substance of M. Dulong.

This constitutes one of the latest discoveries in modern chemistry; and almost all that we know of it in our own country, is through the correspondence and experiments of Sir Humphry Davy.

In September 1812, this philosopher received from M. Ampere, then residing at Paris, a letter containing the following passage: "You are doubtless apprised, Sir, of the discovery made at Paris, nearly a year ago, of a combination of azotic gass and calorine, which has the appearance of an oil, heavier than water, and which detonates with all the violence of the fulminating metals, on the simple heat of the hand; an effect which has deprived the author of this discovery of an eye and a finger. This detonation takes place by the simple separation of the two gasses, namely the combination of oxygen and calorine; light and heat are largely and equally produced by this detonation, in which a single liquid becomes decomposed into two gasses *."

The farther account of this curious substance we shall give in Sir Humphry's own words, as contained in the Philosophical Transactions for 1813.

"The letter," says he, "contained no account of the mode of preparation of this substance, nor any other details respecting it. So curious and important a result could not fail to interest me, particularly as I have long been engaged in experiments on the action of azote and chlorine, without gaining any decided proofs of their power of combining with each other. I perused with avidity the different French chemical and physical journals, especially Les Annales de Chimie and Le Journal de Physique, of which the complete series of the last year have arrived in this country, in hopes of discovering some detail respecting the preparation of this substance; but in vain. I was unable to find any thing relative to it in these publications, or in the Moniteur.

* "Vous avez sans doute appris," &c. see Phil. Trans. for 1813. p. 1.

"It was evident from the notice, that it could not be formed in any operations in which heat is concerned; I therefore thought of attempting to combine azote and chlorine under circumstances which I had never tried before, that of presenting them to each other artificially cooled, the azote being in a nascent state. For this purpose I made a solution of ammonia, cooled it by a mixture of ice and muriate of lime, and slowly passed into it chlorine, cooled by the same means. There was immediately a violent action, accompanied by fumes of a peculiarly disagreeable smell; at the same time a yellow substance was seen to form in minute films on the surface of the liquor; but it was evanescent, and immediately resolved itself into gass. I was preparing to repeat the experiment, substituting the prussiate of ammonia and other ammoniacal compounds, in which less heat might be produced by the action of the chlorine, than in the pure solution of the gass, when my friend Mr. J. G. Children put me in mind of a circumstance of which he had written to me an account, in the end of July, which promised to elucidate the enquiry, viz. that Mr. James Burton, jun. in exposing chlorine to a solution of nitrate of ammonia, had observed the formation of a yellow oil, which he had not been able to collect so as to examine its properties, as it was rapidly dissipated by exposure to the atmosphere. Mr. Children had tried the same experiment with similar results.

"I immediately exposed a phial, containing about six cubical inches of chlorine, to a saturated solution of nitrate of ammonia, at the temperature of about fifty degrees in common day-light. A diminution of the gass speedily took place; in a few minutes a film, which had the appearance of oil, was seen on the surface of the fluid; by shaking the phial it collected in small globules, and fell to the bottom. I took out one of the globules, and exposed it in contact with water to a gentle heat: long before the water began to boil, it exploded with a very brilliant light, but without any violence of sound.

"I immediately proposed to Mr. Children, that we should institute a series of experiments upon its preparation and its properties. We consequently commenced the operations, the results of which I shall describe. We were assisted in our labours, which were carried on in Mr. Children's laboratory at Tunbridge, by Mr. Warburton.

"It was found that the solution of oxalate of ammonia, or a very weak solution of pure ammonia, answered the purpose as well as the solution of nitrate of ammonia. It was formed most rapidly in the solution of ammonia, but it was white and clouded; and though less evanescent than in the strong solution I first used, it was far from being as permanent as in the solutions of nitrate and oxalate. The solution of prussiate of ammonia acted on by chlorine, afforded none of the peculiar oil; but produced white fumes, and became of a bright green colour. An attempt was made to procure the substance in large quantities, by passing chlorine into Wolfe's bottles containing the different solutions: but a single trial proved the danger of this mode of operating; the compound had scarcely begun to form, when, by the action of some ammoniacal vapour on chlorine, heat was produced, which occasioned a violent explosion, and the whole apparatus was destroyed.

"I shall now describe the properties of the new substance. Its colour is very nearly that of olive oil, and it is as transparent, and more perfectly liquid. I have not been able to ascertain its specific gravity with accuracy, but it is probably above 1·6. Its smell is very nauseous, strongly resembling that of the combination of carbonic oxide and chlorine, discovered by my brother; and its effect on the eyes is peculiarly pungent and distressing. A little of it was introduced under water into the receiver of an air pump, and the receiver exhausted; it became an elastic fluid and in its gasseous state was rapidly absorbed or decomposed by the water. When warm water was poured into a glass containing it, it expanded into a globule of elastic fluid, of an orange colour, which diminished as it passed through the water.

"I attempted to collect the products of the explosion of the new substance, by applying the heat of a spirit lamp to a globule of it, confined in a curved glass tube over water: a little gass was at first extricated; but long before the water had attained the temperature of ebullition, a violent flash of light was perceived, with a sharp report; the tube and glass were broken into small fragments, and I received a severe wound in the transparent corner of the eye, which has produced a considerable inflammation of the eye, and obliges me to make the communication by an amanuensis. This experiment proves what extreme caution is necessary in operating on this substance, for the quantity I used was scarcely as large as a grain of mustard seed.

"A small globule of it thrown into a glass of olive oil, produced a most violent explosion; and the glass, though strong, was broken into fragments. Similar effects were produced by its action on oil of turpentine and naphtha. When it was thrown into ether, there was a very slight action; gass was disengaged in small quantities, and a substance like wax was formed, which had lost the characteristic properties of the new body. On alcohol it acted slowly, lost its colour, and became a white oily substance, without explosive powers. When a particle of it was touched under water by a particle of phosphorus, a brilliant light was perceived under the water, and permanent gass was disengaged, having the characters of azote.

"When quantities larger than a grain of mustard seed were used for the contact with phosphorus, the explosion was always so violent as to break the vessel in which the experiment was made. The new body, when acted upon under water by mercury, afforded a substance, having the appearance of corrosive sublimate, and gass was disengaged. On tin foil and zinc it exerted no action; it had no action on sulphur, nor on resin. In their alcoholic solutions it disappeared as in pure alcohol. It detonated most violently when thrown into a solution of phosphorus in ether, or in alcohol. Phosphorus introduced into ether, into which a globule of the substance had been put immediately before, produced no effect. In muriatic acid it gave off gass rapidly, and disappeared without explosion. On dilute sulphuric acid it exerted no violent action. It immediately disappeared without explosion in Libavius's liquor, to which it imparted a yellow tinge.

"It seems probable, from the general tenor of these facts, that the new substance is a compound of azote and chlorine; the same as, or analogous to, that mentioned in the letter from Paris. It is easy to explain its production in our experiments: the hydrogen of the ammonia may be conceived to combine with one portion of the chlorine to form muriatic acid, and the azote to unite with another portion of chlorine to form the new compound. The heat and light produced during its expansion into gasseous matter, supposing it to be composed of azote and chlorine, is without any parallel instance, in our present collection of chemical facts; the decomposition of euchlorine, which has been compared to it, is merely an expansion of matter already gasseous. The heat and light produced by its rarefaction, in consequence of decomposition, depend, probably, on the same cause as that which produces the flash of light in the discharge of the air gun.

The mechanical force of this compound in detonation, seems to be superior to that of any other known, not even excepting the ammoniacal fulminating silver. The velocity of its action appears to be likewise greater.

In a subsequent paper published in the same volume, Sir Humphry Davy observes as follows:

"I received in April, a duplicate of the letter in which the discovery was announced, containing an Appendix, in which the method of preparing it was described. M. Ampere, my correspondent, states that the author obtained it by passing a mixture of azote and chlorine through aqueous solutions of sulphate, or muriate of ammonia. It is obvious, from this statement that the substance discovered in France, is the same as that which occasioned my accident. The azote cannot be necessary; for the result is obtained by the exposure of pure chlorine to any common ammoniacal salt.

"Since I recovered the use of my eyes, I have made many experiments on this compound; it is probable that most of them have been made before in France; but as no accounts of the investigations of M. Dulong on the substance have appeared in any of the foreign journals which have reached this country, and as some difference of opinion and doubts exist respecting its composition, I conceive a few details on its properties and nature will not be entirely devoid of interest."

We cannot follow the analysis, which is too copious and operose for the present work. The author concludes by observing, that, the compound of chlorine and azote agrees with the compounds of the same substance with sulphur, phosphorus, and the metals, in being a non-conductor of electricity; and these compounds are likewise decomposable by heat, though they require that of Voltaic electricity.

Sulphur combines only in one proportion with chlorine; and hence the action of Sulphurane, or Dr. Thompson's muriatic liquor upon water, like that of the new compound, is not a simple phenomenon of double decomposition.

It seems proper to designate this new body by some name: Azotane says Sir Humphry "is the term that would be applied to it, according to my ideas of its analogy to the other bodies which contain chlorine; but I am not desirous, in the present imperfect and fluctuating state of chemical nomenclature, to press the adoption of any new word, particularly as applied to a substance not discovered by myself."

[*Editor.*

THE

GALLERY

OF

NATURE AND ART.

PART II.

A R T.

BOOK II.

PYROTECHNY, or the ART of CONSTRUCTING FIRE-WORKS.

CHAPTER I.

CONSTRUCTION OF THE CARTRIDGES OF ROCKETS.

ROCKETS may be regarded as the grand basis of all fire-works, which are little more than modifications of their form, and of the materials of which they usually consist. A rocket is a cartridge or case made of stiff paper, which being filled in part with gun-powder, saltpetre, and charcoal, rises of itself into the air, when fire is applied to it.

There are three sorts of rockets: small ones, the calibre of which does not exceed a pound bullet; that is to say, the orifice of them is equal to the diameter of a leaden bullet which weighs only a pound; for the calibres, or orifices of the moulds or the models used in making rockets, are measured by the diameters of leaden bullets. Middle sized rockets, equal to the size of a ball of from one to three pounds. And large rockets, equal to a ball of from three to a hundred pounds.

To give the cartridges the same length and thickness, in order that any number of rockets may be prepared of the same size and force, they are put into a hollow cylinder of strong wood, called a mould. This mould is sometimes of metal; but at any rate it ought to be made of some very hard wood.

This mould must not be confounded with another piece of wood, called the former or roller, around which is rolled the thick paper employed to make the cartridge. If the calibre of the mould be divided into 8 equal parts, the diameter of the roller must be equal to 5 of these parts. The vacuity between the roller and the interior surface of the mould, that is to say $\frac{3}{8}$ of the calibre of the mould, will be exactly filled by the cartridge.

As rockets are made of different sizes, moulds of different lengths and diameters must be provided. The calibre of a cannon is nothing else than the diameter of its mouth; and we here apply the same term to the diameter of the aperture of the mould. The size of the mould is measured by its calibre; but the length of the moulds for different rockets does not always bear the same proportion to the calibre, the length being diminished as the calibre is increased. The length of the mould for small rockets ought to be six times the calibre, but for rockets of the mean and larger size, it will be sufficient if the length of the mould be five times or four times the calibre of the moulds.

At the end of this chapter we shall give two tables, one of which contains the calibres of moulds below a pound bullet; and the other the calibres from a pound to a hundred pounds bullet.

For making the cartridges, large stiff paper is employed. This paper is wrapped round the roller, and then cemented by means of common paste. The thickness of the paper when rolled up in this manner, ought to be about one-eighth and a half of the calibre of the mould, according to the proportion given to the diameter of the roller. But if the diameter of the roller be made equal to $\frac{3}{4}$ the calibre of the mould, the thickness of the cartridge must be a twelfth and a half of that calibre.

When the cartridge is formed, the roller is drawn out, by turning it round, until it is distant from the edge of the cartridge the length of its diameter. A piece of cord is then made to pass twice round the cartridge at the extremity of the roller. And into the vacuity left in the cartridge, another roller is introduced, so as to leave some space between the two. One end of the pack-thread must be fastened to some thing fixed, and the other to a stick conveyed between the legs, and placed in such a manner, as to be behind the person who choaks the cartridge. The cord is then to be stretched by retiring backwards, and the cartridge must be pinched until there remains only an aperture capable of admitting the piercer. The cord employed for pinching it is then removed, and its place is supplied by a piece of pack-thread, which must be drawn very tight, passing it several times round the cartridge, after which it is secured by means of running knots made one above the other.

Besides the roller, a rod is used, which being employed to load the cartridge, must be somewhat smaller than the roller, in order that it may be easily introduced into the cartridge. The rod is pierced lengthwise, to a sufficient depth to receive the piercer, which must enter into the mould, and unite with it exactly at its lower part. The piercer, which decreases in size, is introduced into the cartridge through the part where it has been choaked, and serves to preserve a cavity within it. Its length, besides the nipple or button, must be equal to about two-thirds that of the mould. Lastly, if the thickness of the base be a fourth part of the calibre of the mould, the point must be made equal to a sixth of the calibre.

It is evident that there must be at least three rods, pierced in proportion to the diminution of the piercer, in order that the powder which is rammed in by means of a mallet, may be uniformly packed throughout the whole length of the rocket. It may be easily perceived also, that these rods ought to be made of some very hard wood, to resist the strokes of the mallet.

In loading rockets, it is more convenient not to employ a piercer. When loaded on a nipple, without a piercer, by means of one massy rod, they are pierced with a bit and a piercer fitted into the end of a bit-brace. Care however must be taken to make this hole suited to the proportion assigned for the diminution of the piercer. That is to say, the extremity of the hole at the choaked part of the cartridge, ought to be about a fourth of the calibre of the mould; and the extremity of the hole which is in the inside for about two-thirds of the length of the rocket ought to be a sixth of the calibre. This hole must pass directly through the middle of the rocket. In short, experience and ingenuity will suggest what is most convenient, and in what manner the method of loading rockets, which we shall here explain, may be varied.

After the cartridge is placed in the mould, pour gradually into it the prepared composition ; taking care to pour only two spoonfuls at a time, and to ram it immediately down with the rod, striking it in a perpendicular direction with a mallet of a proper size, and giving an equal number of strokes, for example, 3 or 4, each time that a new quantity of the composition is poured in.

When the cartridge is about half filled, separate with a bodkin the half of the folds of the paper which remains, and having turned them back on the composition, press them down with the rod and a few strokes of the mallet, in order to compress the paper on the composition.

Then pierce three or four holes in the folded paper, by means of a piercer, which must be made to penetrate to the composition of the rocket. These holes serve to form a communication between the body of the rocket and the vacuity at the extremity of the cartridge, or that part which has been left empty.

In small rockets this vacuity is filled with granulated powder, which serves to let them off: they are then covered with paper, and pinched in the same manner as at the other extremity. But in other rockets, the pot containing stars, serpents, and running rockets is adapted to it, as will be shewn hereafter.

It may be sufficient however to make, with a bit or piercer, only one hole, which must be neither too large nor too small, such as a fourth part of the diameter of the rocket, to set fire to the powder, taking care that this hole be as straight as possible, and exactly in the middle of the composition. A little of the composition of the rocket must be put into these holes, that the fire may not fail to be communicated to it.

It now remains to fix the rocket to its rod, which is done in the following manner. When the rocket has been constructed as above described, make fast to it a rod of light wood, such as fir or willow, broad and flat at the end next the rocket, and decreasing towards the other. It must be as straight and free from knots as possible, and ought to be dressed, if necessary, with a plane. Its length and weight must be proportioned to the rocket ; that is to say, it ought to be six, seven, or eight feet long, so as to remain in equilibrium with it, when suspended on the finger, within an inch or an inch and a half of the neck. Before it is fired, place it with the neck downwards, and let it rest on two nails, in a direction perpendicular to the horizon. To make it ascend straighter and to a greater height, adapt to its summit a pointed cap or top, made of common paper, which will serve to facilitate its passage through the air.

These rockets, in general, are made in a more complex manner, several other things being added to them to render them more agreeable, such for example as a petard, which is a box of tin-plate, filled with fine gunpowder, placed on the summit. The petard is deposited on the composition, at the end where it has been filled; and the remaining paper of the cartridge is folded down over it to keep it firm. The petard produces its effect when the rocket is in the air and the composition is consumed.

Stars, golden rain, serpents, saucissons, and several other amusing things, the composition of which we shall explain hereafter, are also added to them. This is done by adjusting to the head of the rocket, an empty pot or cartridge, much larger than the rocket, in order that it may contain serpents, stars, and various other appendages, to render it more beautiful.

Rockets may be made to rise into the air without rods. For this purpose four wings must be attached to them in the form of a cross, and similar to those seen on arrows or darts. In length, these wings must be equal to two-thirds that of the rocket; their breadth towards the bottom should be half their length, and their thickness ought to be equal to that of a card.

But this method of making rockets ascend is less certain, and more inconvenient than that where a rod is used; and for this reason it is rarely employed.

We shall now shew the method of finding the diameters or calibre of rockets, according to their weight; but we must first observe that a pound rocket, is that just capable of admitting a leaden bullet of a pound weight, and so of the rest. The calibre for the different sizes may be found by the two following tables, one of which is calculated for rockets of a pound weight and below; and the other for those from a pound weight to 50 pounds.

I. *Table of the calibre of moulds of a pound weight and below.*

Ounces.	Lines.	Drams.	Lines.
16	$19\frac{1}{2}$	14	$7\frac{1}{4}$
12	17	12	7
8	15	10	$6\frac{1}{3}$
7	$14\frac{3}{4}$	8	$6\frac{1}{4}$
6	$14\frac{1}{4}$	6	$5\frac{2}{3}$
5	13	4	$4\frac{1}{2}$
4	$12\frac{1}{3}$	2	$3\frac{3}{4}$
3	$11\frac{1}{2}$		
2	$9\frac{1}{6}$		
1	$6\frac{1}{2}$		

The use of this table will be understood merely by inspection; for it is evident that a rocket of 12 ounces ought to be 17 lines in diameter; one of 8 ounces, 15 lines; one of 10 drams, $6\frac{1}{3}$ lines; and so of the rest.

On the other hand, if the diameter of the rocket be given, it will be easy to find the weight of the ball corresponding to that calibre. For example, if the diameter be 13 lines, it will be immediately seen, by looking for that number in the column of lines, that it corresponds to a ball of 5 ounces.

II. *Table of the calibre of moulds from* 1 *to* 50 *pounds ball.*

Pounds.	Calibre.	Pounds.	Calibre.	Pounds.	Calibre	Pounds.	Calibre.
1	100	14	241	27	300	40	341
2	126	15	247	28	304	41	344
3	144	16	252	29	307	42	347
4	158	17	257	30	310	43	350
5	171	18	262	31	314	44	353
6	181	19	267	32	317	45	355
7	191	20	271	33	320	46	358
8	200	21	275	34	323	47	361
9	208	22	280	35	326	48	363
10	215	23	284	36	330	49	366
11	222	24	288	37	333	50	368
12	228	25	292	38	336		
13	235	26	296	39	339		

The use of the second table is as follows: If the weight of the ball be given, which we shall suppose to be 24 pounds, seek for that number in the column of pounds, and opposite to it, in the column of calibres, will be found the number 288. Then say as 100 is to $19\frac{1}{2}$, so is 288 to a fourth term, which will be the number of lines of the calibre required; or multiply the number found, that is 288, by $19\frac{1}{2}$, and from the product 56·16, cut off the two last figures: the required calibre therefore will be 56·16 lines, or 4 inches 8 lines.

On the other hand, the calibre being given in lines, the weight of the ball may be found with equal ease: if the calibre, for example, be 28 lines, say as $19\frac{1}{2}$ is to 28, so is 100 to a fourth term, which will be 143·5, or nearly 144. But in the above table, opposite to 144, in the second column, will be found the number 3 in the first; which shews that a rocket, the diameter or calibre of which is 28 lines, is a rocket of a 3 pounds ball.

CHAP. II.

COMPOSITION OF THE POWDER FOR ROCKETS, AND THE MANNER OF FILLING THEM.

THE composition of the powder for rockets must be different, according to the different sizes; as that proper for small rockets, would be too strong for large ones. This is a fact respecting which almost all the makers of fire-works are agreed. The quantities of the ingredients, which experience has shewn to be the best, are as follows:

For rockets capable of containing one or two ounces of composition.

To one pound of gunpowder, add two ounces of soft charcoal; or to one pound of gunpowder, a pound of the coarse powder used for cannon; or to nine ounces of gunpowder, two ounces of charcoal; or to a pound of gunpowder, an ounce and a half of saltpetre, and as much charcoal.

For rockets of two or three ounces.

To four ounces of gunpowder, add an ounce of charcoal; or to nine ounces of gunpowder, add two ounces of saltpetre.

For a rocket of four ounces.

To four pounds of gunpowder, add a pound of saltpetre, and four ounces of charcoal; you may add also, if you choose, half an ounce of sulphur; or to one pound two ounces and a half of gunpowder, add four ounces of saltpetre, and two ounces of charcoal; or to a pound of powder, add four ounces of saltpetre, and one ounce of charcoal; or to seventeen ounces of gunpowder, add four ounces of saltpetre, and the same quantity of charcoal; or to three ounces and a half of gunpowder, add ten ounces of saltpetre, and three ounces and a half of charcoal. But the composition will be strongest, if to ten ounces of gunpowder, you add three ounces and a half of saltpetre, and three ounces of charcoal.

For rockets of five or six ounces.

To two pounds five ounces of gunpowder, add half a pound of saltpetre, two ounces of sulphur, six ounces of charcoal, and two ounces of iron filings.

For rockets of seven or eight ounces.

To seventeen ounces of gunpowder, add four ounces of saltpetre, and three ounces of sulphur.

For rockets of from eight to ten ounces.

To two pounds and five ounces of gunpowder, add half a pound of saltpetre, two ounces of sulphur, seven ounces of charcoal, and three ounces of iron filings.

For rockets of from ten to twelve ounces.

To seventeen ounces of gunpowder, add four ounces of saltpetre, three ounces and a half of sulphur, and one ounce of charcoal.

For rockets of from fourteen to fifteen ounces.

To two pounds four ounces of gunpowder, add nine ounces of saltpetre, three ounces of sulphur, five ounces of charcoal, and three ounces of iron filings.

For rockets of one pound.

To one pound of gunpowder, add one ounce of sulphur, and three ounces of charcoal.

For a rocket of two pounds.

To one pound four ounces of gunpowder, add two ounces of saltpetre, one ounce of sulphur, three ounces of charcoal, and two ounces of iron filings.

For a rocket of three pounds.

To thirty ounces of saltpetre, add seven ounces and a half of sulphur, and eleven ounces of charcoal.

For rockets of four, five, six, or seven pounds.

To thirty-one pounds of saltpetre, add four pounds and a half of sulphur, and ten pounds of charcoal.

For rockets of eight, nine, or ten pounds.

To eight pounds of saltpetre, add one pound four ounces of sulphur, and two pounds twelve ounces of charcoal.

We shall here observe, that these ingredients must be each pounded separately, and sifted ; they are then to be weighed and mixed together for the purpose of loading the cartridges, which ought to be kept ready in the moulds. The cartridges must be made of strong paper, doubled, and cemented by means of strong paste, made of fine flour and very pure water.

Of Matches.

Before we proceed farther, it will be proper to describe the composition of the matches necessary for letting the rockets off. Take linen, hemp, or cotton thread, and double it eight or ten times, if intended for large rockets; or only four or five times, if to be employed for stars. When the match has been thus made as large as necessary, dip it in pure water, and press it between your hands, to free it from the moisture. Mix some gunpowder with a little water, to reduce it to a sort of paste, and immerse the match in it; turning and twisting it, till it has imbibed a sufficient quantity of the powder; then sprinkle over it a little dry powder, or strew some pulverised dry powder upon a smooth board, and roll the match over it. By these means you will have an excellent match; which if dried in the sun, or on a rope in the shade, will be fit for use.

CHAP. III.

ON THE CAUSE WHICH MAKES ROCKETS ASCEND INTO THE AIR.

AS this cause is nearly the same as that which produces recoil in fire-arms, it is best explained by illustrating the latter.

When the powder is suddenly inflamed in the chamber, or at the bottom of the barrel, it necessarily exercises an action two ways at the same time; that is to say, against the breech of the piece, and against the bullet or wadding, which is placed above it. Besides this, it acts also against the sides of the chamber which it occupies; and as they oppose a resistance almost insurmountable, the whole effort of the elastic fluid, produced by the inflammation, is exerted in the two directions above mentioned. But the resistance opposed by the bullet, being much less than that opposed by the mass of the barrel or cannon, the bullet is forced out with great velocity. It is impossible, however, that the body of the piece itself should not experience a movement backwards; for if a spring is suddenly let loose, between two moveable obstacles, it will impel them both, and communicate to them velocities in the inverse ratio of their masses; the piece therefore must acquire a velocity backwards nearly in the inverse ratio of its mass to that of the bullet. We make use of the term nearly, because there are various circumstances which give to this ratio certain modifications; but it is always true that the body of the piece is driven backwards, and that if it weighs with its carriage, a thousand times more than the bullet, it acquires a velocity, which is a thousand times less, and which is soon annihilated by the friction of the wheels against the ground, &c.

The cause of the ascent of the rocket is nearly the same. At the moment when the powder begins to inflame, its expansion produces a torrent of elastic fluid, which acts in every direction; that is, against the air which opposes its escape from the cartridge, and against the upper part of the rocket; but the resistance of the air is more considerable than the weight of the rocket, on account of the extreme rapidity with which the elastic fluid issues through the neck of the rocket to throw itself downwards, and therefore the rocket ascends by the excess of the one of these forces over the other.

This however would not be the case, unless the rocket were pierced to a certain depth. A sufficient quantity of elastic fluid would not be produced ; for the composition would inflame only in circular coats of a diameter equal to that of the rocket ; and experience shews that this is not sufficient. Recourse then is had to the very ingenious idea of piercing the rocket with a conical hole, which makes the composition burn in conical strata, which have much greater surface, and therefore produce a much greater quantity of inflamed matter and fluid. This expedient was certainly not the work of a moment.

CHAP. IV.

BRILLIANT FIRE AND CHINESE FIRE.

As iron filings, when thrown into the fire, inflame and emit a strong light, this property, discovered no doubt by chance, gave rise to the idea of rendering the fire of rockets much more brilliant, than when gunpowder, or the substances of which it is composed, are alone employed. Nothing is necessary but to take iron filings, very clean and free from rust, and to mix them with the composition of the rocket. It must however be observed, that rockets of this kind will not keep longer than a week ; because the moisture contracted by the saltpetre rusts the iron-filings, and destroys the effect they are intended to produce.

But the Chinese have long been in possession of a method of rendering this fire much more brilliant and variegated in its colours ; and we are indebted to father d'Incarville, a jesuit, for having made it known. It consists in the use of a very simple ingredient ; namely, cast iron reduced to a powder more or less fine ; the Chinese gave it a name, which is equivalent to that of iron sand.

To prepare this sand, take an old iron pot, and having broken it to pieces on an anvil, pulverise the fragments till the grains are not larger than radish seed: then sift them through six graduated sieves, to separate the different sizes, and preserve these six different kinds in a very dry place, to secure them from rust, which would render this sand absolutely unfit for the proposed end. We must here remark, that the grains which pass through the closest sieve, are called sand of the first order; those which pass through the next in size, sand of the second order; and so on.

This sand, when it inflames, emits a light exceedingly vivid. It is very surprising to see fragments of this matter no bigger than a poppy seed, form all of a sudden luminous flowers or stars, 12 and 15 lines in diameter. These flowers are also of different forms, according to that of the inflamed grain, and even of different colours according to the matters with which the grains are mixed. But rockets into which this composition enters, cannot be long preserved, as those which contain the finest sand will not keep longer than eight days, and those which contain the coarsest, fifteen. The following tables exhibit the proportions of the different ingredients for rockets of from 12 to 36 pounds.

For red Chinese fire.

Calibres. Pounds.	Saltpetre. Pounds.	Sulphur. Ounces.	Charcoal. Ounces.	Sand of the 1st order. oz.	dr.
12 to 15	1	3	4	7	
18 to 21	1	3	5	7	8
24 to 36	1	4	6	8	

For white Chinese fire.

Calibres. Pounds.	Saltpetre. Pounds.	Bruised Gunpowder Ounces.	Charcoal. oz.	dr.	Sand of the 3d order. oz.	dr.
12 to 15	1	12	7	8	11	
18 to 21	1	11	8		11	8
24 to 36	1	11	8	8	12	

When these materials have been weighed, the saltpetre and charcoal must be three times sifted through a hair sieve, in order that they may be well mixed: the iron sand is then to be moistened with good brandy, to make the sulphur adhere, and they must be thoroughly incorporated. The sand thus sulphured must be spread over the mixture of saltpetre and charcoal, and the whole must be mixed together by spreading it over a table with a spatula.

CHAP. V.

OF THE FURNITURE OF ROCKETS.

The upper part of rockets is generally furnished with some composition, which taking fire when it has reached to its greatest height, emits a considerable blaze, or produces a loud report, and very often both these together. Of this kind are saucissons, marroons, stars, showers of fire, &c.

To make room for this artifice, the rocket is crowned with a part of a greater diameter, called the pot. The method of making this pot, and connecting it with the body of the rocket, is as follows.

The mould for forming the pot, though of one piece, must consist of two cylindric parts of different diameters. That on which the pot is rolled up, must be three diameters of the rockets in length, and its diameter must be three fourths that of the rôcket; the length of the other ought to be equal to two of these diameters, and its diameter to $\frac{7}{8}$ that of the rocket.

Having rolled the thick paper intended for making the pot, and which ought to be of the same kind as that used for the rocket, twice round the cylinder, a portion of it must be pinched in that part of the cylinder which has the least diameter: this part must be pared in such a manner, as to leave only what is necessary for making the pot fast to the top of the rocket, and the ligature must be covered with paper.

To charge such a pot, attached to a rocket: having pierced three or four holes in the double paper which covers the vacuity of the rocket, pour over it a small quantity of the composition with which the rocket is filled, and by shaking it, make a part enter these holes; then arrange in the pot the composition with which it is to be charged, taking care not to introduce into it a quantity heavier than the body of the rocket.

The whole must then be secured by means of a few small balls of paper, to keep every thing in its place, and the pot must be covered with paper cemented to its edges: if a pointed summit or cap be then added to it, the rocket will then be ready for use.

We shall now give an account of the different artifices with which such rockets are loaded.

SECTION I.

Of Serpents.

SERPENTS are small flying rockets, without rods, which instead of rising in a perpendicular direction, mount obliquely, and fall back in a zig-zag form without ascending to a great height. The composition of them is nearly the same as that of rockets; and therefore nothing more is necessary than to determine the proportion and construction of the cartridge, which is as follows.

The length of the cartridge may be about 4 inches; it must be rolled round a stick somewhat larger than the barrel of a goose quill, and after being choaked at one of its ends, fill it with the composition a little beyond its middle, and then pinch it so as to leave a small aperture. The remainder must be filled with grained powder, which will make a report when it bursts. Lastly, choak the cartridge entirely towards the extremity; and at the other extremity place a train of moist powder, to which, if fire be applied, it will be communicated to the composition, and cause the whole to rise in the air. The serpent, as it falls will make several turns in a zig-zag direction, till the fire is communicated to the grained powder; on which it will burst with a loud report before it falls to the ground.

If the serpent be not choaked towards the middle, instead of moving in a zig-zag direction, it will ascend and descend with an undulating motion, and then burst as before.

The cartridges of serpents are generally made with playing cards. These cards are rolled round a rod of iron or hard wood, a little larger, as already said, than the barrel of a goose quill. To confine the card, a piece of strong paper is cemented over it.

The length of the mould must be proportioned to that of the cards employed, and the piercer of the nipple must be three or four lines in length. These serpents are loaded with bruised powder, mixed only with a very small quantity of charcoal. To introduce the composition into the cartridge, a quill, cut into the form of a spoon, may be employed: it must be rammed down by means of a small rod, to which a few strokes are given with a small mallet.

When the serpent is half loaded, instead of pinching it in that part, you may introduce into it a vetch seed, and place granulated powder above it to fill up the remainder. Above this powder place a small pellet of chewed paper, and then choak the other end of the cartridge. If you are desirous of making larger serpents, cement two playing cards together; and, that they may be managed with more ease, moisten them a little with water. The match consists of a paste made of bruised powder, and a small quantity of water.

SECTION II.

Marroons.

Marroons are small cubical boxes, filled with a composition proper for making them burst, and may be constructed with great ease.

Cut a piece of pasteboard, according to the method taught in geometry to form the cube; join these squares at the edges, leaving only one to be cemented, and fill the cavity of the cube with grained powder; then cement strong paper in various directions over this body, and wrap round it two rows of pack-thread, dipped in strong glue; then make a hole in one of the corners, and introduce into it a match.

If you are desirous to have luminous marroons, that is to say maroons which, before they burst in the air, emit a brilliant light, cover them with a paste the composition of which will be given hereafter for stars; and roll them in pulverised gunpowder, to serve as a match or communication.

SECTION III.

Saucissons.

Marroons and saucissons differ from each other only in their form. The cartridges of the latter are round, and must be only four times their exterior diameter in length. They are choaked at one end in the same manner as a rocket; and a pellet of paper is driven into the aperture which has been left, in order to fill it up. They are then charged with grained powder, above which is placed a ball of paper gently pressed down, to prevent the powder from being bruised; the second end of the saucisson being afterwards choaked, the edges are pared on both sides, and the whole is covered with several turns of pack-thread, dipped in strong glue, and then left to dry.

When you are desirous of charging them, pierce a hole in one of the ends; and apply a match, in the same manner as to marroons.

SECTION IV.

Stars.

STARS are small globes of a composition which emits a brilliant light, that may be compared to the light of the stars in the heavens. These balls are not larger than a nutmeg or musket bullet, and when put into the rockets must be wrapped up in tow, prepared for that purpose. The composition of these stars is as follows.

To a pound of fine gunpowder well pulverised, add four pounds of saltpetre, and two pounds of sulphur. When these ingredients are thoroughly incorporated, take about the size of a nutmeg of this mixture, and having wrapt it up in a piece of linen rag, or of paper, form it into a ball; then tie it closely round with a pack-thread, and pierce a hole through the middle of it, sufficiently large to receive a piece of prepared tow, which will serve as a match. This star, when lighted, will exhibit a most beautiful appearance; besides the fire, as it issues from the two ends of the hole in the middle, will extend to a greater distance, and make it appear much larger.

If you are desirous to employ a moist composition in the form of a paste, instead of a dry one, it will not be necessary to wrap up the star in any thing but prepared tow; because, when made of such paste, it can retain its spherical figure. There will be no need also of piercing a hole in it, to receive the match; because, when newly made, and consequently moist, it may be rolled in pulverised gunpowder, which will adhere to it. This powder, when kindled, will serve as a match, and inflame the composition of the star, which in falling will form itself into tears.

Another method of making Rockets with Stars.

Mix three ounces of saltpetre, with one ounce of sulphur, and two drams of pulverised gunpowder; or mix four ounces of sulphur, with the same quantity of saltpetre, and eight ounces of pulverised gunpowder. When these materials have been well sifted, besprinkle them with brandy, in which a little gum has been dissolved, and then make up the star in the following manner.

Take a rocket mould, eight or nine lines in diameter, and introduce into it a nipple, the piercer of which is of a uniform size throughout, and equal in length to the height of the mould. Put into this mould a cartridge, and by means of a pierced rod load it with one of the preceding compositions; when loaded, take it from the mould, without removing the nipple, the piercer of which passes through the composition, and then cut the cartridge quite round into pieces of the thickness of three or four lines. The cartridge being thus cut, draw out the piercer gently, and the pieces, which resemble the men employed for playing at drafts, pierced through the middle, will be stars, which must be filed on a match thread, which, if you choose, may be covered with tow.

To give more brilliancy to stars of this kind, a cartridge thicker than the above dimensions, and thinner than that of a flying-rocket of the same size, may be employed; but, before it is cut into pieces, five or six holes must be pierced in the circumference of each piece to be cut. When the cartridge is cut, and the pieces have been filled, cement over the composition small bits of card, each having a hole in the middle, so that these holes may correspond to the place where the composition is pierced.

REMARKS.

1. There are several other methods of making stars, which it would be too tedious to describe. We shall therefore only shew how to make *étoiles à pet*, or stars which give a report as loud as that of a pistol or musket.

Make small saucissons, as taught in the third section; only, it will not be necessary to cover them with pack-thread: it will be sufficient if they are pierced at one end, in order that you may tie to it a star constructed according to the first method, the composition of which is dry; for if the composition be in the form of a paste, there will be no need to tie it. Nothing will be necessary in that case, but to leave a little more of the paper hollow at the end of the saucisson which has been pierced, for the purpose of introducing the composition; and to place in the vacuity, towards the neck of the saucisson, some grained powder, which will communicate fire to the saucisson when the composition is consumed.

2. As there are some stars which in the end become petards, others may be made, which shall conclude with becoming serpents. But this may be so easily conceived and carried into execution, that it would be losing time to enlarge further on the subject. We shall only observe, that these stars are not in use, because it is difficult for a rocket to carry them to a considerable height in the air: they diminish the effect of the rocket or saucisson, and much time is required to make them.

SECTION V.

Shower of Fire.

To form a shower of fire, mould small paper cartridges on an iron rod, two lines and a half in diameter, and make them two inches and a half in length. They must not be choaked, as it will be sufficient to twist the end of the cartridge, and having put the rod into it to beat it, in order to make it assume its form. When the cartridges are filled, which is done by immersing them in the composition, fold down the other end, and then apply a match. The furniture will fill the air with an undulating fire. The following are some of the compositions proper for stars of this kind.

Chinese fire.—Pulverised gunpowder one pound, sulphur two ounces, iron sand of the first order five ounces.

Ancient fire.—Pulverised gunpowder one pound, charcoal two ounces.

Brilliant fire.—Pulverised gunpowder one pound, iron filings four ounces.

The Chinese fire is certainly the most beautiful.

SECTION VI.

Of Sparks.

Sparks differ from stars only in their size and duration; for they are made smaller than stars; and are consumed sooner. They are made in the following manner.

Having put into an earthen vessel an ounce of pulverised gunpowder, two ounces of pulverised saltpetre, one ounce of liquid saltpetre, and four ounces of camphor reduced to a sort of farina, pour over this mixture some gum-water, or brandy in which gum-adraganth or gum-arabic has been dissolved, till the composition acquire the consistence of a thick soup. Then take some lint which has been boiled in brandy, or in vinegar, or even in saltpetre, and then dried and unravelled, and throw into the mixture such a quantity of it as is sufficient to absorb it entirely, taking care to stir it well.

Form this matter into small balls or globes of the size of a pea; and having dried them in the sun or the shade, besprinkle them with pulverized gunpowder, in order that they may the more readily catch fire.

Another Method of making Sparks.

Take the saw-dust of any kind of wood that burns readily, such as fir, elder-tree, poplar, laurel, &c. and boil it in water in which saltpetre has been dissolved. When the water has boiled some time, take it from the fire, and pour it off in such a manner that the saw-dust may remain in the vessel. Then place the saw-dust on a table, and while moist besprinkle it with sulphur, sifted through a very fine sieve: you may add to it also a little bruised gunpowder. Lastly, when the saw-dust has been well mixed, leave it to dry, and make it into sparks as above described.

SECTION VII.

Of Golden Rain.

There are some flying-rockets which, as they fall, make small undulations in the air like hair half frizzled. These are called *fusées chevelues*, bearded rockets; they finish with a kind of shower of fire, which is called golden rain. The method of constructing them is as follows.

Fill the barrels of some goose quills with the composition of flying-rockets, and place upon the mouth of each a little moist gunpowder, both to keep in the composition, and to serve as a match. If a flying-rocket be then loaded with these quills, they will produce, at the end, a very agreeable shower of fire, which on account of its beauty has been called golden rain.

CHAP. VI.

OF SOME ROCKETS DIFFERENT IN THEIR EFFECT FROM COMMON ROCKETS.

Several very amusing and ingenious works are made by mean of simple rockets, of which it is necessary that we should here give the reader some idea.

SECTION I.

Of Courantins, or Rockets which fly along a Rope.

A common rocket, which however ought not to be very large, may be made to run along an extended rope. For this purpose, affix to the rocket an empty cartridge, and introduce into it the rope which is to carry it; placing the head of the rocket towards that side on which you intend it to move: if you then set fire to the rocket, adjusted in this manner, it will run along the rope without stopping, till the matter it contains is entirely exhausted.

If you are desirous that the rocket should move in a retrograde direction; first fill one half of it with the composition, and cover it with a small round piece of wood, to serve as a partition between it and that put into the other half; then make a hole below this partition, so as to correspond with a small canal filled with bruised powder, and terminating at the other end of the rocket: by these means the fire, when it ceases in the first half of the rocket, will be communicated through the hole into the small canal, which will convey it to the other end; and this end being then kindled, the rocket will move backwards, and return to the place from which it set out.

Two rockets of equal size, bound together by means of a piece of strong pack-thread, and disposed in such a manner that the head of the one shall be opposite to the neck of the other, that when the fire has consumed the composition in the one, it may be communicated to that in the other, and oblige both of them to move in a retrograde direction, may also be adjusted to the rope by means of a piece of hollow reed. But to prevent the fire of the former from being communicated to the second too soon, they ought to be covered with oil-cloth, or to be wrapped up in paper.

REMARK.

Rockets of this kind are generally employed for setting fire to various other pieces when large fireworks are exhibited; and to render them more agreeable, they are made in the form of different animals, such as serpents, dragons, &c.; on which account they are called *flying dragons*. These dragons are very amusing, especially when filled with various compositions, such as golden rain, long hair, &c. They might be made to discharge serpents from their mouths, which would produce a very pleasing effect, and give them a greater resemblance to a dragon.

SECTION II.

Rockets which fly along a Rope, and turn round at the same time.

Nothing is easier than to give to a rocket of this kind a rotary motion around the rope along which it advances; it will be sufficient for this purpose, to tie it to another rocket, placed in a transversal direction. But the aperture of the latter, instead of being at the bottom, ought to be in the side, near one of the ends. If both rockets be fired at the same time, the latter will make the other revolve around the rope, while it advances along it.

SECTION III.

Of Rockets which burn in the Water.

Though fire and water are two things of a very opposite nature, the rockets above described, when set on fire, will burn and produce their effect even in the water; but as they are then below the water, the pleasure of seeing them is lost; for this reason, when it is required to cause rockets to burn as they float on the water, it will be necessary to make some change in the proportions of the moulds, and the materials of which they are composed.

In regard to the mould, it may be eight or nine inches in length, and an inch in diameter: the former, on which the cartridge is rolled up, may be nine lines in thickness, and the rod for loading the cartridge must as usual be somewhat less. For loading the cartridge, there is no need for a piercer with a nipple.

The composition may be made in two ways; for if it be required that the rocket, while burning on the water, should appear as bright as a candle, it must be composed of three materials mixed together, viz. three ounces of pulverised and sifted gunpowder, one pound of saltpetre, and eight ounces of sulphur. But if you are desirous that it should appear on the water with a beautiful tail, the composition must consist of eight ounces of gunpowder pulverised and sifted, one pound of saltpetre, eight ounces of pounded and sifted sulphur, and two ounces of charcoal.

When the composition has been prepared according to these proportions, and the rocket has been filled in the manner above described, apply a saucisson to the end of it; and having covered the rocket with wax, black pitch, resin, or any other substance capable of preventing the paper from being spoiled in the water, attach to it a small rod of white willow, about two feet in length, that the rocket may conveniently float.

If it be required that these rockets should plunge down, and again rise up; a certain quantity of pulverised gunpowder, without any mixture, must be introduced into them, at certain distances, such for example, as two, three, or four lines, according to the size of the cartridge.

REMARKS.

1. Small rockets of this kind may be made, without changing the mould or composition, in several different ways, which, for the sake of brevity, we are obliged to omit. Such of our readers as are desirous of further information on this subject, may consult those authors who have written expressly on pyrotechny, some of whom we shall mention at the end of this book.

2. It is possible also to make a rocket which, after it has burnt

some time on the water, shall throw out sparks and stars; and these after they catch fire shall ascend into the air. This may be done by dividing the rocket into two parts, by means of a round piece of wood, having a hole in the middle. The upper part must be filled with the usual composition of rockets, and the lower with stars, which must be mixed with grained and pulverised gunpowder, &c.

3. A rocket which takes fire in the water, and, after burning there half the time of its duration, mounts into the air with great velocity, may be constructed in the following manner.

Take a flying rocket, furnished with its rod, and by means of a little glue attach it to a water rocket, but only at the middle, in such a manner, that the latter shall have its neck uppermost, and the other its neck downward. Adjust to their extremity a small tube, to communicate the fire from the one end to the other, and cover both with a coating of pitch, wax, &c. that they may not be damaged by the water.

Then attach to the flying rocket, after it has been thus cemented to the aquatic one, a rod of the kind described in the second article; and suspend a piece of pack-thread, to support a musket bullet made fast to the rod by means of a needle or bit of iron wire. When these arrangements have been made, set fire to the part after the rocket is in the water; and when the composition is consumed, the fire will be communicated through the small tube to the other rocket: the latter will then rise and leave the other, which will not be able to follow it on account of the weight adhering to it.

SECTION IV.

By means of Rockets, to represent several figures in the Air.

If several small rockets be placed upon a large one, their rods being fixed around the large cartridge, which is usually attached to the head of the rocket, to contain what it is destined to carry up into the air; and if these small rockets be set on fire while the large one is ascending, they will represent, in a very agreeable manner, a tree, the trunk of which will be the large rocket, and the branches the small ones.

If these small rockets take fire when the large one is half burned in the air, they will represent a comet; and when the large one is entirely inverted, so that its head begins to point downwards, in order to fall, they will represent a kind of fiery fountain.

If the barrels of several quills, filled with the composition of flying rockets, as above described, be placed on a large rocket; when these quills catch fire, they will represent, to an eye placed below them, a beautiful shower of fire, or of half frizzled hair, if the eye be placed on one side.

If several serpents be attached to the rocket with a piece of pack-thread, by the ends that do not catch fire; and if the pack-thread be suffered to hang down two or three inches, between every two, this arrangement will produce a variety of agreeable and amusing figures,

SECTION V.

A Rocket which ascends in the Form of a Screw.

A STRAIGHT rod, as experience shews, makes a rocket ascend perpendicularly, and in a straight line: it may be compared to the rudder of a ship, or the tail of a bird, the effect of which is to make the vessel or bird turn towards that side to which it is inclined: if a bent rod therefore be attached to a rocket, its first effect will be to make the rocket incline towards that side to which it is bent; but its centre of gravity bringing it afterwards into a vertical situation, the result of these two opposite efforts will be that the rocket will ascend in a zig-zag or spiral form. In this case indeed, as it displaces a greater volume of air, and describes a longer line, it will not ascend so high, as if it had been impelled in a straight direction; but, on account of the singularity of this motion, it will produce an agreeable effect.

CHAP. VII.

OF GLOBES AND FIRE BALLS.

WE have hitherto spoken only of rockets, and the different kinds of works which can be constructed by their means. But there are a great many other fireworks, the most remarkable of which we shall here describe. Among these are globes and fire balls; some of which are intended to produce their effect in water; others by rolling or leaping on the ground; and some, which are called bombs, do the same in the air.

SECTION I.

Globes which burn on the Water.

THESE globes, or fire balls, are made in three different forms; spherical, spheroidal, or cylindrical; but we shall here confine ourselves to the spherical.

To make a spherical fire ball, construct a hollow wooden globe of any size at pleasure, and very round both within and without, so that its thickness may be equal to about the ninth part of the diameter. Insert in the upper part of it a right concave cylinder, the breadth of which may be equal to the fifth part of the diameter; and having an aperture equal to the thickness, that is, to the ninth part of the diameter. It is through this aperture that the fire is communicated to the globe, when it has been filled with the proper composition, through the lower aperture. A petard of metal, loaded with good grained powder, is to be introduced also through the lower aperture, and to be placed horizontally.

When this is done, close up the aperture, which is nearly equal to the thickness of the cylinder, by means of a wooden tompion dipped in warm pitch; and melt over it such a quantity of lead that its weight may cause the globe to sink in water; which will be the case if the weight of the lead, with that of the globe and the composition, be equal to the weight of an equal volume of water. If the globe be then placed in the water, the lead by its gravity will make the aperture tend directly downwards, and keep in a perpendicular direction the cylinder, to which fire must have been previously applied.

To ascertain whether the lead, which has been added to the globe, renders its weight equal to that of an equal volume of water, rub the globe over with pitch or grease, and make a trial, by placing it in the water.

The composition with which the globe must be loaded, is as follows: to a pound of grained powder, add 32 pounds of saltpetre reduced to fine flour, 8 pounds of sulphur, 1 ounce of scrapings of ivory, and 8 pounds of saw-dust previously boiled in a solution of saltpetre, and dried in the shade, or in the sun.

Or, to 2 pounds of bruised gunpowder, add 12 pounds of saltpetre, 6 pounds of sulphur, 4 pounds of iron filings, and 1 pound of Greek pitch.

It is not necessary that this composition should be beaten so fine as that intended for rockets: it requires neither to be pulverised nor sifted; it is sufficient to be well mixed and incorporated. But to prevent it from becoming too dry, it will be proper to besprinkle it with a little oil, or any other liquid susceptible of inflammation.

SECTION II.

Of Globes which leap or roll on the Ground.

1. Having constructed a wooden globe with a cylinder, similar to that above described, and having loaded it with the same composition, introduce into it four petards, or even more, loaded with good grained gunpowder to their orifices, which must be well stopped with paper or tow. If a globe, prepared in this manner, be fired by means of a match, it will leap about, as it burns, on a smooth horizontal plane, according as the petards are set on fire.

Instead of placing these petards in the inside, they may be affixed to the exterior surface of the globe; which they will make to roll and leap as they catch fire. They may be applied in any manner to the surface of the globe.

2. A similar globe may be made to roll about on a horizontal plane, with a very rapid motion. Construct two equal hemispheres of pasteboard, and adjust in one of them three common rockets filled and pierced like flying rockets that have no petard: these rockets must not exceed the interior breadth of the hemisphere, and ought to be arranged in such a manner, that the head of the one shall correspond to the tail of the other.

The rockets being thus arranged, join the two hemispheres, by cementing them together with strong paper, in such a manner that they shall not separate, while the globe is moving and turning, at the same time that the rockets produce their effect. To set fire to the first, make a hole in the globe opposite to the tail of it, and introduce into it a match. This match will communicate fire to the first rocket; which, when consumed, will set fire to the second by means of another match, and so on to the rest; so that the globe, if placed on a smooth horizontal plane, will be kept in continual motion.

It is here to be observed, that a few more holes must be made in the globe, otherwise it will burst.

The two hemispheres of pasteboard may be prepared in the following manner: construct a very round globe of solid wood, and cover it with melted wax; then cement over it several bands of coarse paper, about two inches in breadth, giving it several coats of this kind, to the thickness of about two lines. Or, what will be still easier and better, having dissolved, in glue water, some of the pulp employed by the paper makers, cover with it the surface of the globe; then dry it gradually at a slow fire, and cut it through in the middle; by which means you will have two strong hemispheres. The wooden globe may be easily separated from the pasteboard by means of heat; for if the whole be applied to a strong fire the wax will dissolve, so that the globe may be drawn out. Instead of melted wax, soap may be employed.

SECTION III.

Of Aërial Globes, called Bombs.

THESE globes are called aërial, because they are thrown into the air from a mortar, which is a short thick piece of artillery of a large calibre.

Though these globes are of wood, and have a suitable thickness, namely, equal to the twelfth part of their diameters, if too much powder be put into the mortar, they will not be able to resist its force; the charge of powder therefore must be proportioned to the globe to be ejected. The usual quantity is an ounce of powder for a globe of four pounds weight; two ounces for one of eight, and so on.

As the chamber of the mortar may be too large to contain the exact quantity of powder sufficient for the fire ball, which ought to be placed immediately above the powder, in order that it may be expelled and set on fire at the same time, another mortar may be constructed of wood, or of pasteboard with a wooden bottom: it ought to be put into a large iron mortar, and to be loaded with a quantity of powder proportioned to the weight of the globe.

This small mortar must be of light wood, or of paper pasted together, and rolled up in the form of a cylinder, or truncated cone, the bottom excepted; which, as already said, must be of wood. The chamber for the powder must be pierced obliquely, with a small gimblet; so that the aperture corresponding to the aperture of the metal mortal, the fire applied to the latter may be communicated to the powder which is at the bottom of the chamber, immediately below the globe. By these means the globe will catch fire, and make an agreeable noise as it rises into the air; but it would not succeed so well, if any vacuity were left between the powder and the globe.

A profile or perpendicular section of such a globe is represented by the right-angled parallelogram, the breadth of which is nearly equal to the height. The thickness of the wood, towards the two sides, is equal, as above said, to the twelfth part of the diameter of the globe; and the thickness of the cover is double the preceding, or equal to a sixth part of the diameter. The height of the chamber, where the match is applied, and which is terminated by a semicircle, is equal to the fourth part of the breadth; and its breadth is equal to the sixth part.

We must here observe that it is dangerous to put wooden covers on aërial balloons or globes; for these covers may be so heavy, as to wound those on whom they happen to fall. It will be sufficient to place turf or hay above the globe, in order that the powder may experience some resistance.

The globe must be filled with several pieces of cane or common reed, equal in length to the interior height of the globe, and charged with a slow composition, made of three ounces of pounded gunpowder, an ounce of sulphur moistened with a small quantity of petroleum oil, and two ounces of charcoal; and in order that these reeds or canes may catch fire sooner, and with more facility, they must be charged at the lower ends, which rest on the bottom of the globe, with pulverised gunpowder moistened in the same manner with petroleum oil, or well besprinkled with brandy, and then dried.

The bottom of the globe ought to be covered with a little gunpowder half pulverised and half grained; which, when set on fire, by means of a match applied to the end of the chamber, will set fire to the lower part of the reed. But care must have been taken to fill the chamber with a composition similar to that in the reeds, or with another slow composition, made of eight ounces of gunpowder, four ounces of saltpetre, two ounces of sulphur, and one ounce of charcoal : the whole must be well pounded and mixed.

Instead of reeds, the globe may be charged with running rockets, or paper petards, and a quantity of fiery stars or sparks mixed with pulverised gunpowder, placed without any order above these petards, which must be choaked at unequal heights, that they may perform their effect at different times.

These globes may be constructed in various other ways, which it would be tedious here to enumerate. We shall only observe, that when loaded, they must be well covered at the top ; they must be wrapped up in a piece of cloth dipped in glue, and a piece of woollen cloth must be tied round them, so as to cover the hole which contains the match.

CHAP. VIII.

JETS OF FIRE.

JETS of fire are a kind of fixed rockets, the effect of which is to throw up into the air jets of fire, similar to jets of water. They serve also to represent cascades ; for if a series of such rockets be placed horizontally on the same line, it may be easily seen that the fire they emit, will resemble a sheet of water. When arranged in a circular form, like the radii of a circle, they form what is called a *fixed sun*.

To form jets of this kind, the cartridge for brilliant fires must, in thickness, be equal to a fourth part of the diameter, and for Chinese fire; only to a sixth part.

The cartridge is loaded on a nipple, having a point equal in length to the same diameter, and in thickness to a fourth part of it ; but as it generally happens that the mouth of the jet becomes larger than is necessary for the effect of the fire, you must begin to charge the cartridge, as the Chinese do, by filling it to a height equal to a fourth part of the diameter with clay, which must be rammed down as if it were gunpowder. By these means the jet will ascend much higher. When the charge is completed with the composition you have made choice of, the cartridge must be closed with a tompion of wood, above which it must be choaked.

The train or match must be of the same composition as that employed for loading; otherwise the dilatation of the air contained in the hole made by the piercer, would cause the jet to burst.

Clayed rockets may be pierced with two holes near the neck, in order to have three jets in the same plane.

If a kind of top, pierced with a number of holes, be added to them, they will imitate a bubbling fountain.

Jets intended for representing sheets of fire ought not to be choaked. They must be placed in a horizontal position, or inclined a little downwards.

It appears to us that they might be choaked so as to form a kind of slit, and be pierced in the same manner; which would contribute to extend the sheet of fire still farther. A kind of long narrow mouth might even be provided for this particular purpose.

PRINCIPAL COMPOSITIONS FOR JETS OF FIRE.

1st. *Jets of five lines or less, of interior diameter.*

Chinese fire.—Saltpetre 1 pound, pulverised gunpowder 1 pound, sulphur, 8 ounces, charcoal 2 ounces.

White fire.—Saltpetre 1 pound, pulverised gunpowder 8 ounces, sulphur 3 ounces, charcoal 2 ounces, iron sand of the first order 8 ounces.

2d. *Jets of from ten to twelve lines in diameter.*

Brilliant fire.—Pulverised gunpowder 1 pound, iron-filings of a mean size, 5 ounces.

White fire.—Saltpetre 1 pound, pulverised gunpowder 1 pound, sulphur 8 ounces, charcoal 2 ounces.

Chinese fire.—Saltpetre 1 pound 4 ounces, sulphur 5 ounces, sand of the third order 12 ounces.

3d. *Jets of fifteen or eighteen lines in diameter.*

Chinese fire.—Saltpetre 1 pound 4 ounces, sulphur 7 ounces, charcoal 5 ounces, of the six different kinds of sand mixed 12 ounces.

Pere d'Incarville, in his memoirs on this subject, gives various other proportions for the composition of these jets; but we must confine ourselves to what has been here said, and refer the reader to the author's memoirs, which will be found in the *Manuel de l'Artificier*.

The saltpetre, pulverised gunpowder, and charcoal, are three times sifted through a hair sieve. The iron sand is besprinkled with sulphur, after being moistened with a little brandy, that the sulphur may adhere to it; and they are then mixed together: the sulphured sand is then spread over the first mixture, and the whole is mixed with a ladle only; for if a sieve were employed, it would separate the sand from the other materials. When sand larger than that of the second order is used, the composition is moistened with brandy, so that it forms itself into balls, and the jets are then loaded: if there were too much moisture, the sand would not perform its effect.

SECTION I.

Of Fires of different Colours.

It is much to be wished that, for the sake of variety, different colours could be given to these fireworks at pleasure; but though we are acquainted with several materials which communicate to flame various colours, it has hitherto been possible to introduce only a very few colours into that of inflamed gunpowder.

To make white fire, the gunpowder must be mixed with iron or rather steel filings.

To make red fire, iron sand of the first order must be employed in the same manner.

As copper filings, when thrown into a flame, render it green, it might be concluded, that if mixed with gunpowder, it would produce a green flame; but this experiment does not succeed. It is supposed that the flame is too ardent, and consumes the inflammable part of the copper too soon. But it is probable that a sufficient number of trials have not yet been made; for is it not possible to lessen the force of gunpowder in a considerable degree, by increasing the dose of the charcoal?

However, the following are a few of those materials which, in books on pyrotechny, are said to possess the property of communicating various colours to fireworks.

Camphor mixed with the composition, makes the flame to appear of a pale white colour.

Raspings of ivory give a clear flame of a silver colour, inclining a little to that of lead; or rather a white dazzling flame.

Greek pitch produces a reddish flame, of a bronze colour.

Black pitch, a dusky flame, like a thick smoke, which obscures the atmosphere.

Sulphur, mixed in a moderate quantity, makes the flame appear blueish.

Sal ammoniac and verdigris give a greenish flame.

Raspings of yellow amber communicate to the flame a lemon colour.

Crude antimony gives a russet colour.

Borax ought to produce a blue flame; for spirit of wine, in which sedative salt, one of the component parts of borax, is dissolved by the means of heat, burns with a beautiful green flame.

Much, however, still remains to be done in regard to this subject; but it would add to the beauty of artificial fireworks, if they could be varied by giving them different colours: this would be creating for the eyes a new pleasure.

SECTION II.

Composition of a Paste proper for representing Animals, and other Devices in Fire.

It is to the Chinese also that we are indebted for this method of representing figures with fire. For this purpose, take sulphur reduced to an impalpable powder, and having formed it into a paste with starch, cover with it the figure you are desirous of representing on fire: it is here to be observed, that the figure must first be coated over with clay, to prevent it from being burnt.

When the figure has been covered with this paste, besprinkle it while still moist with pulverised gunpowder; and when the whole is perfectly dry, arrange some small matches on the principal parts of it, that the fire may be speedily communicated to it on all sides.

The same paste may be employed on figures of clay, to form devices and various designs. Thus, for example, festoons, garlands, and other ornaments, the flowers of which might be imitated by fire of different colours, could be formed on the frieze of a piece of architecture covered with plaster. The Chinese imitate grapes exceedingly well, by mixing pounded sulphur with the pulp of the jujube, instead of flour paste.

SECTION III.

Of Suns, both fixed and moveable.

None of the pyrotechnic inventions can be employed with so much success, in artificial fireworks, as suns; of which there are two kinds, fixed and revolving: the method of constructing both is very simple.

For fixed suns, cause to be constructed a round piece of wood, into the circumference of which can be screwed twelve or fifteen pieces in the form of radii; and to these radii attach jets of fire, the composition of which has been already described; so that they may appear as radii tending to the same centre, the mouth of the jet being towards the circumference. Apply a match in such a manner, that the fire communicated at the centre may be conveyed, at the same time, to the mouth of each of the jets; by which means, each throwing out its fire, there will be produced the appearance of a radiating sun. We here suppose that the wheel is placed in a position perpendicular to the horizon.

These rockets or jets may be so arranged as to cross each other in an angular manner; in which case, instead of a sun, you will have a star, or a sort of cross resembling that of Malta. Some of these suns are made also with several rows of jets: these are called *glories*.

Revolving suns may be constructed in this manner. Provide a wooden wheel, of any size at pleasure, and brought into perfect equilibrium around its centre, in order that the least effort may make it turn round. Attach to the circumference of it fire-jets placed in the direction of the circumference; they must not be choaked at the bottom, and ought to be arranged in such a manner, that the mouth of the one shall be near the bottom of the other, so that when the fire of the one is ended, it may immediately proceed to another. It may easily be perceived, that when fire is applied to one of these jets, the recoil of the rocket will make the wheel turn round, unless it be too large and ponderous: for this reason, when these suns are of a considerable size, that is when they consist for example of twenty rockets, fire must be communicated at the same time to the first, the sixth, the eleventh, and the sixteenth;

from which it will proceed to the second, the seventh, the twelfth, the seventeenth, and so on. These four rockets will make the wheel turn round with rapidity.

If two similar suns be placed one behind the other, and made to turn in a contrary direction, they will produce a very pretty effect of cross-fire.

Three or four suns, with horizontal axes passed through them, might be implanted in a vertical axis, moveable in the middle of a table. These suns, revolving around the table, will seem to pursue each other. It may be easily perceived that, to make them turn around the table they must be fixed on their axes, and these axes, at the place where they rest on the table, ought to be furnished with a very moveable roller.

[*Montuela's Ozanan. Frezier Traité des Feux d'Artifice. Perrinet d'Orone. Manuel de l'Artificier.*

The attention which has lately been paid to the amusing subject of pyrotechny in this metropolis, in the course of the public fireworks exhibited with so much spirit, and upon so extensive a scale, in the royal parks, has made us fuller in this department than perhaps we otherwise should have been. We believe there is scarcely a device which Mr. Congreve has exhibited, that we have not explained.

[*Editor.*

THE

GALLERY

OF

NATURE AND ART.

PART II.

A R T.

BOOK III.

Of METALLURGY, and the ARTS connected with it.

HAVING in the preceding part of this work treated of mineralogy, and metallic mines, we shall devote the present book to a few examples of the curious modes of working and mixing metals, and the most important uses to which they are applied.

CHAP. I.

OF CALAMINE, BLENDE OR BLACK JACK, ZINC, AND BRASS.

THE two principal ores of zinc are *calamine* and *blende.* The Arabic word *climia*, or, as it is pronounced by some, *calimia*, denotes the same substance which we call *lapis calaminaris*, *calamine*, or *calamy;* and hence Salmasius is of opinion, that they judge very preposterously who would derive *calamine* from *calaem*, an Indian word signifying, according to him, a species of metal resembling tin, which is dug near Malacca*. With due deference to his authority, I would observe, that Indian calaem is not like tin. Many years ago the Dutch took a Portuguese vessel which was laden with calaem†; and from all the experiments which were made upon that substance, it appeared to be zinc, or that metallic substance which we in Europe have very lately learned the method of extracting from calamine. Both calamine and zinc have the property of changing copper to a yellow colour; and this is the most distinguishing property of them both; it is that for which they are both sought after in commerce: and as climia and calaem have the same radical letters, and denote in the Arabic and Indian languages two substances which agree in one of their most characteristic properties, I leave it to others to determine whether they are not the same word, and in which of the two languages that word was originally formed. The other ore of zinc is called by the Germans blende, from its blinding or misleading appearance; it looking like an ore of lead, but yielding (as was formerly thought) no metallic substance of any kind‡. A particular sort of lead ore has been called by Pliny, galena, from a Greek word signifying to shine, because it is composed of shining particles; our potters ore and the Derbyshire lead ore are of this sort: blende much resembles galena; but, yielding no lead, it has been called false or pseudo-galena, or mock-lead: our English miners have called it black jack, and that is the name by which it is known to the makers of brass. Black jack resembles lead ore so much, that the miners sometimes succeed in selling, to inexperienced smelters, black jack instead of lead ore: I have heard of the fraud being carried to so great an extent in Derbyshire, that from a ton of ore

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* Cadmia Arabibus dicitur climia, quod quidam pronunciarunt calimia, unde Græcis recentioribus κελιμια interdum scribitur, unde nostris Gallis calamina et lapis calaminaris: quam vocem quidam præposterè deducunt ab Indico calaem, quod metalli genus est stanno simile, haud longè ex Malacca erui solitum. Salm. de Homony. Hy. lat. C. CXII.

† Savotus de Num. P. II. C. XIV.

‡ Pseudo-galena nomen suum exinde acquisivit, quod faciem quasi mineræ plumbeæ præ se ferat, sed mentiatur, cum id revera non contineat quod externo aspectu pollicetur. Germania appellatur blende, a blenden; quia, cum falso speciem mineræ saturninæ præ se fert, exinde oculos fascinet, vel iis imponat. Pott de Pseudo-galena, p. 106.—They have in Staffordshire a sort of iron, which they call blende-metal, of which they make nails, hammers, &c. Plot's Staff.

there was not obtained above a few ounces of lead; though a ton of unadulterated lead ore yields in Derbyshire, at an average, fourteen or fifteen hundred weight of lead.

Calamine is found in most parts of Europe; we have great plenty of it in Somersetshire, Flintshire, Derbyshire, and in many other parts of England. It is scarcely to be distinguished by its appearance from some sorts of lime-stone; for it has none of the metallic lustre usually appertaining to ores: it differs, however, by its weight from every sort of stone; it being, bulk for bulk, near twice as heavy as either flint or limestone. Before the reign of Elizabeth, this mineral was held in very little estimation in Great Britain; and even at so late a period as towards the end of the 17th century, it was commonly carried out of the kingdom as ballast by the ships which traded to foreign parts, especially to Holland.* It use is now as perfectly understood in England, as in any part of the world; and as we have greater plenty of calamine, and that of a better sort, than most other nations have, there is no fear of our losing the advantages in this article of trade which we are now possessed of.

Great quantities of calamine have of late years been dug in Derbyshire, on a spot called Bonsale Moor, in the neighbourhood of Matlock. A bed of iron stone, about four feet in thickness lies over the calamine; and the calamine is much mixed not only with this iron stone, but with cawk, lead ore, and limestone. The calamine miners never wish to meet with lead ore; they say that it eats up the calamine: and the lead miners in return never wish to meet with calamine in a rich vein of lead ore, since they are persuaded that it injures the quality of the ore. It would be too much to infer, from these observations of the miners, that one of these substances arises from the natural decomposition of the other. Juxtaposition of substances in the bowels of the earth, is no certain proof of their being derived from each other: for no one will contend that chert is derived from the limestone in which it is bedded, or flint and pyrites from the chalk in which they are found; yet when a great variety of substances are found mixed together in the same little lump, the mind cannot help conjecturing that a more improved state of mineralogy will shew some connection in their origin. I have often seen calamine, and black jack, and lead

* Essay on Metal: Words by Sir J. Petty, and Phil. Trans. for 1694.

ore—and cawk, black jack, and lead ore, bedded together in the same piece of spar.

The calamine annually raised in Derbyshire, amounts to about 1500 tons. Sixty years ago (as I was informed by an intelligent dealer in calamine, whose father was one of the first who dug it in that country), they did not raise forty tons in a year. The Derbyshire calamine does not bear so good a price as that which is gotten about Mendip in Somersetshire; the former being sold for about forty shillings, and the latter for sixty-five or seventy shillings a ton, before dressing: when thoroughly dressed, the Derbyshire calamine may be bought for about six guineas, and the other for eight pounds, a ton. This dressing of the calamine consists, principally, in picking out all the pieces of lead ore, limestone, iron stone, cawk, and other heterogeneous substances which are mixed with it, when it is first dug from the mine; this picked calamine is then calcined in proper furnaces, and by calcination it loses between a third and a fourth of its weight.

The substance which is lost during calcination of the calamine is not either sulphur or arsenic, or any thing which can be collected by the sides of an horizontal chimney, as is the case in some sorts of copper and lead ores, hence it would be quite unserviceable to roast calamine in a furnace with such a chimney. The truth of this remark will appear from the following experiment.

I took 120 grains of the best Derbyshire calamine, and dissolved them in a diluted vitriolic acid: the solution was made in a Florence Flask, and the weight of the acid and flask was taken before the solution commenced. About twenty hours after the solution had been finished, I weighed the flask and its contents, and found that there had been a loss of forty grains, or one third the weight of the calamine; about a grain of earth remained at the bottom undissolved. If the same quantity of the purest limestone had been dissolved in the same way, there would have been a loss of weight equal to fifty-four grains: the substance which is separated from calamine by calcination, or by solution in an acid, is of the same nature with that which is separable from limestone by the same processes—fixed air. This air having the property of changing the blue colour of vegetables to red, as well as many other properties of an acid, and being contained in great abundance in the atmosphere, has been called by some, aërial acid; and by others, from its constituting nine parts in twenty of chalk and other calcareous earths, chalky acid; and from its being destructive of flame and animal life, some have denominated it mephitic air. The weight which was thus lost by dissolving the Derbyshire calamine in an acid, corresponds sufficiently with that which the workmen observe to be lost during the calcination of that mineral; so that these processes mutually confirm each other.

Bergman observes that 100 grains of Flintshire calamine lost by calcination thirty four grains*: now this quantity corresponds, as much as can be expected in things of this sort, with the loss which I observed during the solution of 120 grains of the Derbyshire calamine; for if I had dissolved only 100 grains, the loss would have been $33\frac{1}{3}$. The same author, however, remarks that 100 grains of Flintshire calamine, when dissolved in an acid, gave only twenty-eight grains of air: and he thinks that six grains of water are contained in every 100 grains of that sort of calamine; for he takes the difference which he observed between the weight of air obtained by solution, and the loss of weight sustained during the calcination of 100 grains of calamine, to be owing to the water which is dispersed during the process of calcination†. Fontana obtained 190 grains of fixed air from 576 grains of Somersetshire calamine: according to the same proportion, had he used only 100 grains, he would have had thirty-three grains of fixed air, instead of the twenty-eight which Bergman got from the Flintshire calamine; I say instead of the twenty-eight, for I am inclined to think that the Derbyshire, Flintshire, and Somersetshire calamines do not differ much from each other in the quantity of air which they

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* Vol. II. p. 327.

† Bergman has used the same method of analysing other substances containing fixed air, particularly calcareous earths. He found that 100 grains of transparent calcareous spar gave, by solution in an acid, thirty-four grains of fixed air, and lost by calcination forty-five grains; the difference, eleven grains, he says is water; which, though expelled by the fire, remains mixed with the acid; and hence 100 grains of such spar contain fifty-five grains of lime, thirty-four grains of fixed air, and eleven grains of water. I have a little difficulty in admitting this mode of inferring the quantity of water contained in these bodies: I do not absolutely deny the justice of it; but I hesitate concerning it; because, from experiments which I made with all the care I could, I found that fine transparent spar, very white marble, &c. lost, as nearly as could be estimated, the same weight, whether they were dissolved in an acid, or calcined in a strong fire.

contain; but that the apparent difference in the analyses of them here mentioned, proceeds rather from the mode of operating than from the substances themselves. But, though future experience should prove that very pure pieces of the calamines we are speaking of do exactly agree to the quantity of air contained in them, it will not follow that the calamines, as prepared for sale by the miners or burners, will be similar to each other in all their properties; since they may be mixed with different quantities and with different sorts of heterogeneous substances, from which it may be impossible wholly to free them.

The reader must not conclude, from what has been said, that all sorts of calamine lose one third of their weight by calcination, or afford fixed air by solution in acids. Bergman analysed some calamine from Hungary, and he found 100 grains of it to consist of eighty-four grains of the earth of zinc, three of the earth of iron, one of clay, and twelve of siliceous earth: no mention is made of water in this analysis.*

In the great works where calamine is prepared for the brass makers, after it has been properly calcined, by which process, as has been observed, it loses between a third and a fourth part of its weight, it is again carefully picked, the heterogeneous parts having been rendered more discernable by the action of the fire; it is then ground to a fine powder: afterwards it is washed in a gentle rill of water, in order to free it as much as possible from the earthy particles with which it may be mixed; for these, being twice as light as the particles of the calamine, are carried off from it by the water: it is then made up for sale. A ton of the crude Derbyshire calamine, as dug from the mine, is reduced, by the various processes it undergoes before it becomes saleable, to about twelve hundred weight: and hence it has lost eight parts in twenty. Of the eight hundred weight thus lost in a ton, $6\frac{2}{3}$ may be esteemed fixed air: the remaining part, amounting to $1\frac{1}{3}$. consists of some impurities which have been picked out or washed away, and of some portion of the metallic part of the calamine, which is inflamed and driven off during the calcination: for I cannot agree with Wallerius†, in supposing that the ores of zinc lose no part of their substance during the ordinary process of calcination; the blue flame which is visible in the furnace where the calamine is

* Berg. Chem. Ess. vol. II. p. 325. † Metallur.

calcined, and the injury which the calamine sustains from being calcined with too strong a fire, are proofs to the contrary. It would be possible to use calamine for the purpose of making brass without calcining it; for the fixed air would be dissipated by the heat applied in making the brass. But, as in using a ton of uncalcined calamine, there would be between six and seven hundred weight put into the brass pots which would be of no manner of use in the operation, it is a wiser method to get rid of so large a quantity of unserviceable matter; especially as the carriage of six or seven hundred weight to the distance to which the prepared calamine is sent for the making of brass, would cost more than the calcination of a ton of it amounts to.

There are many sorts of blende or black jack, which differ from each other not only in their external appearance, but in their internal constitution. In general they contain zinc and sulphur, united together by the intervention of iron, or of calcareous earth; and they must be previously freed from their sulphur by calcination, before they can be applied to the making of brass. Some sorts of black jack lose one-fourth, others about one-sixth of their weight by calcination: what is thus dispersed consists principally of sulphur, with a little water; what remains consists of a large portion of zinc earth, mixed with one or more of the following substances, viz. iron, lead, copper, clay, and flint. Black jack is found in North Wales, in Cornwall, and in Derbyshire; and probably it may be met with in many other parts of Great Britain. It has for many years been used, as well as calamine, for the making of brass at Bristol; and I believe it was first used there under a patent: but so little was this application of it known in other parts of the kingdom, that in the year 1777, they begged me in Derbyshire (where they had a little before that time began to save it) not to divulge the purpose to which it might be applied.

It has not been long well understood, that either calamine or black jack contained any metallic substance. Matthiolus, Agricola, Caneparius, and other expert and more ancient metallurgists, esteemed calamine to be a mineral in which there was no metallic substance*. Their mistake on this subject was very excusable; for the metallic substance contained in the calamine being of a volatile and combustible nature, it consumed or dissipated by the ordinary

* Canep. de Atram. p. 12—21.

processes in which metals are extracted from their ores. Most ores require to be fluxed in contact with charcoal, or some other substance containing phlogiston, before they will yield their metals; and when they are thus fluxed, the metal, instead of being dispersed in vapour, is collected into a mass at the bottom of the vessel, or furnace, in which the operation is performed. Calamine, in like manner, must be united to phlogiston, before its metallic part, which is called zinc, will be properly formed; but as soon as it is formed, it flies off in vapour, and taking fire, burns with a vivid flame. This phenomenon is easily made apparent, by mixing calamine in powder and charcoal dust together, and exposing the mixture to a melting heat; for a flame will issue from it very different from what charcoal alone would yield: no mass of any metallic substance will be found at the bottom of the vessel; but in the place where the experiment is made, there will be seen many white flocks floating in the air: these flocks are the ashes of the metallic substance of the calamine; they are called flowers of zinc, lana philosophorum, nihil album, and by other fanciful names. The metallic vapour which rises from a mixture of calamine and charcoal, when exposed to a proper degree of heat, and the firing of which causes the flame which may be observed, cannot burn without air; and it was on this principle that Marggraf proceeded, when he extracted zinc from calamine by distillation in close vessels in 1746. He put eight parts of powdered calamine, and one of powdered charcoal, well mixed together, into an earthen retort; and having fitted a receiver, with a little water in it, to the neck of the retort, in such a manner as to exclude the air, he exposed the mixture to a strong heat; there rose into the neck of the retort, where it was condensed, the metallic vapour of the calamine. By this method he ascertained the quantity of zinc contained in different sorts of calamine.

	Parts.	Parts.
Calamine from near Cracow	16 gave	$2\frac{1}{2}$ of zinc.
——— from England	16 ——	3 ———
——— from Breslaw	16 ——	$4\frac{1}{2}$ ———
——— from Hungary	16 ——	$2\frac{1}{3}$ ———
——— from Holywell in Flintshire	16 ——	7 ———

He tried some stones from Aix-la-Chapelle, which had been given him for calamine, in the same way, but obtained no zinc from them; and thence he concludes that they were not calamine stones: for every stone, says he, which being mixed with charcoal, and exposed in close vessels to the action of a violent fire, does not yield zinc, or which in an open fire does not with copper and charcoal produce brass, ought not to be considered as a calamine stone*. Henckel had long before given a similar definition of zinc, when he observed that it was the only substance in nature which had the quality of giving copper a yellow colour†.

Pott wrote a dissertation on zinc in 1741, in which he enters into the history of the discovery of this semi-metal. Bergman has availed himself of all that Pott knew on that subject, and has added several things of his own: I cannot compress the matter into a less compass than he has done. "The semi-metal which at present is called zinc, was not known so much as by name to the ancient Greeks and Arabians. The name which it bears at present first occurs in Theophrastus Paracelsus‡, but no one as yet has been able to discover the origin of this appellation. A. G. Agricola calls it contrefeyn §; Boyle, speltrum‖: by others it is denominated spiauter, and Indian tin ¶. Albertus Magnus, more properly called Bolstadt, who died in 1280**, is the first who makes express mention of this semi-metal. He calls it golden marcasite, asserts that it approaches to a metallic nature, and relates that it is inflammable. However, as zinc is white, the name of golden marcasite is not very proper; it would therefore appear probable that it derives that name from the golden colour which it communicates to copper, had not Albertus expressly said, that copper united with golden marcasite becomes white; but he has probably either misunderstood or misrepresented what he had heard related by others. It may also happen that zinc was formerly thought to contain gold. J. Matthesius††, in 1562, mentioned a white and a red zinc; but the yellowness and redness are only to be understood of the ores. Hollandus, Basil Valentine, Aldrovandus, Cæsius, Cæsalpinus, Fallopius, and Scroeder, observe a profound silence on that head.‡‡ The eastern Indians have long since been in possession of the method of extracting pure zinc from the ore;

* Opus. de Marg. vol. I. p. 94.

† Pyrito. French Trans. p. 248.

‡ In Operibus passim.

§ De Re metallica.

‖ Ponderib. Flammæ.

¶ Tæda Trifida Chymica

** In Libro Mineralium.

†† Sarepta.

‡‡ Pott on Zinc.

at least in the course of the last century this metal was brought from thence to Europe. Jungius mentions the importation of zinc from India, in 1674*; a metal of this kind, under the name of tutenag, is still brought from thence, which must be carefully distinguished from the compound metal of that name. G. E. Van Lohneiss tells us, in 1617, that a long time before, zinc had been collected by fusion at Goslar†. It has been long used to form orichalcum from the ores of zinc, by the addition of copper; but it does not yet appear at what time this art was invented. Pliny makes mention of the orichalcum, as also of three species of Corinthian vases, one of which is yellow, and of the nature of gold‡. Erasmus Ebner, of Noremberg, in the year 1550, was the first who used the cadmia of Goslar for this purpose. In the year 1721, Henckel indeed mentioned that zinc might be obtained from lapis calaminaris by means of phlogiston, but he conceals the method §. The celebrated Anton. Van Swab, in 1742, extracted it from the ores by distillation, at Westerwick, in Dalecarlia‖. It was determined to found a work for the purpose of extracting larger quantities of this semi-metal; but afterwards, for various reasons, this project was laid aside: therefore the illustrious Marggraf, not knowing what had been done by the Swedish mineralogists, in the year 1746 published a method of performing this operation, which he had discovered himself ¶. It is not known how zinc is extracted in China. A certain Englishman, who several years ago took a voyage to that country for the purpose of learning the art, returned safely home indeed, and appears to have been sufficiently instructed in the secret, but he carefully concealed

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* De Mineralibus.

† Bericht Von. Bergvercken.

‡ Hist. Nat. XXX. C. II.

§ Pyritologia—Henckel's words deserve to be quoted; I take them from the French translation of the Pyritologia, p. 295. On fait, par exemple, avec la calamine, non seulement du fer, il est vrai en petite quantité, mais encore une trés-grande quantité de zinc, que l'on obtient non-seulement en lui presentant le corps avec lequel il peut s'incorporer, c'est-à-dire le cuivre qui est son aiman, mais encore ce demi-metal se montre simplement par l'addition d'une matiére grasse qui metallise; il faut seulement, pour eviter que ce phenix ne se reduise en cendre, empêcher qu'il ne se brûle, et observer le tems et les circonstances.

‖ Elogium magni hujus metallurgi coram R. Acad. Stock. recitatum.

¶ Mem. de l'Acad. de Berlin.

it. We find afterwards that a manufactory had been established at Bristol, where zinc is said to be obtained by distillation per descensum. We have already seen that it had been before obtained in Sweden by distillation per ascensum, which afterwards was effected in larger quantity by Mess. Cronstedt and Riman, two very celebrated mineralogists and metallurgists. The difficulties occasioned by the volatile and combustible nature of this metal, for a long time retarded the knowledge of the ores containing it: nor is that wonderful; as, being of a metallic form, it has even to our times been considered as composed of two or three ingredients. Albertus Magnus thinks iron an ingredient; Paracelsus called it a spurious son of copper; Lemery holds it to be a species of bismuth; Glauber, and many alchemists, consider it merely as an immature solar sulphur; Homberg, as a mixture of tin and iron; Kunckel as a coagulated mercury; Schluter, as tin made brittle by sulphur, &c. The celebrated Brandt, in 1735, shewed that blende contained zinc*; and soon after D. Swab actually extracted it from the Bolognian pseudo-galena, which possesses a metallic splendor. The Baron Funch, in 1744, determined the presence of zinc in pseudo-galena from the flame and the flowers†; and in 1746, Mr. Marggraf set the matter out of doubt.

Bergman in his history of the discovery of the method of extracting zinc from calamine, wholly omits the mention of Dr. Isaac Lawson; of whom Pott, in his Essay on zinc, speks very respectfully, acquainting us that he really obtained some grains of that semi-metal from calamine. So that though Henckel was the first, Lawson was, probably, the second person in Europe who procured zinc from calamine; whether he was the Englishman who, according to Bergman, went to China to discover the method of doing it, is what I have not been able to learn with certainty. Our English writers, who have touched on this subject, speak in high terms of Lawson, I suppose from their personal knowledge of him, for they do not refer to any written account‡. Thus

* Act. Upsal.

† Act. Stock.

‡ Pott gives us several quotations from a dissertation of Dr. Lawson's De Nihil, which I have never met with, and amongst others the following one: Quamvis lapis caliminaris nec sublimatione, nec cum fluxu nigro det zincum, tamen similes flores, similis in igne color, similis tinctura cupri, et augmentum ponderis probabilissimum præbent argumentum lapidem calaminarem esse mineram zinci. Pott De Zinco, p. 9.

Dr. Pryce says, "* the late Dr. I. Lawson observing that the flowers of lapis calaminaris were the same as those of zinc, and that its effects on copper were also the same with that semi-metal, never remitted his endeavours till he found the method of separating pure zinc from that ore." And Dr. Campbell, in his Survey of Britain, is still more particular; "† the credit, if not the value of calamine, is very much raised since an ingenious countryman of ours discovered that it was the true mine of zinc; this countryman was Dr. I. Lawson, who died before he had made any advantage of his discovery." The authors of the Supplement to Chambers' Dictionary, published in 1753, expressly affirm, that "‡ Dr. Lawson was the first person who shewed that calamine contained zinc; we have now on foot at home a work established by the discoverer of this ore, which will probably make it very unnecessary to bring any zinc into England." To all this I shall only add one testimony more, from which it may appear that the English knew how to extract zinc from calamine, before Mr. Van Swab taught the Swedes the method of doing it; though this gentleman, unless I have been misinformed, instructed the late Mr. Champion of Bristol, either in the use of black jack for the same purpose as calamine, or taught him some improvements in the method of obtaining zinc from its ores. The testimony occurs in a dissertation of Henckel's on *Zinc*, published in 1737: he is there speaking of the great hopes which some persons had entertained of the possibility of obtaining zinc from calamine; hopes, he says, which had been realized in England, Ce qu'un Anglois arrivé depuis peu de Bristol, dit avoir vu réussir dans son pays §.

The manufactory, however, of zinc was not established at Bristol till about the year 1743, when Mr. Champion obtained a patent for the making of zinc. About 200 tons of zinc are annually made at the place where the manufactory was first set up; and about seven years ago, zinc began to be made at Henham, near Bristol, by James Emerson, who had been many years manager of that branch under Mr. Champion, and his successors in the business.

* Mineral. Cornub. p. 46.

† Polit. Surv. of Brit. Vol. II. p. 35.

‡ Artic. Calam. & Zinc.

§ This observation was first published in the 4th vol. of the Acta Physico-Medica Acad. Nat Cur. 1737; but I have made the quotation from the ed. of Henckel's Works, published at Paris, 1760, Vol. III. p. 494.

Near twenty years ago, I saw the operation of procuring zinc from calamine performed at Mr. Champion's copper works near Bristol; it was then a great secret, and though it be now better known, yet I am not certain whether there are any works of the kind yet established in any other part of either England or Europe, except that before mentioned at Henham. In a circular kind of oven, like a glass-house furnace, there were placed six pots about four feet each in height, much resembling large oil jars in shape; into the bottom of each pot was inserted an iron tube, which passed through the floor of the furnace into a vessel of water. The pots were filled with a mixture of calamine and charcoal, and the mouth of each was then close stopped with clay. The fire being properly applied, the metallic vapour of the calamine issued through the iron tube, there being no other place through which it could escape, and the air being excluded, it did not take fire, but was condensed into very small particles in the water, and being remelted was formed into ingots, and sent to Birmingham under the name of zinc or spelter*. The reader will understand that this zinc will be more or less pure, according as the calamine is free from or mixed with iron, lead, copper, or other metallic substances. At Goslar in Germany, they smelt an ore which contains lead, and silver, and copper, and iron, and zinc in the same mass; the ore is smelted for the purpose of procuring the lead and silver, and by a particular contrivance in the furnace, which is well described by Cramer†, they obtain a portion of zinc in substance; another portion of it is inflamed, and the ashes of the zinc which is thus consumed, and which it has been observed before are called philosophic wool, &c. stick to the top and sides of the furnace, and are denominated by the smelters *cadmia fornacum*, or furnace fragment: these ashes are used as calamine is for the making of brass. We know nothing of the method of fluxing the zinc which is brought from India. According to Musschenbroeck, a cubic foot of Indian zinc weighs 7240 ounces; the same bulk of Goslar zinc, taking the medium of three specimens, gave 7210 ounces‡; the Goslar zinc, which I examined, gave only 6593 ounces to a cubic foot; a cubic foot of English zinc, from Bristol, weighs

* There is another substance which is denominated spelter or spelter solder by the braziers; it is composed of two parts of zinc and one of brass.

† Ars Docim. Vol. I. p. 236.

‡ Introd. ad Phil. Nat. Vol. II.

7028; and hence if the lightness of zinc be a criterion of its purity, our English zinc is preferable to the Indian, and nearly equal to the German zinc.

If the reader has never seen a piece of zinc, it will give him some idea of it to be told, that in colour it is not unlike lead; that it is hard and sonorous, and malleable in a small degree; that it does not melt so easily as tin or lead, but more easily than silver or copper; that in a degree of heat just sufficient to melt it, it burns away into a kind of grey ashes without being inflamed; that in a stronger heat it burns with a yellowish blue or green flame, resolving itself into a white earth, which is driven off by the violence of the fire during the combustion, or remains surrounding the burning zinc like a piece of cotton wool. This combustion of zinc is as striking an experiment as any in chemistry, and it is in the power of any person to make it, by sprinkling filings of zinc on a pan of burning charcoal, or on a poker, or other piece of iron heated to a white heat; it is this property which renders fine filings of zinc of great use in fire-works. Zinc is a very singular metallic substance; it not only burns when sufficiently heated with a vivid flame, but it yields an inflammable air by solution in the acids of vitriol and of sea salt, and even in some of its ores it manifests a phosphoric quality: I have seen a piece of black jack from Freiburg, which being scratched in the dark with the nail of a finger emitted a strong white light. The Chinese zinc is said to contain about half a pound of lead in an hundred, and the German zinc somewhat more*; and our English zinc is thought by some to make the copper with which it is melted harsher and less malleable than when either of the other sorts of zinc is used; though this opinion I suspect is rather founded in prejudice than in truth. There is an easy method, when pure zinc is required, of obtaining it: nothing more is required than to melt it with sulphur and some fat substance to prevent its calcination, for the sulphur will unite itself to the lead, the copper, or the iron contained in the zinc, and reduce them to a kind of scoria, which may be separated from the melted zinc, but it has no action on the zinc itself†. The zinc

* Berg. Ess. Vol. II. p. 318, note.

† I am aware that Mr. Morveau has found out a method of combining zinc with sulphur; but in this general view, I purposely pass over many things which are deservedly esteemed of great importance by persons deeply skilled in chemistry.

made by Mr. Emerson is whiter and brighter than any other either English or foreign zinc; but I do not know that it owes these qualities to its being purified by sulphur. Zinc and copper, when melted together in different proportions, constitute what are called pinchbecks, &c. of different yellow colours. Marggraf melted pure zinc and pure copper together, in a great variety of proportions, and he found that eleven, or even twelve parts of copper being mixed with one part of zinc (by putting the zinc into the copper when melted) gave a most beautiful and very malleable tombac or pinchbeck*. Mr. Baumé gives the following process for making a metal, which he says is called *Or de Manheim*, and which is used for imitating gold in a variety of toys, and also on lace.—Melt an ounce and a half of copper, add to it three drams of zinc, cover instantly the mixture with charcoal dust to prevent the calcination of the zinc†. This covering the melted mass with charcoal is certainly serviceable in the way the author mentions; and it is on a similar principle, that when they melt steel at Sheffield they keep the surface of it covered with charcoal; but I think it probable also, that the charcoal contributes to exalt the golden colour of the pinchbeck. These yellow metals are seldom so malleable as brass, on account of the zinc which is used in making them not being in so pure a state, as that is which is combined with copper when brass is made; yet it appears from the experiments of Marggraf and Baumé before mentioned, that when pure zinc and pure copper are used in proper proportions, very malleable brass may be made thereby. Mr. Emerson has a patent for making brass with zinc and copper, as I have been informed; and his brass is said to be more malleable; more beautiful, and of a colour more resembling gold than ordinary brass is. It is quite free from knots or hard places, arising from iron, to which other brass is subject; and this quality, as it respects the magnetic needle, renders it of great importance in making compasses. The method of making ordinary brass I will now describe.

Copper in thin plates, or which is better, copper reduced (by being poured, when melted, into water) into grains of the size of large shot, is mixed with calamine and charcoal, both in powder, and exposed in a melting pot for several hours to a fire not quite strong enough to melt the copper, but sufficient for uniting the metallic earth of the calamine to the phlogiston of the coal; this

* Mem. of Berlin, 1774.

† Chy. par M. Baumé, Vol. II. p. 662.

union forms a metallic substance, which penetrates the copper contiguous to it, changing its colour from red to yellow, and augmenting its weight in a great proportion. The greater the surface of a definitive weight of copper, the more space has the metallic vapour of the calamine to attach itself to; and this is the reason that the copper is granulated, and that it is kept from melting and running into a mass at the bottom of the vessel, till near the end of the operation, when the heat is increased for that purpose.

The German brass-makers, in the time of Erckern, used to mix sixty-four pounds of small pieces of copper with forty-six pounds of calamine and charcoal, and from this mixture they generally obtained 90 pounds of brass *. Cramer recommends three parts of powdered calamine to be mixed with an equal weight of charcoal dust and two parts of copper, and says that the brass obtained by the process exceeds the weight of copper by a fourth, or even a third part of its weight †. At most of our English brass-works they use forty-five pounds of copper to sixty pounds of calamine for making ingot brass, and they seldom obtain less than sixty, or more than seventy, pounds of brass; at Holywell they reckoned the medium product to be sixty-eight: and hence a ton of copper by this operation, becomes rather more than a ton and a half of brass. This is a larger increase of weight in the copper than is observed in any of the foreign manufactories that I have ever read of; and it may be attributed to two causes—to the superior excellence of our calamine, and to our using granulated copper. Postlethwayte, in his Commercial Dictionary, attributes the difference in the increase of weight acquired by the brass to the different natures of the coppers which are used: "There is an increase of forty-eight or fifty pounds in an hundred, if copper of Hungary or Sweden be used; that of Norway yields but thirty-eight, and that of Italy but twenty." When they make brass which is to be cast into plates, from which pans and kettles are to be made, and wire is to be drawn, they use calamine of the finest sort, and in a greater proportion than when common brass is made—generally fifty-six pounds of calamine to thirty-four of copper. Old brass which has been frequently exposed to the action of fire, when mixed with the copper and calamine in the making of brass, renders

* Fleta minor, by Sir J. Pettys. p. 286. Newman gives the same proportions, p. 65.

† Cram. Ars Doc. Vol. II. p. 246.

the brass far more ductile, and fitter for the making of fine wire, than it would be without it; but the German brass, particularly that made at Nuremberg, is, when drawn into wire, said to be preferable to any made in England for musical instruments. If this preference be real, it will cease to exist as soon as any ingenious man shall undertake to examine the subject; for our materials for making brass are as good as any in the world. The quantity of charcoal, which is used, is not the same at all works; it is generally about a fourth part of the weight of the calamine: an excess of charcoal can be attended with no other inconvenience than that of uselessly filling up the pots in which the brass is made; but powdered pitcoal which is used at some works in conjunction with, or in the place of charcoal, greatly injures the malleability of the brass. As to black jack, the other ore of zinc, it is not so commonly used as calamine for the making of brass. The manufacturers have been somewhat capricious in their sentiments concerning it; some have preferred it to calamine, and others have wholly neglected it; and the same persons at different times have made great use of it, or entirely laid it aside. There must have been some uncertainty in the produce or goodness of brass made by this mineral, to have occasioned such different opinions concerning it; and this uncertainty may have proceeded either from the variable qualities of the mineral itself, or from the unskilfulness of the operators in calcining, &c. a mineral to which they had not been much accustomed. Several ship loads of it were sent a few years ago from Cornwall to Bristol, at the price of forty shillings down to a moidore a ton *. Upon the whole, however, experience has not brought it into reputation at Bristol.

For many purposes brass is more useful than copper; it is lighter, harder, more sonorous, more fusible, less liable to scale in the fire, and to rust in the air. It is not malleable when hot, and in this respect it is inferior to copper: but when cold it may be beat out into thin leaves, as may be seen in the brass leaf, which emulates in colour and thinness gold leaf. If a brass leaf be held in the flame of a candle, the metallic part of the calamine will be inflamed, and the brass will be changed into copper. This change of brass into copper will take place in the largest masses, as well as in thin leaves of it, if the brass be kept a sufficient time in a

* Miner. Cornu. p. 47.

state of fusion. The varieties in the colour, malleability, and ductility of brass, proceed from the quantity and quality of the calamine imbibed by the copper; and the quality of the copper itself is a circumstance of no small importance in the making of brass. "I have observed, says Dr. Lewis*, in a large set of experiments on this subject, that a little of the calamine (that is, of the zinc contained in the calamine) dilutes the colour of the copper, and renders it pale; that when the copper has imbibed about one twelfth of it's own weight, the colour inclines to yellow; that the yellowness increases more and more till the proportion comes almost to one-half; that on further augmenting the calamine, the brass becomes paler and paler, and at last white." As to the different qualities of different kinds of copper, they are sufficiently known to workmen employed in fabricating it; and philosophers have so far observed them, as to distinguish the different sorts of copper by the different weights which appertain to equal bulks of them. The lightest copper which Musschenbroeck has noticed, is that which is precipitated from the copper waters in Hungary; a cubic foot of this sort weighed, when melted, 7242 ounces: and the heaviest sort he mentions is the Japan copper; a cubic foot of it, when simply melted, weighed 8726 ounces. The difference of the weights of equal bulks of these two sorts of copper is very considerable; but yet it is much less than what may be observed between two specimens of the same sort of copper, one of which has been cast, and the other has been wrought: the same Hungarian copper, which, when barely melted, weighed 7242 ounces to the cubic foot, when it had been condensed by being long hammered, weighed 9020. Many of our English writers estimate the weight of a cubic foot of copper at 9000 ounces †, but they do not say whether the copper was melted merely, or hammered; nor from what mine it was procured. I found the weight of a cubic foot of plate-brass from Bristol to be 8441 ounces, and that of a cubic foot of old brass from the bottom of an old kettle to be 8819; which shews that it approached to the weight of copper, and indeed from the redness of it's appearance it seemed as if all the zinc had been burned away. I had a present made me of a fine celt (the antiquaries are not

* Newman's Chem. by Lewis, notes, p. 65.

† Cotes, Ferguson, Martin, Campbell.

agreed concerning the uses to which the celts were applied, nor whether they are to be esteemed British or Roman instruments); it was covered over with a thick patina. I heated it in the fire, in order to get rid of this precious patina, or green rust, and took the specific gravity of it when quite freed from its rust, with great care; a cubic foot of it would have weighed only 6290 ounces. It was not malleable either when hot or cold. I then melted it: when in a state of fusion it emitted a blue flame, and a thick white smoke, which are esteemed certain marks of zinc. I melted it a second time, but there was no appearance of either flame or smoke, the zinc had been all consumed: I could not observe any lead in it; a cubic foot of it, after it was gently cooled from its state of fusion, weighed 8490 ounces; and it was now malleable, as cold brass always is: it was composed, I think, of copper, calamine, and tin; and I have heard that some celts contain a little silver. The change of texture which it had undergone, by being long buried in the earth, occasioned its comparative levity: this diminution of weight, which decaying brass sustains, is not peculiar to brass; it probably belongs to iron and other metallic substances subject to decay; and it certainly belongs to many species of stones. I have in another place observed, that a cubic foot of toadstone has different weights, according as the stone is more or less decayed; that which is most decayed being the lightest. We have a stratum of blueish grey ragstone in Westmoreland, which lies under the limestone; large cobbles of this sort of stone, which are exposed to the air, are decayed to a certain depth from the surface, whilst the inward part seems entire; a cubic foot of the outward part of one of these stones weighed 2378, when the inward part of the same stone weighed 2603 ounces to the cubic foot. This ragstone is very hard, but the same phenomenon may be noticed in a stone still harder. The Cambridgeshire black flint weighs 2592 ounces to the cubic foot; the same flint being in part decayed and become externally white, though black within, weighed 2414; and when become wholly white, 2400 ounces to the cubic foot; the general reason of this seems to be, that the pores of the decayed body are augmented. Mr. Kirwan has well explained the manner in which nature operates in decomposing stones. "Flints, jaspers, petro-silex, felt spar, granites, lavas, and ferrugineous stones, have frequently been said to be decomposed by the air, and the observations of Mr. Greville and Sir W. Hamilton have removed every doubt I entertained on this head. With regard to ferrugineous stones, in which the calx of iron is not much dephlogisticated, this decomposition is easily understood; for this calx gradually becomes more dephlogisticated by the action of the water and air, attracts water and fixed air, and loses its adherence with the siliceous, or other stony particles: this is seen to happen to basaltes, toadstone, ferrugineous limestone, &c. In other stones, this decomposition may arise from their containing calcareous earth in a caustic state, or manganese; for these will gradually attract water and fixed air, and then swell, burst, and loosen the whole texture of the stone, as we see happen to bricks that contain lime. Thus also glass is decomposed by long exposure to the air, the alkali attracting water and aërial acid. Mortar, on the contrary, hardens by long exposure to the air, because, though the aërial acid be attracted, yet a great part of the water exhales*." The changes produced by the long exposure of bodies to the air, and the causes of them, deserve a more minute investigation than has hitherto been bestowed on them; some advantage might, perhaps, be derived from the inquiry to our manufacturers; for I have cause to think that iron, which has been exposed to the air for three or four years, is a very different substance from the same iron when just made: and the same observation will probably hold with respect to copper and brass.—But to return from this digression. The calamine of Bohemia contains iron; most of our English calamine contains lead; and there are some sorts which contain both iron and lead, and other metals in different proportions: these sorts can seldom be freed from the extraneous metals; and hence, in the ordinary method of making brass, they will be mixed with it, being fusible in the degree of heat usually employed in making brass. Cramer mentions a very ingenious method of making brass, by which, if it should be thought necessary to do it, the brass may be preserved pure from these heterogeneous mixtures. He orders the calamine and charcoal to be mixed with moistened clay, and rammed to the bottom of the melting pot, and the copper mixed with charcoal to be placed upon the clay; then, the proper degree of heat being applied, the vapour of the zinc contained in the calamine will ascend through the clay, and attach itself to the copper, but the iron or lead contained in the

* Elements of Min. by R. Kirwan. p. 111.

calamine, not being volatile, will remain in the clay, and the brass when the whole is melted will not be mixed with them, but rest pure on the surface of the clay. Mr. John Champion, brother to him who first established the manufactory of zinc at Bristol, is a very ingenious metallurgist, and he has lately obtained a patent for making brass by combining zinc in vapour with heated copper plates, and the brass is said to be very fine; whether the process he uses has any correspondence with this mentioned by Cramer, or not, his brass will certainly be free from the mixture of lead, &c. But the care to purify brass from such metallic mixtures as may be accidentally contained in the calamine, is, or is not necessary, according to the purposes to which brass is applied. These mixtures may probably injure the malleability of the brass, but they may at the same time increase its hardness, or render it susceptible of a better polish, or give it a particularity of colour, or some other quality by which it may be more useful in certain manufactories, than if it was quite free from them, and consisted of nothing but the purest metallic part of the calamine, united to the purest copper. This may be illustrated from what is observable in other metals. The red iron ore from Furness, in Lancashire, produces an iron which is as tough as Spanish iron; it makes very fine wire; but when converted into bars, it is not esteemed so good as that which is made in the forest of Dean, and other places. There are but few sorts of iron which, though useful in other respects, are fit for being converted into steel: some sorts of iron will admit a high polish, as may be seen in many expensive grates which are sold as grates of polished steel, though they are nothing but iron; whilst others take but a very indifferent polish; the Swedish, Russian, and English irons, and even the irons made at different furnaces in the same country, are respectively fit for some purposes, and unfit for other: he who should attempt to use the same iron for the making of wire, and for coach and waggon wheels, would betray great ignorance in his business. In like manner, a notable difference may be observed in different sorts of copper, yet all of them have their respective uses: the Swedish copper is more malleable than the copper of Hungary; the copper of Anglesey differs from the copper of Cornwall and of Staffordshire. The braziers prefer that copper which they can work with the greatest facility; but the malleability of copper should not be esteemed the only criterion of its goodness; for the copper which is less malleable may admit a finer polish, and may last longer when exposed, as in breweries, in the navy, &c. to the action of the fire, than the copper which is more malleable. This has been proved by experiment. Three plates of copper, equal to each other in surface and thickness, were exposed, for the same length of time, to a violent fire, with a view of seeing which would best sustain its action; one plate was made of copper which had been purified by a chemical process, another was made of copper from Hungary, and the third of Swedish copper. The purified copper, when freed from the calcinated scales, had lost five grains of its weight, that of Hungary had lost eight, and that of Sweden eleven grains *.

Queen Elizabeth, in 1565, granted by patent all the calamine in England and within the English pale of Ireland to her assay master William Humphrey, and one Christopher Schutz, a German, and, as the patent sets forth, a workman of great cunning, knowledge, and experience, as well in the finding of calamine, as in the proper use of it for the composition of the mixt metal called latten or brass †. With these patentees were soon after associated some of the greatest men in the kingdom, as Sir Nicholas Bacon, the Duke of Norfolk, the Earls of Pembroke and Leicester, Lord Cobham, Sir William Cecil, and others, and the whole were incorporated into a society, called, The Society for the Mineral and Battery Works, in the year 1568. Mines of latten, whatever may have been at that period meant by the word, are mentioned in the time of Henry VI. who made his chaplain, John Bottwright, comptroller of all his mines of gold and silver, copper, latten, lead, within the counties of Devon and Cornwall ‡; yet I am disposed to think, that the beginning of the brass manufactory in England may be properly referred to the policy of Elizabeth, who invited into the kingdom various persons from Germany, who were well skilled in metallurgy and mining. In 1639, a proclamation was issued prohibiting the importation of brass wire §; and about the year 1650, one Demetrius, a German, set

* Mem. de Brux. Vol. IV.

† Opera Mineralia Explicata, p. 34. This work was written by Moses Stringer, M.D. in 1713, and contains a complete history of the ancient corporation of the city of London, of and for the mines, the mineral and battery works.

‡ Id. p. 20. § Id. p. 147.

up a brass work in Surry, at the expence of six thousand pounds *; and above eight thousand men are said to have been employed in the brass manufactories which were established in Nottinghamshire, and near London; yet Sir John Pettus in his account of royal mines, published in 1670, observes that these brass works were then decayed, and the art of making brass almost gone with the artists †. But though the art was then almost gone, yet it was never, after its first establishment, altogether lost; for about the year 1708, we find that there were brass manufacturers in England, and that they presented a memorial to the House of Commons, setting forth several reasons for continuing the brass manufactory in this kingdom, and soliciting for it the protection of parliament ‡. In this memorial they stated, that England, by reason of the inexhaustible plenty of calamine, might become the staple of brass manufactory for itself and foreign parts; that the continuing the brass works in England would occasion plenty of rough copper to be brought in, and make it the staple (in time) of copper and brass; that the Swedes had endeavoured to subvert the English brass manufactory, by lowering the price of Swedish brass wire, inveigling away workmen, and other means. In compliance with the purport of this memorial, an act of parliament was passed in the same year, by which the former duties payable on the exportation of copper of the produce of Great Britain, and of brass wire, were taken off, and these articles were allowed to be exported free of duty. In 1720 it was remarked, that this nation could supply itself with copper and brass of its own produce, sufficient for all occasions, if such duties were laid on foreign copper and brass, as would discourage their importation, and at the same time encourage the sale of our own metals §. At present the brass manufactory is established among us in a very great extent; we are so far from being obliged to have recourse to any of our neighbours for this commodity, that we annually export large quantities of manufactured brass to Flanders (it was formerly called Flanders metal), France, Germany, Portugal, Spain, Russia, Africa, and most other parts of the world. In 1783, a bill was passed by the House of Commons for repealing certain statutes prohibiting the exportation of

* Essays on Metal. Words—Brass.

† Fodinæ Regal. p. 33.

‡ Oper. Min. Exp. 156.

§ State of the copper and Brass Manufactures, by W. Wood—the same person whom Swift handled so roughly in his Drapier's Letters.

brass. In the reign of Edward III. the exportation of iron, either made at home or brought into England, had been prohibited upon the pain of forfeiting double the value of the quantity exported *. And in the reigns of Henry VIII. and Edward VI. several acts of parliament had been passed, prohibiting the exportation of brass, copper, latten, bell-metal, pan-metal, gun-metal, shrof-metal, under the same penalty †. The general reason for passing these acts certainly does not apply to the present state of our mines and manufactures, for the reason was this—lest there should not be metal enough left in the kingdom fit for making of guns and other engines of war, nor for household utensils. The forementioned acts of parliament were particularly repealed, by an act passed in the sixth year of William and Mary, by which it was rendered lawful to export, after the 25th of March, 1694, all manner of iron, copper, or mundick metal; but the prohibition of the other metals was continued. The brass-makers in 1783 applied for the same liberty which had been granted to the iron and copper smelters, a liberty of exporting the crude commodity; this liberty was not granted them by the legislature, for the bill which had passed the House of Commons, was thrown out by the Lords. The Birmingham manufacturers presented a petition to the House of Commons, against the bill which was then pending; in which petition it was represented—that frequent attempts had been made to erect manufactures similar to those of Birmingham in different parts of Europe, and that the excellence of some of the Birmingham articles depended upon brass of very different qualities; and that, fortunately for this country, there were several sorts of brass that were peculiarly adapted to the different branches of their manufactures; so that the sort which was suitable for one article, was improper for another: and that they had reason to believe, that the manner of adapting the various sorts of English brass to different articles in their manufactures, was not known to foreigners; but that if free liberty was given to export brass, every maker might be induced to discover the peculiar uses of his sort, and that very disagreeable consequences to their manufactures might thereby be produced. The petitioners also represented—that brass-makers, in different provinces of this kingdom, had not succeeded in making

* 28 Ed. III. c. 5.

† 21 Hen. VIII. c. 10.—33 Hen. VIII. c. 7.—2 & 3 Ed. VI. c. 37.

the sorts of brass made in other provinces; and that one great company of brass-makers had not succeeded in making brass suitable for the Birmingham market, though they had professed an earnest desire to do so. And they humbly apprehended, that there never had been such a quantity of brass exported as to render it a national object; and that there was not a probability of any such quantity being exported, though so much might be as to raise a ruinous competition to their manufactures, &c.

The brass makers, it may be said, suffered an injury in being prohibited from exporting a commodity by which they might be gainers, merely lest the great brass manufacturers should lose somewhat of their profit, by having a less extensive trade. But this is not a proper state of the case; it is not for the sake of the great brass manufacturers that the prohibition of exporting brass is continued, nor is there any want of that metal in the kingdom; but lest foreigners should rival us in a trade which, in affording employment to many thousands of people, is of the greatest consequence to the kingdom in general. The proprietors of fullers earth have been prohibited from exporting that material; not out of any partial regard of the legislature for the great woollen manufacturers, but lest the number of persons employed in that manufacture should be much lessened, if foreigners were supplied with an article so essentially necessary to its perfection, as fullers earth is found to be; and though other nations have fullers earth, yet that which is met with in England is reckoned to be fitter for the woollen manufactory, than any other which has yet been found in any part of the world. This observation may be applied to the subject we are speaking of. Great quantities of good brass are made by most nations in Europe, as well as by the English; but the English brass is more adapted to the Birmingham manufactories than any other sort is; and hence in France, Portugal, Russia, and Germany, our unmanufactured brass is allowed to be imported free of duty, but heavy duties are imposed in those countries on manufactured brass when imported. The manner of mixing different sorts of brass, so as to make the mixture fit for particular manufactures, is not known to foreigners; though this is a circumstance of the greatest importance: but there can be little doubt, that if foreign nations were possessed of all the sorts of English brass, they would soon seduce our workmen to instruct them in the manner of mixing them, and in some other little circumstances, which are not generally known, but on which the success of the manufacture depends in a great degree. On these and other accounts, till commerce puts on a more liberal appearance than it has hitherto done in Europe; till different nations shall be disposed to consider themselves, with respect to commercial interests, as different provinces only of the same kingdom; it may, probably, be thought expedient to continue the acts prohibiting the exportation of unwrought brass, though the reasons which induced the legislature to pass them have long since ceased to exist. I do not enter into the inquiry, when the custom-house officers began to make a distinction between wrought and unwrought brass, so as to admit the former to an entry for exportation and not the latter; but I apprehend it was in the year 1721, when various goods and merchandizes of the product or manufactures of Great Britain were allowed, by act of parliament, to be exported free of duty; lapis calaminaris, lead, and several other articles are enumerated in the act, on which the duty was to be continued; but in this enumeration there is no mention made of unwrought brass, though it may properly be considered as a merchandize of the product of Great Britain; but the quantity of brass which was then made in the kingdom was so small, that it did not, probably, enter into the contemplation of the legislature to forbid an exportation, which did not seem likely ever to take place. Brass is made in various parts of Great Britain; but the Bristol, Macclesfield, and Warrington companies are the only ones, I believe, which go through all the processes of smelting the copper from its ore, of preparing the calamine, and of uniting it with copper for the making of brass. The trade of brass making has within these few months been much deranged throughout the nation, by an agreement which has been entered into by some of the principal copper companies, to the exclusion of others, to buy up all the copper of the mines now at work in the kingdom. The effect of this plan is not yet generally either felt or foreseen.

[*Bishop Watson.*

CHAP. II.

ON ORICHALCUM, AURICHALCUM, OR THE BRASS OF THE ANCIENTS.

WE have a proof, from the writings of Cicero, that the Romans, in his time, understood by the term orichalcum, a metallic substance resembling gold in colour, but very inferior to it in value. He puts the following case—" Whether, if a person should offer a piece of gold to sale, thinking that he was only disposing of a piece of orichalcum, an honest man ought to inform him that it was really gold, or might fairly buy for a penny what was worth a thousand times as much*." It is not contended, that the argument, in this place, required any great accuracy in ascertaining the relative values of gold and orichalcum ; yet we may reasonably conclude from it, that orichalcum might by an ignorant person be mistaken for gold, and that it was but of small estimation when compared with it.

Julius Cæsar robbed the capitol of three thousand pound weight of gold, and substituted as much gilded copper in its stead†; in this species of sacrilege, he was followed by Vitellius, who despoiled the temples of their gifts and ornaments, replacing the gold and silver by tin and orichalcum ‡. From this circumstance also, we may collect, that the Roman orichalcum resembled gold in colour, though it was far inferior to it in value.

It is probable, that the orichalcum, here spoken of, was a metallic substance greatly analogous to our brass, if not wholly the same with it. The value of our brass is much less than that of gold, and the resemblance of brass to gold in colour, is obvious at first sight. Both brass and gold, indeed, are susceptible of a variety of shades of yellow ; and, if very pale brass be compared with gold mixed with much copper, such as the foreign goldsmiths, especially, use in their toys, a disparity may be seen ; but the nearness of the resem-

* Circer. de Off. L. III.

† Suet. in Jul. Cæs. C. LIV.

‡ Id. in Vitel. C. VI.

blance is sufficiently ascertained in general, from observing that substances gilded with brass, or, as it is commonly called, Dutch leaf, are not easily distinguished from such as are gilded with gold leaf.

The Romans were not only in possession of a metallic substance, called by them orichalcum, and resembling gold in colour, but they knew also the manner of making it; and the materials from which they made it, were the very same from which we make brass. I am sensible, that in advancing this opinion, I dissent from authors of great credit, who esteem the art of making brass to be wholly a modern invention. Thus M. Cronstedt (though I differ in opinion from him) "does not think it just to conclude, from old coins and other antiquities, that it is evidently proved, that the making of brass was known in the most ancient times *;" the authors of the French Encyclopedie assure us, that "our brass is a very recent invention †:" and Dr. Laughton ‡ says, "the vessels here called brazen, after ancient authors, cannot have been of the materials our present brass is composed of; the art of making it is a modern discovery."

Pliny, speaking of some copper which had been discovered near Corduba in the province of Andalusia in Spain, says, "this of all the kinds of copper, the Livian excepted, absorbs most cadmia, and imitates the goodness of aurichalcum §." The expression, 'absorbs most cadmia,' seems to indicate, that the copper was increased in bulk, or in weight, or in both, by means of the cadmia. Now it is well known, that any definite quantity of copper is greatly increased, both in bulk and in weight, when it is made into brass by being fluxed in conjunction with calamine. The other attribute of the copper, when mixed with cadmia, was, its resembling aurichalcum. We have seen from Cicero, that the term orichalcum was applied to a substance far less valuable than gold, but similar to it in colour; and it is likely enough, that the Romans, commonly called the mixture of copper and cadmia, orichalcum, though Pliny says, that it only resembled it; he, as a naturalist, speaking with precision, and distinguishing the real orichalcum, which in his time, he says, was no where produced, from the factitious one, which from its resemblance to it, had usurped its name.

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* Miner. p. 218.

† Art. Orichalque.

‡ Laughton's Hist. of Ancient Egypt, p. 58.

§ Hist. Nat. L. XXXIV. S. II.

Sextus Pompeius Festus abridged a work of Verrius Flaccus, a grammarian of considerable note in the time of Augustus. In this abridgment, he defines cadmia to be an earth which is thrown upon copper, in order to change it into orichalcum*. The age in which Festus flourished is not ascertained: he was unquestionably posterior to Martial, and some have thought that he lived under the Christian Emperors. But leaving that point to be settled by the critics, if he expressed himself in the words of the author whose work he abridged, we have from him a decisive proof, that cadmia was considered as a species of earth, and that the Romans used it for the converting of copper into a metallic substance called, in the Augustan age, orichalcum.

In opposition to this, it ought to be remarked, that some understand by the cadmia of Pliny, not calamine, but native arsenic. They seem to have been led into this opinion, from observing that Pliny says, lapis ærosus was called cadmia. For apprehending that by lapis ærosus Pliny understood a kind of stone which caused ulcers and erosions in the flesh of those who were occupied in working it, and knowing that arsenic produced such an effect, they have concluded that cadmia was native arsenic†. This, probably, is a mistake arising from a misinterpretation of the word ærosus. Pliny usually, if not constantly, applies that word to substances in which copper is contained, without having any respect to the actions of such substances on the flesh of animals. Arsenic, moreover, when mixed with copper, does not give a gold, but a silver-like appearance to copper. And lastly, Pliny‡, in another place expressly says, that the stone from which brass (æs) was made, was called cadmia; now it is impossible to make either brass or copper from arsenic.

Ambrose, bishop of Milan, in the fourth century, says, that copper, mixed with certain drugs, was kept fluxed in the furnace till it acquired the colour of gold, and that it was then called aurichalcum§. Primasus, bishop of Adrumetum in Africa, in the

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* Cadmia Terra quæ in æs conjicitur, ut fiat orichalcum.—Fes. de Ver. Seq.

† —— nous supçonnons que Pline a voulu designer par lapis ærosus, une pierre qui mange et fait des ulceres ou érosions à ceux qui la travaillent, et qui est probablement l'arsenic vierge. Miner. par M. Valmont de Bomare, V. II. p. 64.—If the word had been erosus, this criticism might have been admitted.

‡ Hist. Nat. L. XXXIV. 10.

§ Æs namque in fornace, quibusdam medicaminibus admixtis, tamdiu conflatur usque dum colorem auri accipiat, et dicitur aurichalcum.—Amb. in Apoc. C. I.

sixth century, observes, that aurichalcum was made from copper, brought to a golden colour by a long continued heat, and the admixture of a drug*. Isidorus, bishop of Seville in Spain, in the seventh century, describes aurichalcum as possessing the splendor of gold, and the hardness of copper, and he uses the very words of Primasius respecting the manner of it's being made†. The drug spoken of by these three bishops was probably cadmia. Prepared cadmia is highly commended by Pliny as useful in disorders of the eyes‡; and it is still with us, under the more common appellation of calamine, in some repute for the same purpose. Hence, considering the testimonies of Festus and Pliny to the application of cadmia in making either orichalcum, or a substance imitating the goodness of orichalcum, we cannot have much doubt in supposing, that cadmia was the drug alluded to by Ambrose, and by those who seemed to have borrowed, with some inaccuracy of expression, his description of the manner of making orichalcum.

What we call brass, was anciently in the French language called archal; and brass wire is still not unfrequently denominated fil d'archal. Now if we can infer, from the analogy of languages, that archal is a corruption of aurichalcum, we may reasonably conjecture, that our brass, which is the same with the French archal, is the same also with the Roman aurichalcum.

Though we may, from what has been advanced, conclude, without much apprehension of error, that the Romans knew the method of making brass, by melting together calamine and copper; yet the invention was probably derived to them from some other country.

We meet with two passages, one in Aristotle, the other in Strabo, from which we may collect, that brass was made in Asia, much after the same manner in which it appears to have been made at Rome.

Strabo informs us, that in the environs of Andêra, a city of Phrygia, a wonderful kind of stone was met with, which being calcined became iron; and being then fluxed with a certain earth,

* Aurichalcum ex ære fit, cum igne multo; et medicamine adhibito, perducitur ad aureum colorem.—Prima. in Apoc. C. I.

† Aurichalcum dictum, quod et splendorem auri, et duritiam æris possideat; fit autem ex ære et igne multo, ac medicaminibus perducitur ad aureum colorem.—Isid. Orig.

‡ Hist. Nat. L. XXXIV. C, X.

dropped out a silver-looking metal, which, being mixed with copper, formed a composition which some called orichalcum*. It is not improbable, I think, that this stone resembled black jack, or some other ore of zinc. Black jack may, in a common way of speaking, be called a stone. It abounds in iron; and, when calcined, looks like an iron earth; it yields zinc by distillation, sometimes mixed with silver and lead: and both the metallic substance which may be extracted from black jack, and the sublimate which arises from it whilst it is smelted, will, when mixed with copper, make brass.

The Mossynæci inhabited a country not far from the Euxine Sea; and their copper, according to Aristotle, was said to have become splendid and white, not from the addition of tin, but from it's being mixed and cemented with an earth found in that country.† This cementing of copper with an earth, is what is done, when brass is made, by uniting copper with calamine, which is often called, and indeed has the external appearance of, an earth; and that Asia was celebrated for its cadmia or calamine, we have the testimony of Pliny‡. The copper of the Mossynæci is said to have become white by this operation. Whiteness appertains to brass, either absolutely or relatively; for brass is not only much whiter than copper, but when it is made with a certain quantity of a particular sort of calamine, for there are very various sorts of it, its ordinary yellow colour is changed into a white. Cicero, we have seen, supposes that orichalcum might have been mistaken for gold, and as such it must have been yellow; yet Virgil applies the epithet white to orichalcum:

> Ipse dehinc auro squalentem *alboque* orichalco
> Circumdat loricam humeris §.

Aristotle also speaks of having heard of an Indian copper, which was shining, and pure, and free from rust, and not distinguishable in colour from gold‖; and he informs us, that amongst the vessels of Darius there were some, of which, but for the peculiarity of their smell, it would have been impossible to say whether they were made of gold or copper. This account seems very descriptive of common brass, which may be made to resemble gold per-

* Strab. Geo. L. XIII.
† Aris. de Mirab. Op. Tom. II. p. 721.
‡ Hist. Nat. L. XXXIV. C. II.
§ Virg. Æn. L. XII. 87.
‖ Aris. de Mirab. T. II. y. 719.

fectly in colour; but which, upon being handled, always emits a strong and peculiar smell, not observable either in gold or gilded copper.

The kings of Persia, who preceded the Darius mentioned by Aristotle, were in possession of similar vessels; but they seem to have been rare, and of course were held in high estimation. Among the magnificent presents of gold and silver vessels which Artaxerxes and his counsellors gave to Ezra, for the service of the temple at Jerusalem, there were twenty basons of gold, and but two vessels of yellow shining copper, precious as gold, or, as some render the words, resembling gold*. Sir John Chardin, in his MS. note, has mentioned a mixed metal used in the East, and highly esteemed there; and, as the origin of this composition is unknown, it might, for aught we know, be as old as the time of Ezra, and be brought from those more remote countries into Persia, where these two basons were given to be conveyed to Jerusalem. "I have heard," says the note, "some Dutch gentlemen speak of a metal in the island of Sumatra, and among the Macassars, much more esteemed than gold, which royal personages alone might wear. It is a mixture, if I remember right, of gold and steel, or of copper and steel." He afterwards added to this note (for the colour of the ink differs), "Calmbac is this metal composed of gold and copper. It in colour nearly resembles the pale carnation rose, has a very fine grain, the polish extremely lively. I have seen something of it, &c. Gold is not of so lively and brilliant a colour; I believe there is steel mixed with the gold and copper." He seems to be in doubt about the composition, but very positive as to its beauty and high estimation†.

The supposition of brass having been anciently made in India, seems to be rendered improbable by both Pliny and Strabo; Pliny expressly saying, that the Indians had no copper‡, and without copper we are certain that brass cannot be made; and Strabo representing them as so ignorant of the art of fluxing metals§, that according to him, if they had been possessed of the materials, they would not have had the ability to use them for the composing of brass. But these writers, it is apprehended, knew very little of India. Strabo, in particular, laments his want of materials to compose a consistent account of India; and few of the authors

* Ezra viii. 27. † Harmer's Obs. on Scrip. Vol. II. p. 491.
‡ Hist. Nat. L. XXXIV. C. XVII. § Geo. L. XIV.

from whose works Pliny compiled his Natural History, can be supposed to have had any intercourse with that country. Strabo, moreover, contradicts both Pliny's observation, and his own. In describing the great pomp with which some of the Indians were accustomed to celebrate their festivals, he speaks of huge gilt kettles, cups, and tables, made of Indian copper*; from which it appears, not only that the Indians were not destitute of copper, but that they were skilful metallurgists, since they knew how to flux it, to form it into vessels of various kinds, and to gild it. Perhaps, this Indian copper of which the vessels were made, instead of being gilt, only resembled gold in colour, and was really a sort of brass. It is granted that this is but a conjecture, but it is not devoid of probability; for, not to mention that the author, whoever he was, from whom Strabo extracted this account, might in a public exhibition have easily mistaken polished brass for gilt copper; nor the little probability that cauldrons, and kettles, and such vessels as were in constant use, would be gilded in any country; we have reason to believe, from what has been observed before, that a peculiar kind of vessels, probably resembling some of those exhibited in the Indian festivals, had been long in use in Persia, and that they were made of Indian copper without any gilding. We know that there is found in India, not only copper strictly so called, but zinc also, which being mixed with copper constitutes brass, pinchbeck, tombac, similor, and all the other metallic mixtures which resemble gold in colour. On the whole, it appears probable to me, that brass was made in the most remote ages in India, and in other parts of Asia, of copper and calamine, as it is at present. If the celt be allowed to be a British instrument, then may we be certain, from what was observed concerning it in the last Essay, that our ancestors knew the method of mixing together calamine and copper; for though tin and copper, when melted together in certain proportions, will give a blueish green flame, yet the flame is not accompanied with a thick white smoke, and there are few proportions in which any flame at all is to be seen.

With respect to orichalcum, it is generally supposed that there were two sorts of it, one factitious, the other natural; the factitious, whether we consider its qualities or composition, appears to have been the same with our brass. As to the natural orichalcum,

* Id. LXXVI.

there is no impossibility in supposing that copper ore may be so intimately blended with an ore of zinc, or of some other metallic substance, that the compound, when smelted, may yield a mixt metal of a paler hue than copper, and resembling the colour of either gold or silver. In Du Halde's History of China, we meet with the following account of the Chinese white copper. "The most extraordinary copper is called pe-tong, or white copper: it is white when dug out of the mine, and still more white within than without. It appears, by a vast number of experiments made at Peking, that its colour is owing to no mixture; on the contrary, all mixtures diminish it's beauty; for when it is rightly managed, it looks exactly like silver: and were there not a necessity of mixing a little tutenag, or some such metal with it, to soften it, and prevent its brittleness, it would be so much the more extraordinary; as this sort of copper is, perhaps to be met with no where but in China, and that only in the province of Yunnan*." Notwithstanding what is here said, of the colour of this copper being owing to no mixture, it is certain that the Chinese white copper, as brought to us, is a mixt metal; so that the ore, from which it is extracted, must consist of various metallic substances; and from some such ore it is possible that the natural orichalcum, if ever it existed, may have been made. But, though the existence of natural orichalcum cannot be shewn to be impossible, yet there is some reason to doubt whether it ever had a real existence or not: for I pay not much attention to what Father Kircher has said of orichalcum being found between Mexico and the straits of Darien; because no other author has confirmed his account, at least none on whose skill in mineralogy we may rely†.

We know of no country in which it is found at present; nor was it any where found in the age of Pliny, nor does he seems to have known the country where it ever had been found. He admits, indeed, its having been formerly dug out of the earth; but it is remarkable that, in the very passage he is mentioning by name the countries most celebrated for the production of different kinds of copper, he only says in general, concerning orichalcum, that it had been found in other countries, without specifying any particular country. Plato acknowledges that orichalcum was a thing only

* Fol. Trans. Vol. I. p. 16.

† Kirch. Mund. Sub.

talked of even in his time; it was no where then to be met with, though in the island of Atlantis it had been formerly extracted from its mine. The Greeks were in possession of a metallic substance called orichalcum, before the foundation of Rome; for it is mentioned by Homer and by Hesiod, and by both of them in such a manner as shews that it was held in great esteem. Other ancient writers have expressed themselves in similar terms of commendation; and it is principally from the circumstance of the high reputed value of orichalcum, that authors are induced to suppose the ancient orichalcum to have been a natural substance, and very different from the factitious one in use at Rome, and probably in Asia; and which, it has been shewn, was nothing different from our brass.

But this circumstance, when properly considered, does not appear to be of weight sufficient to establish the point. Whenever the method of making brass was first found out, it is certain that it must have been for some time, perhaps for some ages, a very scarce commodity; and this scarcity, added to its real excellence as a metallic substance, must have rendered it very valuable, and entitled it to the greatest encomiums. Diodorus Siculus speaks of a people who willingly bartered their gold for an equal weight of iron or copper*; and the Europeans have long carried on a similar kind of commerce with various nations. Gold, in some views, is justly esteemed the most valuable of metals; in other, and those the most important to the well-being of mankind, is far inferior to iron, or copper, or brass. An individual, whose life depended upon the issue of a single combat, to be decided by the sword, would have no hesitation in preferring a sword of steel, to one of gold; and an army, which should be possessed of golden armour, would not scruple to exchange it, in the day of battle, for the iron accoutrements of their enemies. The preference of the harder metals to gold, is no less obvious in agriculture, than in war; a ploughshare, mattock, chisel, hammer, saw, nail, of gold, is not for use so valuable, as an instrument of the same kind made of iron or brass. Hence, there is no manner of absurdity in supposing that orichalcum, when first introduced among the ancients might have been prized at the greatest rate, though it had been possessed of no other properties, than such as appertain to brass. When iron was either not at all known, or not common in the

* Lib. III.

world, and copper instruments, civil and military, were almost the only ones in use*, a metallic mixture, resembling gold in splendour, and preferable to copper, on account of its superior hardness, and being less liable to rust, must have greatly excited the attention of mankind, been eagerly sought after, and highly extolled by them. The Romans, no doubt, when it had been stipulated in the league which Porsenna made with them, after the expulsion of the Tarquins, that they should not use iron, except in agriculture, must have esteemed a metallic mixture such as brass, at a rate not easily to be credited†. It is not here attempted to prove, that there never was a metallic substance called orichalcum, superior in value and different in quality from brass; but merely to shew, that the common reason assigned for its existence, is not so cogent as is generally supposed.

Considering the few ancient writers we have remaining, whose particular business it was to speak with precision concerning subjects of art, or of natural history, we ought not to be surprised at the uncertainty in which they have left us concerning orichalcum. Men have been ever much the same in all ages; or, if any general superiority in understanding is to be allowed, it may seem to be more properly ascribed to those who live in the manhood or old age of the world, than to those who existed in its infancy or childhood: especially as the means of acquiring and communicating knowledge, with us, are far more attainable than they were in the times of either Greece or Rome. The compass enables us to extend our researches to every quarter of the globe with the greatest ease‡; and an historical narration of what is seen in distant countries, is now infinitely more diffused than it could have been, before the invention of printing; yet, even with these advantages, we are, in a great measure, strangers to the natural his-

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* Hesiod.

† In fœdere quod, expulsis regibus, populo Romano dedit Porsenna, nominatim comprehensum invenimus, ne ferro nisi in agricultura uterentur. Plin. Hist. Nat. Vol. II. p. 666.—Was Porsenna induced to prohibit the Romans the use of iron arms, from the opinion, which seems to have prevailed in Greece two hundred years afterward—that wounds, made with copper weapons, were more easily healed, than those made with iron? Aris. Op. L. IV. p. 43.

‡ Buffon quotes Homer's Odyssey, and some Chinese authors, to prove that the use of the mariner's compass in navigation was known to the ancients, at least three thousand years ago. Nat. Hist. by Buffon, Vol. IX. p. 17. Smellie's Trans.

tory of the earth, and the civil history of the nations which inhabit it. He who imports tutenag from the East Indies, or white copper from China or Japan, is sure of meeting with a ready market for his merchandize in Europe, without being asked any questions concerning the manner how, or the place where, they are prepared. An ingenious manufacturer of these metallic substances might wish, probably, to acquire some information about them, in order to attempt a domestic imitation of them; but the merchant who imports them, seems to be too little interested in the success of his endeavours, to take much pains in procuring for him the requisite information. Imitations, however, have been made of them, and we have an European tutenag, and an European white copper*, differing, in some qualities, from those which are brought from Asia, but resembling them in so many other, that they have acquired their names. Something of this kind may have been the case with respect to orichalcum, and the most ancient Greeks may have known no more of the manner in which it was made, than we do of that in which the Chinese prepare their white copper: they may have had too an imitation of the original, and their authors may have often mistaken the one for the other, and thus have introduced an uncertainty and confusion into their accounts of it.

There is as little agreement amongst the learned concerning the etymology of orichalcum, as concerning its origin. Those who write it aurichalcum, suppose that it is an hybridous word, composed of a Greek term signifying copper, and a Latin one signifying gold. The most general opinion is, that it ought to be written orichalcum, and that it is compounded of two Greek words, one signifying copper, and the other a mountain, and that we rightly render it by, mountain copper. I have always looked upon this as a very forced derivation, inasmuch as we do not thereby distinguish orichalcum from any other kind of copper; most copper mines, in every part of the world, being found in mountainous countries. If it should be thought, that some one particular mountain, either in Greece or Asia, formerly produced an ore,

* The ingenious Dr. Higgins has been honoured by the Society for the Encouragement of Arts, &c. with a gold medal for white copper, made with English materials, in imitation of that brought from the East Indies. His process has not, I believe, been yet made public. Mem. of Agricul. Vol. III, p. 459.

which being smelted yielded a copper of the colour of gold, and that this copper was called orichalcum, or the mountain copper, it is much to be wondered at, that neither the poets nor the philosophers of antiquity have bestowed a single line in its commendation; for as to the Atlantis of Plato, before mentioned, no one, it is conceived, will build an argument for the existence of natural orichalcum, on such an uncertain foundation: and, if there had been any such mountain, it is probable, that the copper it produced would have retained its name, just as at this time of day we speak of Ecton copper in Staffordshire, and Paris-mountain copper in Anglesey.

Some men are fond of etymological inquiries, and to them I would suggest a very different derivation of orichalcum. The Hebrew word *or*, *aur*, signifies light, fire, flame; the Latin terms *uro*, to burn, and *aurum*, gold, are derived from it, inasmuch as gold resembles the colour of flame; and hence, it is not improbable, that orichalcum may be composed of an Hebrew and Greek term, and that it is rightly rendered, flame-coloured copper. In confirmation of this it may be observed, that the Latin epithet *lucidum*, and the Greek one *φαεινον*, are both applied to orichalcum by the ancients; but I would be understood to submit this conjecture, with great deference, to those who are much better skilled than I am in etymological learning.

[*Bishop Watson.*

Dr. Watson has justly observed in the preceding essay, that none of the poets or philosophers have spoken in favour of *orichalcum.* Among the Roman poets the term employed both for copper and brass, or orichalcum, was *æs*; which is the only term adopted by Lucretius when he evidently means mineral copper, either in its ores or in metallic veins. This, however, by his translators is in almost all cases translated brass, but most erroneously; for, as we have just seen, brass is a mixed metal, and has never, that we know of, been traced in a native state. Mr. Good is the only one of the translators who has entered into the scientific meaning of the term, and has avoided the error: nor can we conclude this chapter better than by quoting his translation of the "Nature of Things," which describes the mode by which philosophers in the time of Lucretius supposed mankind to have acquired their first rude knowledge of metals.

Learn next that silver, gold,*
Lead, hardier COPPER, iron, first were trac'd
When o'er the hills, some conflagration dire
Burn'd from its basis the deep-rooted grove;
By lightnings haply kindled, or the craft
Of hosts contending o'er the woodland scenes,
A double fear thus striking through their foes:
Or by the shepherd's wish his bounds t' enlarge
O'er tracts of specious promise; or, perchance,
Wild beasts to slaughter, and their spoils possess;
For such, with fire and guileful pit, mankind
First caught, ere hounds were marshall'd to the chace,
Or round the copse the mazy net-work drawn.
Whate'er the cause, when now the unctuous flame
Had from their utmost roots, with hideous crash,
Fell'd the tall trees, and, with its torrid heat,
The soil deep-redden'd, rills of liquid gold,
Lead, silver, copper, through its fervid pores

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* Quod super est, ÆS atque aurum, ferrumque repertum est, &c.
Lib. V. v. 1240.

The passage is too long for us to quote the original at length; upon the part of it before us the learned translator has the following note:—"The term *æs*, in the original, is generally interpreted in the different versions *brass*, which as a generic substantive, it will undoubtedly include, as well as *copper*. But *brass*, the appropriate term for which is *aurichalcum*, being a compound metal, and the invention of subsequent ages, it is obvious the poet here refers to the original metal whence brass was manufactured. Marchetti employs the term *rame*, which is equally general with *æs*, and may alike be adopted to signify either copper or brass.

The existence of the metals here referred to in the interior of the earth, is thus described by Garth, in his Dispensary:

Here, sullen to the sight, at large is spread
The dull unwieldy mass of lumpish lead:
There, glimmering in their dawning beds, are seen
The more aspiring seeds of sprightly tin.
The *copper* sparkles next in ruddy streaks,
And in the gloom betrays its glowing cheeks:
The silver then, with bright and burnish'd grace,
Youth, and a blooming lustre in its face,
To th' arms of those more yielding metals flies,
And in the folds of their embraces lies.

On the invention and composition of brass or aurichalcum among the Greeks and Romans, see the same work, Note on Book VI. v. 1113.

Glided amain, and every hollow fill'd.
These when, condens'd, long after men survey'd
Glistening in earth, attracted by the glare,
The splendid mass they dug; and mark'd, surpriz'd,
Each form'd alike, and, to the channell'd bed
Where late it lay, adapted most precise.
Then instant deem'd they, liquified by flame,
The power was theirs each various shape t' assume,
Drawn dextrous out, of point or edge acute;
The power unrivall'd theirs each tool to frame
Art needs to fell the forest, and its trees
Mould into planks or beams; to cleave, or smooth,
Pierce, hollow, scoop, whate'er the plan conceiv'd.
Nor strove they less such instruments t' obtain
From gold, or silver, than stern copper's strength.
Yet vainly: for their softer texture fail'd,
Powerless to bear the sturdy toil requir'd.
Whence copper chief they courted, while all gold
Neglected lay, too blunt, and dull for use.
Now triumphs gold, while copper sinks despised.
So rolling years the seasons change of things:
What once was valu'd loses all its worth,
And what was worthless rises in its stead,
Swells into notice daily, every hour
Blooms with new praise, and captive leads the world.

[*Editor.*

CHAP. III.

OF GUN-METAL; BRONZE, OR STATUARY-METAL; BELL METAL; POT-METAL; AND SPECULUM-METAL, OR METALLIC MIRRORS.

Besides brass there are many other metallic mixtures, into which copper enters as the principal ingredient; the most remarkable of these are gun-metal, bell-metal, pot-metal, and speculum-metal.

It has been remarked of Queen Elizabeth, that she left more brass ordnance at her death, than she found of iron on her accession to the throne. This must not be understood as if gun metal was in her time made chiefly of brass, for the term brass was sometimes used to denote copper; and sometimes a composition of iron, copper, and calamine, was called brass; and we at this day commonly speak of brass cannon, though brass does not enter into the composition used for the casting of cannon. Aldrovandus* informs us, that 100 pounds weight of copper, with twelve of tin, made gun-metal; and that if, instead of twelve, twenty pounds weight of tin was used, the metal became bell-metal. The workmen were accustomed to call this composition metal, or bronze, according as a greater or a less proportion of tin had been used. Some individuals, he says, for the sake of cheapness, used brass or lead instead of tin, and thus formed a kind of bronze for various works. I do not know whether connoisseurs esteem the metal, of which the ancients cast their statues, to be of a quality superior to our modern bronze; but if we should wish to imitate the Romans in this point, Pliny has enabled us to do it; for he has told us, that the metal for their statues, and for the plates on which they engraved inscriptions, was composed in the following manner. They first melted a quantity of copper; into the melted copper they put a third of its weight of old copper, which had been long in use; to every hundred pounds weight of this mixture they added twelve pounds and a half of a mixture, composed of equal parts of lead and tin †.

In Diego Ufano's Artillery, published in 1614, we have an account of the different metallic mixtures then used for the casting of cannon, by the principal gun-founders in Europe.

Copper	.	160—	100—	100—	100 parts.
Tin	. .	10—	20—	8—	8
Brass	. .	8—	5—	5—	0

The best possible metallic mixture cannot be easily ascertained, as various mixtures may answer equally well the rude purpose to which ordnance is applied. Some mixtures, however, are unquestionably better adapted to this purpose than others, in some particular points. Of two metallic mixtures, which should be equally strong, the lightest would have the preference: at the last siege of Prague, part of the ordnance of the besiegers was melted by the

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* Aldrovandus, p. 108. † Hist. Nat. L. XXXIV. S. XX.

frequency of the firing; the mixture of which it was made contained a large portion of lead; and it would have been less prone to melt, and consequently preferable, had it contained none.

Woolwich, I believe, is the only place in England, where there is a foundry for the casting of brass cannon. The metallic composition there used, consists of copper and tin. The proportion in which these two metals are combined, is not always the same, because the copper is not always of equal purity, and the finest copper requires the most tin; they seldom use more than twelve, or less than eight parts of tin to every 100 of copper. This metallic mixture is sold, before casting, for £.75 a ton, and Government pays for casting it £.60 a ton. The guns of the East India Company are less ornamented than those of Government; on that and other accounts they are cast for £.40 a ton. I have here put down the weights of the brass ordnance, now most generally in use, as cast at Woolwich.

Weight of brass cannon now in use.

	cwt.	qr.	lb.
42 pounders	61	2	10
24	51	0	0
12	29	0	0
6	19	0	0

These were on board the Royal George in 1780, but had been removed, I believe, before she was lost.

Battering cannon.

42 pounders	61	2	10
32	55	2	10
24	51	0	0
18	48	0	0
12	29	0	0
9	25	0	0
6	19	0	0

Field-pieces.

24 pounders	16	3	13
12	8	3	8
6	4	3	10
3	2	3	10

Howitzers.	cwt.	qr.	lb.
10 inches	31	2	16
8	12	1	16
$5\frac{1}{5}$	4	0	18
Mortars (Land Service).			
13 inches	25	0	0
10	10	2	8
8	4	0	10
5	1	1	0
$4\frac{2}{5}$	0	3	0
Mortars (Sea Service).			
13 inches	81	1	8
10	32	3	7

In casting these pieces of cannon, they generally make the thickness of the sides, near the muzzle, half the diameter of the shot, and at the touch-hole, or charging cylinder, three-fourths of the diameter. Brass cannons are dearer than those made of iron; and, which is a disadvantage, they give a louder report at the time of explosion, so as to occasion a tingling in the ears of the persons on shipboard, which takes away for a time the faculty of hearing.

Cannon might be cast of copper alone; but the mixture of tin and copper is harder and denser, and less liable to rust than pure copper is, and upon these accounts it is preferable to copper. Tin melts with a small degree of heat, copper requires a very great heat to melt it; a mixture of copper and tin melts much easier than pure copper, and upon this account also, a mixture of copper and tin is preferred to pure copper, not only for the casting of cannon, but of statues, &c. for pure copper, in running through the various parts of the mould, would lose so much of its heat as to set before it ought to do.

Bell-metal consists also of tin and copper. Authors do not agree in the proportions; some ordering one part of tin to be melted with four parts of copper*; others making the proportion for bell-metal to be the same as that for gun-metal; or one part of tin to about ten parts of copper, to which they order a little brass

* Pemb. Chem. p. 321.

to be added*. It may in general be observed, that a less proportion of tin is used for making church bells than clock bells, and that they add a little zinc for the bells of repeating watches and other small bells. This zinc becomes manifest on melting these bells, by the blue flame which it exhibits.

There is a very remarkable experiment mentioned by Glauber†. "Make," says he, "two balls of copper, and two of pure tin not mixed with lead, of one and the same form and quantity, the weight of which balls observe exactly; which done, again melt the aforesaid balls or bullets into one, and first the copper, to which melted add the tin, lest much tin evaporate in the melting, and presently pour out the mixture melted into the mould of the first balls, and there will not come forth four, nor scarce three balls, the weight of the four balls being reserved." This subject has been prosecuted since Glauber's time‡, and it has been discovered, that when metallic substances are melted together, it seldom happens that a cubic inch of each of the two ingredients will form a mass exactly equal to two cubic inches; the mixture will in some instances be greater, and in other less than two cubic inches. In the instance of tin and copper, where the bulk of the mixture is so much less than the sum of the bulks of the two component parts, it might be expected that the compound metal would possess properties, not merely intermediate between those of copper and tin, but essentially different from them both. And accordingly we find, that this mixture is not only more brittle, more hard, and more sonorous, than either copper or tin; but it is more dense also, than either of them; a cubic foot of it weighing, not only more than a cubic foot of tin, but than a cubic foot of copper itself.

Pot-metal is made of copper and lead, the lead being one-fourth or one-fifth the weight of the copper. In Pliny's time pot-metal (ollaria temperatura) was made of a pound and a half or two pounds of lead, and an equal portion of tin, mixed with 100 parts of copper. Copper and lead seem not to be combined together in the same way that copper and tin are; for when pot-metal is exposed to a melting heat, the lead is first fused, and shews itself

* Waller. Miner. vol. II. p. 242. New Chem. by Lewis, p. 66. Macq. Chem. vol. I. p. 70. Eng. Trans.

† Glauber's Works, fol. ed. 1689, p. 81.

‡ Gellert's Chy. Metal. & Chem. Dict. art. Allay.

in little drops over the surface of the pot-metal, whilst the copper remains unfused.

It is reported of James II. that he melted down and coined all the brass guns in Ireland, and afterwards proceeded to coin the pewter with this inscription—*Melioris tessera fati.* The Congress in America had recourse to the same expedient: they coined several pieces of about an inch and a half in diameter, and of 240 grains in weight; on one side of which was inscribed in a circular ring near the edge—*Continental Currency*, 1776—and within the ring a rising sun, with—*fugio*—at the side of it, shining upon a dial, under which was—*Mind your business.*—On the reverse were thirteen small circles joined together like the rings of a chain, on each of which was inscribed the name of some one of the thirteen states; on another circular ring, within these, was inscribed—*American Congress*—and in the central space—*We are One.*—I have been particular in the mention of this piece of money, because, like the leaden money which was struck at Vienna, when that city was besieged by the Turks in 1529, it will soon become a great curiosity. I estimated the weight of a cubic foot of this continental currency; it was equal to 7440 ounces: this exceeds the weight of a cubic foot of our best sort of pewter, and falls short of that of our worst; I conjecture that the metal of the continental currency consisted of twelve parts of tin and of one of lead. Plautus*, and other Roman authors, make mention of leaden money; some are of opinion that we ought to understand by that expression, copper mixed with lead; but that cannot be the meaning, if it be true, that the Romans did not mix lead with their copper currency till the age of Septimius Severus, for Plautus lived many years before that emperor. I will not enter into the controversy: and I have introduced this observation relative to the leaden money of the Romans, merely to shew the correspondence which some of the Roman copper medals bore to our pot-metal; for those which were struck after the age of Septimius Severus, being exposed to a proper degree of heat, sweat out drops of lead, as it has been remarked our pot-metal does; but metals of greater antiquity have no such property†.

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* Tace sis, faber, qui cudere soles plumbeos nummos. Plau. Mos. A. IV. S. II. L. XI. et Casin. A. II. S. III. L. XL. et Mart. L. X. E. LXXIV.

† Illi enim qui studii hujus amore tenentur, cum monetam æream ante Septimium Severum cusam igne probent nihil plumbi inde secerni deprehendunt

The sex have in all ages used some contrivance or other to enable them to set off their dress to the best advantage; and the men were probably never without their attention to that point. We find Juvenal* satirizing the emperor Otho for making a speculum part of his camp equipage.

> Res memoranda novis annalibus, atque recenti
> Historia, *speculum* civilis sarcina belli.

Homer, in describing Juno at her toilet †, makes no mention of a speculum; but in Callimachus ‡ we see, though it suited not the majesty of Juno, nor the wisdom of Pallas, to use a speculum before they exhibited their persons to Paris, who was to determine the prize of beauty; that Venus, on the same occasion, had frequent recourse to one, before she could adjust her locks to her own satisfaction. The most ancient account we have of the use of specula is that in Exodus (xxxviii. 8.) "And he made the laver of brass [copper, or a mixture of copper and tin] and the foot of it of brass of the looking-glasses of the women." The English reader may wonder how a vessel of brass could be made out of looking-glasses; the Hebrew word might properly be rendered by specula, or metallic mirrors. The Jewish women were, probably, presented with these mirrors, as they were with other articles of value by their Egyptian neighbours, when they left the country; for it was the custom of the Egyptians, when they went to their temples, to carry a mirror in their left hand§: it is remarkable, that the Peruvians, who had so many customs in common with the Egyptians, were very fond also of mirrors; which they ordinarily formed of a sort of lava that bore a fine polish.

Pliny || says, that the best specula were anciently made at Brundusium of copper and tin; that Praxiteles, in the time of Pompey the Great, was the first who made one of silver; but that silver ones were in his time become so common, that they were used even by the maid servants. The metallic mixture of tin and cop-

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Aliter autem comparata sunt numismata post ætatem Severi cusa, quippe ex quibus guttulæ quædam plumbi, vel modico ignis calore diversis in locis exprimuntur.—Savot de Num. Ant. P. II. C. I. These pot-metal medals were probably cast.

* Sat. II. l. 102. † Il. L. XIV. l. 170.

‡ Hym. in Lavac. Pallad. § Cyril. de Ado.

|| Hist. Nat. L. XXXIII. S. XLV.

per was known long before the age of Pliny; it is mentioned by Aristotle*, incidentally, when he is describing a method of rendering copper white, but not by tin; and from its great utility, it will probably never fall into disuse. We have ceased, indeed, since the introduction of glass mirrors, to use it in the way the ancients did; but it is still of great use amongst us, since the specula of reflecting telescopes are commonly made of it. Mr. Mudge has ascertained†, not only the best proportion in which the copper and tin should be mixed together, but has found out also a method of casting the specula without pores. He observes, that the perfection of the metal, of which the speculum should be made, consists in its hardness, whiteness, and compactness. When the quantity of tin is a third of the whole composition, the metal then has its utmost whiteness; but it is at the same time rendered so hard that it cannot be polished without having its surface splintered and broke up. After many experiments, he at length found that fourteen ounces and one half of grain tin‡, and two pounds of copper made the best composition; an addition of half an ounce more tin rendered the composition too hard to be properly polished. The casting the metal so as that it may be compact and without pores, is a matter of the greatest consequence; he hit upon the manner of doing it by accident. His usual way of casting a speculum metal, was to melt the copper and to add the tin to the melted copper: the mass when cast was seldom free from pores. After having used all his copper in trying experiments to remedy this defect, he recollected that he had some metal which had been reserved, when one of the bells of St. Andrew had been re-cast: he added a little fresh tin to it, and casting a metal with it, it turned out free from pores, and in all respects as fine a metal as he ever saw. Upon considering this circumstance, he proceeded to form a metallic mass in the usual way, by adding tin to melted copper; this mass was porous, it was in the state of the bell-metal he had tried; and upon re-melting it, it became, as the bell-metal

* De Mirab. † Philos. Trans. 1777. p. 296.

‡ Grain tin is worth ten or twelve shillings per hundred more than mine tin, because it is smelted from a pure mineral by a charcoal fire; whereas mine tin is usually corrupted with some portion of mundick, and other minerals, and is always smelted with a bituminous fire, which communicates a harsh, sulphureous, injurious quality to the metal. Pryce, Min. Cornu. p. 137.—Mr. Mudge probably used what is called grain-tin in the shops, or the purest sort, which is usually sold in pieces like icicles.

had done, compact and free from pores. He accounts for this difference by observing, that the heat necessary to melt copper, calcines part of the tin; and the earthy calcined particles of the tin, being mixed in the mass of the metal, render it porous; but the composition of tin and copper, melting with less than half the heat requisite to melt the copper, the tin is not liable to be calcined in the second melting, as in the first. I am rather disposed to think, that the absence of the pores is to be attributed to the more perfect fusion of the metal: for I have observed at Sheffield, that the same weight of melted steel will fill the same mould to a greater or less height, according to the degree of fusion the steel has been in; if it has been in a strong heat, and thin fusion, the bar of cast steel will be an inch in thirty-six shorter than when the fusion has been less perfect. Upon breaking one of the bars, which had been made from steel in an imperfect fusion, its inside was full of blebs; a shorter bar of the same weight and diameter, which had been in a thin fusion, was of a closer texture. Now the mixture of tin and copper melts far easier than copper does, and it is likely, on that account, to be in a thinner fusion when it is cast.

It may deserve to be remarked, and I shall have no other opportunity of doing it, that the melting or casting of steel was introduced at Sheffield, about forty years ago, by one Waller from London; and was afterwards much practised by one Huntsman, from whom steel so prepared, acquired the name of *Huntsman's cast steel*. It was first sold for fourteen-pence, but may now be had for ten-pence a pound; it costs three-pence a pound in being melted, and for drawing ingots of cast steel into bars of the size of razors, they pay only six shillings for a hundred weight, and ten shillings for the same quantity when they make the bars into a size fit for small files, &c. The cast steel will not bear more than a red heat; in a welding heat it runs away under the hammer like sand. Before the art of casting steel was introduced at Sheffield, all the cast steel used in the kingdom was brought from Germany; the business is carried on at Sheffield with greater advantage than at most other places, for their manufactures furnish them with great abundance of broken tools; and these bits of old steel they purchase at a penny a pound, and melt them, and on that account they can afford their cast steel cheaper than where it is made altogether from fresh bars of steel.

CHAP. IV.

OF TINNING COPPER—TIN—PEWTER.

Unhappily for mankind, the fatal accidents attending the use of copper vessels, in the preparation of food and physic, are too common, and too well attested, to require a particular enumeration or proof: scarce a year passes, but we hear of some of them, especially in foreign countries; and many slighter maladies, originating from the same source, daily escape observation, or are referred to other causes, in our own.

In consequence of some representations from the College of Health, the use of copper vessels in the fleets and armies of Sweden was abolished in the year 1754; and tinned iron was ordered to be substituted in their stead*. The Swedish government deserves the greater commendation for this proceeding, as they have great plenty of excellent copper in the mines of that country, but no tin. An intelligent surgeon suggested, in 1757, the probability of the use of copper vessels in the navy, being one of the causes of the sea scurvy, and recommended the having them changed for vessels of iron; he remarked, that of the 200 sail of ships which went to sea from Scarborough, most of them used iron pots for boiling their victuals, and that the symptoms called highly scorbutic, were never seen, except in some few of the larger ships in which copper vessels were used †. Notwithstanding this hint, and the example of Sweden, I do not know that any other European state has prohibited the use of copper vessels for the dressing of food on board their ships; but many of them have shewn a laudable attention to prevent its malignity, by inquiring into the best manner of covering its surface with some metallic substance, less noxious, or less liable to be dissolved than itself. This operation is usually called tinning, because tin is the principal ingredient in the metallic mixture, which is made use of for that purpose; and, indeed, since the year 1755,

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* Mem. de l'Acad. de Prusse, par M. Paul, vol. IV. Dis. Prel. p. 63.

† Medical Observ. by a Society of Phys. in Lond. vol. II. p. 1.

it has been frequently, in this country at least, used alone. In that year, The Society for the Encouragement of Arts, Manufactures and Commerce, thought it an object deserving their attention, to offer a premium for the tinning copper and brass vessels with pure tin, without lead or any other alloy. There were several candidates for the premium; and since that time, the tinning with pure tin, and hammering it upon the copper, has become very general in England. But this mode of tinning does not appear to have been known, or at least it does not appear to have been adopted in other countries; for in the Memoirs of the Royal Academy at Brussels, for the year 1780, M. l'Abbé Marci recommends, as a new practice, the tinning with pure block-tin from England; though, he says, block tin is a compound body, even as it is imported from England; but he thinks it a much safer covering for copper than what is ordinarily used by the braziers; and he gives some directions as to the manner of performing the operation. The Lieutenant General of the Police at Paris, gave it in commission to the College of Pharmacy, in 1781, to make all the experiments which might be necessary for determining—whether pure tin might or might not be used for domestic purposes, without danger to health? The researches which were made, in consequence of this commission, by Messieurs Charland and Bayen with great ability, were published by order of the French government; and they have greatly contributed to lessen the apprehensions relative to the use of tin, which had been generally excited by the experiments of Marggraf, published first in the Berlin Memoirs for 1747. That gentleman, in pursuing an experiment of Henckel, who first discovered arsenic in tin, shewed, that, though there was a sort of tin which being fluxed from an ore of a particular kind, contained no arsenic, the East India tin, which is generally esteemed the purest of all others, contained a great deal of arsenic. M. Bosc d'Antic, in his works, which were published at Paris, 1780, sets aside the authority of Marggraf, Cramer, and Hellot, relative to the existence of arsenic in tin; and is not only of opinion, that the Cornish tin does not conceal any arsenic in its substance, but that its use as kitchen furniture is not dangerous. Messieurs Charland and Bayen found that neither the East India, nor the purest sort of English tin, contained any arsenic; but that the English tin, usually met with in commerce, did contain arsenic; though in so small a proportion that it did not amount, in that species of tin which contained the most of it, to more than one grain in an ounce; that is, it did not constitute more than one five-hundredth and seventy sixth part of the weight of the tin, there being 576 grains in a French ounce. This proportion of arsenic is so wholly inconsiderable, that it is very properly concluded, that the internal use of such small portions of tin, as can mix themselves with our food, from being prepared in tinned vessels, can be in no sensible degree dangerous on account of the arsenic which the tin may contain. But though tin may not be noxious, on account of the arsenic which it holds, it still remains to be decided, whether it may not be poisonous of itself; as lead is universally allowed to be, when taken into the stomach. The large quantities of tin, which are sometimes given in medicine with much safety, and the constant use which our ancestors made of it in plates and dishes, before the introduction of china or other earthen ware, without experiencing any mischief, render all other proof of the innocent nature of pure tin superfluous. And hence it may be proper to add a few observations concerning the purity of tin.

The ores of metallic substances often contain more substances than that particular one from which they receive their denomination. M. Eller, of Berlin, had in his collection an ore, which contained gold and silver, and iron and quicksilver, closely united together in the same mass. Lead ore, it has been remarked, so often contains silver, that it is seldom found without it; it is often also mixed with a sulphureous pyrites, which is a sort of iron ore, and with black jack, which is an ore of zinc; so that lead, and silver, and iron, and zinc, are commonly enough to be met with in the same lump of lead ore. Tin ore, in like manner, though it is sometimes unmixed, is often otherwise; it frequently contains both tin, and iron, and copper. The fire with which tin ore is smelted, is sufficiently strong to smelt the ores of the metals which are mixed with it; and hence the reader may understand, that, without any fraudulent proceeding in the tin smelter, there may be a variety in the purity of tin, which is exposed to sale in the same country; and this variety is still more likely to take place, in specimens of tin from different countries, as from the East Indies, from England, and from Germany. This natural variety in the purity of tin, though sufficiently discernible, is far less than that which is fraudulently introduced. Tin is above five times as dear as lead; and as a mixture consisting of a large portion of tin with a small one of lead, cannot easily be distinguished from a mass of pure tin; the temptation to adulterate tin is great, and the fear of detection small. In Cornwall, the purity of tin is ascertained, before it is exposed to sale, by what is called its coinage: the tin, when smelted from the ore, is poured into quadrangular moulds of stone, containing about 320 pounds weight of metal, which, when hardened, is called a block of tin; each block of tin is coined in the following manner:—"The officers appointed by the Duke of Cornwall assay it, by taking off a piece of one of the under corners of the block, partly by cutting, and partly by breaking; and if well purified, they stamp the face of the block with the impression of the seal of the Duchy, which stamp is a permission for the owner to sell, and at the same time an assurance that the tin so marked has been purposely examined, and found merchantable *." This rude mode of assay, is not wholly improper; for if the tin be mixed with lead, the lead will by its superior weight sink to the bottom, and thus be liable to be discovered, when the bottom corner of the block is examined. But though the seal of the Duchy may be some security to the original purchasers of block tin, it can be none at all to those foreigners who purchase our tin from Holland; for, if we may believe an author of great note—"in Holland every tin founder has English stamps, and whatever his tin be, the inscription, block tin, makes it pass for English †." This foreign adulteration of English tin may be the reason that Musschenbroeck, who was many years professor of natural philosophy at Utrecht, puts the specific gravity of what he calls pure tin equal to 7320, but that of English tin, and he has been followed by Wallerius, equal to 7471 ‡; for it will appear presently, that such sort of tin must have contained near one-tenth of its weight of lead.

* Borlase's Nat Hist. of Cornw. p. 183.

† Newman's Chem. by Lewis, p. 89.

‡ Musschen. Ess. de Phys. 1739. French Trans. Wallerii Min vol. I. p. 154. There is a very good Table of Specific Gravities, published in the second volume of Musschenbroeck's *Introductio ad Philosophiam Naturalem*, 1763, in which the author does more justice to English tin, putting the weight of a cubic foot of the purest sort equal to 7295; avoir. ounces. One specimen of the purest sort of Malacca tin gave 7331, and another 6125 ounces a cubic foot, which is the lightest of all the tins which he examined.

Weight of a cubic foot of English tin, according to different authors.

Cotes, Ferguson, Emerson	7320 oz. avoir.
Boerhaave's Chem. by Shaw	7321
Musschenbroeck & Wallerius	7471
Martin — — —	7550

From the following experiments it may appear probable, that not one of these authors, in estimating the specific gravity of tin, has used the purest sort, but rather a mixture of that with lead, or some other metal.

A block of tin, when it is heated till it is near melting, or after being melted, and before it becomes quite fixed, is so brittle that it may be shattered into a great many long pieces like icicles, by a smart blow of a hammer*: tin in this form is called by our own manufacturers grain tin, by foreigners virgin tin, or tears of tin; and they tell us, that its exportation from Britain is prohibited under pain of death†. The tin which I used in the following experiments, was of this sort, but I first melted it, and let it cool gradually; a circumstance, I suspect, of some consequence in de_ determining the specific gravity not only of tin, but of other metals. I have put down in the following table, the specific gravity of this tin, and of the lead I mixed with it by fusion, and of the several mixtures when quite cold; the water in which they were weighed was 60°.

Weight of a cubic foot of lead, tin, &c.

Lead — —	11270 oz. avoir.
Tin — —	7170
Tin 32 parts, lead	1—7321
Tin 16 — lead	1—7438
Tin 10 — lead	1—7492
Tin 8 — lead	1—7560
Tin 5 — lead	1—7645
Tin 3 — lead	1—7940
Tin 2 — lead	1—8160
Tin 1 — lead	1—8817

* This property is not peculiar to tin; I have seen masses of lead which, under similar circumstances, exhibited similar appearances; and it has been observed, that zinc, when heated till it is just ready to be fused, is brittle.

† Ency. Fran. and Mr. Baumé calls it "étain en roche, à cause que sa forme

Blocks of tin are often melted by the pewterers into small rods; I think the rods are not so pure as the grain tin; at least, I found that a cubic foot of the specimen I examined, weighed 7246 ounces: but even this sort exceeds in purity any of the kinds examined by the authors above mentioned. Chemistry affords certain methods of discovering the quantity of lead with which tin is alloyed, but these methods are often troublesome in the application; an enlarged table, of the kind of which I have here given a specimen, will enable us to judge with sufficient precision of the quantity of lead contained in any mixture of tin and lead, of which we know the specific gravity. Pewterers, however, and other dealers in tin, use not so accurate a method of judging of its purity, but one founded on the same principle; for the specific gravities of bodies being nothing but the weights of equal bulks of them, they cast a bullet of pure tin, and another of the mixture of tin and lead, which they want to examine, in the same mould; and the more the bullet of the mixture exceeds the bullet of pure tin in weight, the more lead they conclude it contains.

Pewter is a mixed metal; it consists of tin united to small portions of other metallic substances, such as lead, zinc, bismuth, and the metallic part, commonly called regulus of antimony. We have three sorts of pewter in common use; they are distinguished by the names of plate—trifle—ley. The plate pewter is used for plates and dishes; the trifle chiefly for pints and quarts; and the ley-metal for wine measures, &c. Our very best sort of pewter is said to consist of 100 parts of tin, and of 17 of regulus of antimony,* though others allow only 10 parts of regulus to 100 of tin†; to this composition the French add a little copper. Crude antimony, which consists of nearly equal portions of sulphur and of a metallic substance, may be taken inwardly with great safety; but the metallic part, or regulus, when separated from the sulphur, is held to be very poisonous. Yet plate pewter may be a very innocent metal, the tin may lessen or annihilate the noxious qualities of the metallic part of the antimony. We have an instance somewhat similar to this in standard silver, the use of which has never

ressemble à des stalactites;" he says also, that its exportation is prohibited, but that he does not see the reason for the prohibition, as it is not more pure than Cornish tin: and in this observation he is right, it is nothing but Cornish tin in a particular form. Chym. par M. Baumé, vol. III. p. 422

* Med. Trans. vol. I. p. 286.

† Pemb. Chem. p. 322.

been esteemed unwholesome, notwithstanding it contains near one-twelfth of its weight of copper. Though standard silver has always been considered as a safe metal, when used for culinary purposes; yet it is not altogether so, the copper it contains is liable to be corroded by saline substances into verdigris. This is frequently seen, when common salt is suffered to stay a few days in silver saltcellars, which have not a gold gilding; and even saline draughts, made with volatile salt and juice of lemons, have been observed to corrode a silver tea-spoon, which had been left a week in the mixture.

The weight of a cubic foot of each of these sorts of pewter is,

Plate	—	—	7248
Trifle	—	—	7359
Ley	—	—	7963

If the plate pewter be composed of tin and regulus of antimony, there is no reason to expect, that a cubic foot of it should be heavier than it appears to be; since regulus of antimony, according to the different ways in which it is made, is heavier or lighter than pure tin. A very fine silver-looking metal is said to be composed of 100 pounds of tin, 8 of regulus of antimony, 1 of bismuth, and 4 of copper. The ley pewter, if we may judge of its composition by comparing its weight with the weights of the mixtures of tin and lead, mentioned in the table, contains not so much as a third, but more than a fifth part of its weight of lead; this quantity of lead is far too much, considering one of the uses to which this sort of pewter is applied; for acid wines will readily corrode the lead of the flagons, in which they are measured, into sugar of lead; this danger is not so great with us, where wine is seldom sold by the measure, as it is in other countries where it is generally sold so, and their wine measures contain, probably, more lead than ours do. Our English pewterers have at all times made a mystery of their art; and their caution was formerly so much encouraged by the legislature, that an act of parliament was passed, rendering it unlawful for any master pewterer to take an apprentice, or to employ a journeyman, who was a foreigner. In the present improved state of chemistry, this caution is useless; since any one tolerably skilled in that science, would be able to discover the quality and quantity of the metallic substances, used in any particular sort of pewter; and it is not only useless now, but one would have thought it must have been always so; whilst tin, the principal ingredient, was found in no part of Europe in so pure a state, nor in so great plenty as in England.

Borlase and Pryce, who have written so minutely on the method of preparing the tin in Cornwall, are both of them silent, as to any operation the tin undergoes subsequent to its coinage; nor do they say any thing of its being mixed with other metallic substances previous to its coinage; but assure us, that the tin, as it flows from the ore, is laded into troughs, each of which contains about three hundred pounds weight of metal, called slabs, blocks, or pieces of tin, in which size and form it is sold in every market in Europe. Foreigners, however, in general assert, that our tin as exported is a mixed metal; and the French Encyclopedists in particular (article Etain) inform us, on the authority of Mr. Rouelle, that the virgin tin is again melted and cast into iron moulds of half a foot in thickness; that the metal is cooled very slowly; that when cold it is divided horizontally into three layers; that the uppermost, being very soft pure tin, is afterwards mixed with copper, in the proportion of 3 pounds of copper to 100 of tin; that the second layer, being of a harsher nature, has 5 pounds of lead added to 100 of the tin; and that the lowest layer is mixed with 9 pounds of lead to an hundred of the tin; the whole is then remelted, and cooled quickly; and this, they say, is the ordinary tin of England: and Geoffroy had formerly given much the same account*. There is, probably, no other foundation for this report, but that pewter has been mistaken for tin, these metals being sometimes called by the same name; and fine pewter being sometimes made from a mixture of 1 part of copper with 20 or 30 parts of tin.

The mixture generally used for the tinning of copper vessels, consists of 3 pounds of lead, and of 5 pounds of pewter; when a finer composition is required, ten parts of lead are mixed with sixteen of tin; or one part of lead with two of tin: but the proportions in which lead and tin are mixed together, even for the same kind of work, are not every where the same; different artists having dif-

* —— fusores aperto furni ostiolo, metallum in formas quasdam ex arena paratas diffluere sinunt, ibique in massas grandiores concrescit. Superior stanneæ massæ pars adeo mollis est et flexilis, ut sola elaborari nequeat sine cupri miscela, trium scilicet librarum super stanni libras centum. Massæ pars media binas tantum cupri libras recipit. Infima vero adeo fragilis est et intractabilis, ut cum hujus metalli centum libris plumbi libras octodecim consociare oporteat. Geoff. Mat. Med. vol. I. p. 282.

ferent customs. Vessels tinned with pure tin, or with the best kind of pewter, which contains no lead, do not stain the fingers when rubbed with them: whilst those which are tinned with composition, into which lead enters as a constituent part, colour the fingers with a blackish tinge.

Zinc was long ago recommended for the tinning of copper vessels, in preference both to the mixture of tin and lead, and to pure tin*: and zinc certainly has the advantage of being harder than tin, and of bearing a greater degree of heat before it will be melted from the surface of the copper; so that on both these accounts it would, when applied on the surface of copper, last longer than tin; just as tin, for the same reasons, lasts longer than a mixture of tin and lead. But whether zinc makes any part of the compound metal for tinning copper, so as to prevent the necessity of repeated tinning, for which a patent was granted some years ago, is what I cannot affirm. Whatever may the excellence of that composition, or of any other composition, which may be invented with respect to its durability, and its not contracting rust; still it ought not to be admitted into general use, till it has been proved, that it is not soluble in vegetable acids, or that its solutions are not noxious†. A method has of late years been introduced at Rouen, of applying a coat of zinc upon hammered iron saucepans. The vessels are first made very bright, so that not a black speck can be seen; they are then rubbed with a solution of sal ammoniac, and afterwards dipped into an iron pot full of melted zinc, and being taken out, the zinc is found to cover the surface of the iron; and if a thicker coat of zinc is wanted, it may be obtained by dipping the vessel a second time. This kind of covering is so hard, that the vessels may be scoured with stand without its being rubbed off‡. Kitchen utensils, which are made of cast iron, are usually tinned to prevent the iron's rusting; and, as great improvements have been lately made in rendering cast iron malleable, it is not unlikely, but that tinned iron vessels may become of general use.

* Mem. de l'Acad. des Scien. à Par. 1742.

† This doubt with respect to zinc is said to have been removed.—M. de la Planche, a physician at Paris, tried the experiment on himself: he took the salts of zinc, formed by the vegetable acids, in a much stronger dose than the aliments prepared in copper vessels, lined with zinc, could have contained, and he felt no dangerous effects from them. Fourcroy's Chem. vol. I. p. 442.

‡ Journ. de Phy. Deccem. 1778.

The common method of tinning consists in making the surface of the copper vessel quite bright, by scraping it, and by washing it with a solution of sal ammoniac; it is then heated, and the tin, or metallic mixture designed for tinning, is melted, and poured into it, and being made to flow quickly over every part of the surface of the vessel, it incorporates with the copper, and, when cold, remains united with it. Rosin or pitch is sometimes used, to prevent the tin from being calcined, and the copper from being scaled, either of which circumstances would hinder the sticking of the tin.

I had the curiosity to estimate the quantity of pure tin, which is used in tinning a definite surface of copper. The vessel was accurately weighed before and after it was tinned, its surface was equal to 254 square inches; its weight, before it was tinned, was 46 ounces, and its weight, after the operation, was barely $46\frac{1}{2}$ ounces; so that half an ounce of tin was spread over 254 square inches, or somewhat less than a grain of tin upon each square inch. How innocent soever pure tin may be, yet the tenuity of the coat of it, by which copper vessels are covered, in the ordinary way of tinning, cannot fail to excite the serious apprehensions of those who consider it; for in the experiment which I have mentioned, the tin was laid on with a thicker coat than in the common way; instead of a grain, I suspect that not a quarter of a grain of tin is spread over a square inch in the common way of tinning. A discovery has been lately made at Paris of a method of giving to copper or iron a coat of any required thickness, by tinning them; the composition used for the tinning is not mentioned; but it is said that a piece of copper, which in the common way of tinning only absorbed 21 grains of tin, absorbed of the new composition 432 grains, or above twenty times as much*. Till this discovery is generally known, our workmen should study to cover the copper with as thick a coat as they are able of pure tin. The danger from the corrosion or solution of the tin by vinegar, juice of lemons, or other vegetable acids, if any at all, cannot it is apprehended, be sensibly felt, except in very irritable habits, or where sour broths, sauces, or syrups, are suffered to stand long in tinned vessels before they are used. And, indeed, a proper attention to keeping the vessels clean, might render the use of copper itself, for the boiling of food, especially of animal food,

* L'Esprit des Journaux, Mai, 1785.

wholly safe. The French may be allowed to excel us in cookery, but we probably excel them in cleanliness; for the melancholy accidents attending the use of copper vessels, are much less frequent in England than in France; and this difference proceeds, I conjecture, from the superior care of the English in keeping their vessels clean, and from the cheapness and purity of the tin we use in tinning copper. We are not certain that the art of tinning copper vessels was known to the Jews, when they came out of Egypt; the vessels used in the temple service were made of copper by divine appointment, and by being constantly kept clean, no inconveniences followed. The wort, from which malt liquor is brewed, is boiled in copper vessels; the distillers and confectioners prepare their spirits and syrups in un-tinned vessels of the same metal, without our suffering any thing in our health from these practices; at least, without our being generally persuaded that we suffer any thing. A new copper vessel, or a copper vessel newly tinned, is more dangerous than after it has been used; because its pores, which the eye cannot distinguish, get filled up with the substances which are boiled in it, and all the sharp edges of the prominent parts become blunted, and are thereby rendered less liable to be abraded.

M. de la Lande, in describing the cabinet at Portici, observes, that the kitchen utensils, which have been dug up at Herculaneum, are almost all of them made of a compound metal like our bronze, and that many of the vessels are covered with silver, but none of them with tin: and hence he concludes, that the useful art of applying tin upon copper, was unknown to the Romans; "cet art utile d'appliquer l'étain sur le cuivre manquoit aux Romains*." By the same mode of arguing, it might be inferred, that whatever is not met with in one house or town, is not to be found in a whole country: yet should a town in England, in which there happened to be plenty of tinned, but no plated or silvered copper, be swallowed up by an earthquake, a future antiquary, employed in digging up its ruins, would make a bad conclusion, if he should thence infer, that the English understood, indeed, at that time, the art of applying a covering of tin, but not one of silver upon copper. If the ingenious author had recollected what is said in the 34th book of Pliny's Natural History, he would have seen reason

* Voyage d' un François en Italie, vol. VII. p. 120.

to believe, that the Romans, at least when Pliny wrote that book, did understand the method of tinning copper which is now in use; for this great naturalist assures us in express terms, that tin, smeared upon copper vessels, rendered the taste more agreeable, and restrained the virulence of copper rust. It is to no purpose to object, that the tin (stannum) of Pliny was a substance different from our tin; for though it should be in some measure granted that it was a mixture of lead and silver, yet the same author tells us, in the same place, that white lead (plumbum album), by which it is universally allowed our tin is meant,* was so incorporated with

* Mr. Good, while he acknowledges that by *plumbum album* was generally meant tin, informs us that by the same term pewter, or a mixture of lead and tin, was also occasionally intended. The passage we refer to is in his note upon Lucretius. VI. 579.

> Denique, et auro res aurum concopulat una,
> Ærique æs PLUMBO fit utei jungatur ab ALBO.
> One cement sole with gold concentrates gold,
> And nought but PEWTER brass with brass unites.

The cement here referred to, says he, is doubtless, the chrysocolla, a mineral sand, found on the shores of the Red Sea, of an elegant green colour, denominated by the natives of modern times tincar, or tincal. The borax, now in use for similar purposes, does not differ essentially from the chrysocolla, when dissolved and crystalised, and is, by some chemists, supposed to be precisely the same.

Pewter is, in the present day, the common solder for copper and brass: it is generally a combination of tin, lead, and regulus of antimony. From the lead employed in the manufacture, and the splendid whiteness of its appearance when too much lowered or adulterated, it is here happily denominated by our poet plumbum album; literally "white lead:" and by this term it is erroneously translated by Guernier. I say, erroneously; for the cerusse, or white lead of modern days, is no solder whatever in metallic preparations. Creech omits the verse entirely, and thus dexterously runs away from the difficulty. De Coutures is wrong in the whole passage: "l'argent," says he, "est allié avec l'or, et l'airain avec le plomb." "Silver unites itself with gold, and brass with lead." Marchetti is quite correct:

> ——con lo stagno il rame
> Si salda al rame.

I must leave it to the chemists to determine what substance was employed formerly, instead of the regulus of antimony; or whether the ancients were acquainted with a metal of this description, and its different powers in different states of combination. Yet, probably, the plumbum album, or copper solder of the Romans, was a mixture of lead and tin alone.

Since writing the above, I have met with an excellent memoir of M. Klaproth, inserted in the Berlin Memoirs de l'Academie Royale des Sciences, Vol. for 1792—1795; in which the author asserts, that the plumbum nigrum of the Romans was lead, and the plumbum album, candidum, or argentarium, tin, or the κασσιτερον of the Greeks. There can be no doubt that this appellation copper by boiling, that the copper could scarcely be distinguished from silver.* Nay, it appears that the Romans not only used pure tin, but the same mixture of tin and lead, which some of our workmen use at this time in tinning vessels. A mixture of equal parts of tin and lead, they called argentarium; a mixture of two parts of lead and one of tin, they call tertiarium; and with equal parts of tertiarium and tin, that is, with two parts of tin and one of lead, they tinned whatever vessels they thought fit. They, moreover, applied silver upon copper, in the same way in which they applied tin upon it;† and they used this silvered copper (I do not call it plated, because copper is plated by a different process) in ornamenting their carriages, and the harness of their horses, as we now use plated copper; on this head Pliny observes, and a rigid philosopher will apply the observation to ourselves, that such was the luxury of the Romans, that it was then simply reckoned a piece of elegance to consume in the ornaments of coaches, and in the

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was generally applied to tin alone; but as this metal, when employed simply, will be found a very indifferent solder for copper, it is obvious, that the plumbum album of our poet, and of the Roman coppersmiths in general, must also have included a compound of tin with lead, or some other metal, as well as pure unmixed tin. M. Klaproth, who has paid much attention to numismatic analysis, has discovered that the coins of Magna Græcia and Sicily consisted of copper, alloyed with from an eighth to a twelfth part of lead, and half as much of tin. The Roman coins he has at times found to have been formed of pure copper; and occasionally with an alloy of one-fourth, or one-sixth, part of zinc, and a small portion of tin. The ancients were only acquainted with zinc in its ore, which is calamine; their brass was denominated aurichalcum, and was a compound of calamine and copper. Zinc, as a semi-metal, was not known till its discovery by Albertus Magnus, in the 13th century. According to Aristotle, the Greeks acquired their knowledge of converting copper into brass, or aurichalcum, from a people who inhabited the borders of the Euxine sea, whom he denominates Mossynæci; and it is from this word M. Klaproth derives the term messing, which is the German appellation for brass.

[*Editor.*

* Stannum illitum æneis vasis, saporem gratiorum reddit, et compescit æruginis virus, mirumque, pondus non auget—from the copper not being sensibly increased (for Pliny here speaks popularly), we may infer, that the covering of tin which the copper received was very slight, and the art alluded to by Pliny in this place, was probably the same with that of tinning now in use—album (scil. plumbum) incoquitur æreis operibus, Galliarum invento, ita ut vix discerni possit ab argento, eaque incoctilia vocant. This description seems to be expressive of the manner of tinning, by putting the copper into melted tin, as is practised in the tinning of iron plates. Plin. Hist. Nat. L. XXXIV. S. XLIII.

† —— deinde et argentum incoquere simili modo cœpere equorum maxime ornamentis, &c. Id. ib.

trappings of horses, metals, which their ancestors could not use in drinking vessels, without being astonished at their own prodigality: we are not yet, however, arrived at the extravagance of Nero and his wife, who shod their favourite horses with gold and silver.

Pliny mentions an experiment as characteristic of tin—that when melted and poured upon paper, it seemed to break the paper by its weight, rather than by its heat; and Aristotle, long before Pliny, had remarked the small degree of heat which was requisite to fuse Celtic (British) tin.* This metal melts with less heat than any other simple metallic substance, except quicksilver; it requiring for its fusion not twice the heat in which water boils; but compositions of tin and lead, which are used in tinning, melt with a still less degree of heat, than what is requisite to melt simple tin: and a mixture composed of 5 parts of lead, 3 of tin, and 8 of bismuth, though solid in the heat of the atmosphere, melts with a less degree of heat, than that in which water boils.

[*Watson's Chemical Essays.*

SECTION I.

Of tinning iron—Of plating, and gilding copper.

Iron is tinned in a different manner from copper. In some foreign countries, particularly in France, Bohemia, and Sweden, the iron plates, which are to be tinned, are put under a heavy hammer which gives, in some works, 76 strokes in a minute: they can in one week, with one hammer, fabricate 4320 plates; the iron is heated in a furnace eight times, and put eight times under the hammer during the operation, and it loses near an eighth part of its weight. Iron and copper are both of them very apt to be scaled by being heated, and they thereby lose greatly of their weight. Twenty-four hundred weight of pure plate copper will not, when manufactured into tea-kettles, pans, &c. give above twenty-three hundred weight. Twenty-one hundred weight of bar iron will give a ton, when split into rods; but taking into consideration all iron and steel wares, from a needle to an anchor, it is estimated that thirty hundred of bar iron will, at an average, yield a ton of wares.†

* De Mirab.

† See an instructive pamphlet, intitled, A Reply to Sir L. O'Brien, by W. Gibbons, 1785.

Thirty hundred weight of cast iron is reduced to twenty, when it is to be made into wire; and twenty-six to twenty-two, when it is to be made into bar iron. Steel suffers much less loss of weight in being hammered, than iron does. Cast steel does not lose above two parts, and bar steel not above four, in one hundred, when drawn into the shape of rasors, files, &c. The iron plates in England are not hammered, but rolled to proper dimensions by being put between two cylinders of cast iron, cased with steel. This method of rolling iron is practised in Norway, when they form the plates with which they cover their houses; but whether it was invented by the English, or borrowed from some other country (as many of our inventions in metallurgy have been, especially from Germany), I have not been able to learn. In the first account which I have seen of its being practised in England, it is said to have been an invention of Major Hanbury at Pontypool; the account was writen in 1697, and many plates had then been rolled*. The milling of lead, however, which is an operation of the same kind, had been practised in the year 1670; for an act of parliament was passed in that year, granting unto Sir Philip Howard and Francis Watson, Esq. the sole use of the manufacture of milled lead for the sheathing of ships. A book was published in 1691, intitled, The New Invention of Milled Lead for sheathing of Ships, &c. It appears from this book, that about twenty ships, belonging to the navy, had been sheathed with lead; but the practice was discontinued, on account of complaints of the officers of the navy, that the rudder irons and bolts under water had been wasted to such a degree, that in so short a space of time, as had never been observed upon any unsheathed and wood-sheathed ships. The persons then interested in sheathing with lead, published a sensible defence; and among other things they remarked, that both the Dutch and the English had ever been in the habit of sheathing the stern-posts and the beards of the rudders with lead or copper; and that the Portuguese and Spaniards did then sheath the whole bodies of their ships, even of their gallions, with lead, and had done it for many years. Copper sheathing has since taken place in the navy; but it is said to be liable to the same objections which were, above a century ago, made to lead sheathing. It is preferable, however, to lead, on account of its lightness. If the fact

* Phil. Trans. Abr. Vol. V.

should be once well established, that ships sheathed with lead or copper will not last so long as those which are unsheathed, or sheathed only with wood, it would be a problem well deserving the consideration of chemists, to inquire into the manner how a metallic covering operates in injuring the construction of the ships, and whether that operation is exerted on the iron bolts, or on the timbers of the ship. When the iron plates have been either hammered or rolled to a proper thickness, they are steeped in an acid liquor, which is produced from the fermentation of barley meal, though any other weak acid would answer the purpose; this steeping, and a subsequent scouring, cleans the surface of the iron from every speck of rust or blackness, the least of which would hinder the tin from sticking to the iron, since no metal will combine itself with any earth, and rust is the earth of iron. After the plates have been made quite bright, they are put into an iron pot filled with melted tin; the surface of the melted tin is kept covered with suet or pitch, or some fat substance, to prevent it from being calcined; the tin presently unites itself to the iron, covering each side of every plate with a thin white coat: the plates are then taken out of the melted tin; and undergoing some further operations, which render them more neat and saleable, but are not essential to the purpose of tinning them, they are packed up in boxes, and are every where to be met with in commerce under the name of tin-plates, though the principal part of their substance is iron; and hence the French have called them *fer blanc*, or white iron: Sir John Pettus says, that they were with us vulgarly called latten; though that word more usually I think denoted brass.

Tin is not, but iron is, liable to contract rust by exposure to air and moisture, and hence the chief use of tinning iron is to hinder it from becoming rusty; and it is a question of some importance, whether iron of a greater thickness than the plates we have been speaking of, might not be advantageously tinned. I desired a workman to break off the end of a pair of pincers, which had been long used in taking the plates out of the melted tin; the iron of the pincers seemed to have been penetrated through it's whole substance by the tin; it was of a white colour, and had preserved it's malleability. It is usual to cover iron stirrups, buckles, and bridle bits, with a coat of tin, by dipping them after they are made, into melted tin; and pins, which are made of copper wire, are whitened, by being boiled for a long time with granulated tin in a lye made of allum and tartar. Would the iron bolts used in ship-building be preserved from rusting by being long boiled in melted tin?—Would it be possible to silver iron plates by substituting melted silver for melted tin? I do not know that this experiment has ever been tried; but an intelligent manufacturer will see many advantages which would attend the success of it.

It is customary, in some places, to alloy the tin, used for tinning iron plates, with about one-seventieth part of its weight of copper: foreigners make a great secret of this practice: I do not know whether any of our manufacturers use copper; some of them I have reason to believe do not. Too much copper renders the plates of a blackish hue; and if there is too little, the tin is too thick upon the plates; but this thickness, though it may render the plates dearer, or the profit of the manufacturer less, will make them last longer. When the tin is heated to too great a pitch, some of the plates have yellowish spots on them; but the coat of tin is thinner and more even, when the tin is of a great, than of a moderate heat; and the yellowness may be taken away, by boiling the plates for two or three minutes in lees of wine; or, where they cannot be had, sour small beer, or other similar liquors, may, probably, be used with the same success. The quantity of tin used in tinning a definite number of plates, each of a definite size, is not the same at different manufactories. In some fabrics in Bohemia, they use fourteen pounds weight of tin for making three hundred plates, each of them being eleven and one-third inches long, by eight and a half broad; according to this account, one pound of tin covers a surface of twenty-eight and one-third square feet: in other, where the tin is laid on thicker, one pound will not cover above twenty-two square feet; the thickness of the tin, even in this case, is small, not much exceeding the one-thousandth part of an inch; though that is near twice the thickness which tin has upon copper in the ordinary way of tinning. I have inquired of our English manufacturers concerning the quantity of tin used by them in covering a definite surface of iron; and from what I could collect, it is very nearly the same with that used in Bohemia, from whence we derived the art of tinning, or twenty-eight square feet to a pound of tin.

There are various tin plate manufactories established of late years in different parts of England and Wales. Saxony and part of Bohemia formerly supplied all the known world with the commodity; but England now exports large quantities of it to Holland, Flanders, France, Spain, Italy, and other places. About the year 1670, Andrew Yarrington, (he deserves a statue for the attempt) undertook, at the expence of some enterprizing persons, a journey into Saxony, in order to discover the art of making tin plates: he succeeded to his utmost wishes; and, on his return, several parcels of tin plates were made, which met the approbation of the tin-men in London and Worcester*. Upon this success, preparations were made for setting up a manufactory, by the same persons who had expended their money in making the discovery; but a patent being obtained by some others, the design was abandoned by the first projectors, and the patentees never made any plates; so that the whole scheme seems to have been given up till the year 1720, when the fabricating of tin plates made one of the many very useful projects (though they were mixed with some which were impracticable) for which that year will ever be memorable. How soon after that year the manufacture of tin plates gained a lasting establishment, and where they were first made, are points on which I am not sufficiently informed; an old Cambridge workman has told me, that he used them at Lynn, in Norfolk, in the year 1730, and that they came from Pontypool. The tin-men, at the first introduction of the English plates, were greatly delighted with them; they had a better colour, and were more pliable than the foreign ones, which were then, and still continue to be hammered; it being impossible to hammer either iron or copper to so uniform a thickness, as these metals are reduced to by being rolled. It is said that a Cornish tin-man flying out of England for a murder in 1243, discovered tin in Saxony, and that before that discovery, there was no tin in Europe, except in England †; a Romish priest, converted to be a Lutheran, carried the art of making tin plates from Bohemia into Saxony, about the year 1620 ‡; and Andrew Yarrington, as we have seen, brought it from Saxony into England about the year 1670; Saxony at that time being the only place in which the plates were made. They are now made not

* England's Improvement by Sea and Land, by Andrew Yarrington, Gent. 1698.

† Heylin's Geog.

‡ Yarrington.

only in England, but in France, Holland, Sweden, &c. though from the cheapness of our tin, and the excellency of some sorts of our iron, the greatest share of the tin plate trade must ever center with ourselves. Our coal is another circumstance which tends to give Great Britain an advantage over some other countries, in such manufactures as require a great consumption of fuel. Wood was scarce in Saxony about a century ago, and it is now still more scarce in France. They are beginning, it is said, in that country, to use coal and coak, or charred pit-coal, called by them *charbon de terre épuré*, and they have granted a patent to an individual for the preparation of it*. Another individual has begun to distil tar from pit-coal, and he gets about five pounds weight of tar from an hundred of coal (which is pretty nearly what I suggested, in 1781, as possible to be obtained from the same quantity, Vol. II. p. 352). The French † expect great advantage from this mode of depurating coal: but we have nothing to apprehend on that score; for the patriotic zeal of the Earl of Dundonald has put us in possession of every advantage which can be expected from a discovery, which he has had the honour of bringing to perfection.

The plating of copper is performed in the following manner: Upon small ingots of copper they bind plates of silver with iron wire, generally allowing one ounce of silver to twelve ounces of copper. The surface of the plate of silver is not quite so large as that of the copper ingot; upon the edges of the copper, which are not covered by the silver, they put a little borax; and exposing the whole to a strong heat, the borax melts, and in melting contributes to melt that part of the silver to which it is contiguous, and to attach it in that melted state to the copper. The ingot, with it's silver plate, is then rolled under steel rollers, moved by a water wheel, till it is of a certain thickness; it is afterwards further

* Acad des Scien. à Paris, 1781; where M. Lavoisier gives an useful memoir on the comparative excellencies of pit-coal, coak, wood, and charcoal, as fuels.—Il suit de ces experiences, que pour produire des effets égaux, il faut employer: charbon de terre 600 livres; charbon de terre charbonné 552; charbon de bois mêlé 960; bois de hêtre 1125; bois de chene 1089.

† Il suffit de dire qu'elle peut fournir à la capitale un nouveau chauffage, devenu nécessaire dans un moment ou l'on est menacé d'une disette de bois; qu'elle peut ouvrir dans le royaume une nouvelle brance de commerce; etablir de nouvelles manufactures; faire valoir des mines, restées jusqu'a présent inutiles.—L'Esprit des Journ. Juillet, 1785.

rolled by hand rollers, to a greater or less extent, according to the use for which it is intended; the thinnest is applied to the lining of drinking horns. One ounce of silver is often rolled out into a surface of about three square feet, and its thickness is about the three thousandth part of an inch; and hence we need not wonder at the silver being soon worn off from the sharp angles of plated copper, when it is rolled to so great an extent. Plated copper has, of late years, become very fashionable for the mouldings of coaches, and for the buckles, rings, &c. of horse harness. It might be used very advantageously in kitchen utensils, by those who dislike the use of tinned copper, and cannot afford to be at the expence of silver saucepans, &c. The silver, instead of being rolled on the copper to so great a thinness as it is in most works, might be left in kitchen furniture considerably thicker, so that an ounce of silver might be spread over one square foot; the silver coating would in this case still be very thin, yet it would last a long time. Fire does not consume silver, and the waste in thickness, which a piece of plate sustains from being in constant use for a century, is not much; as may be collected from comparing the present weight of any piece of college plate, which has been daily used, with the weight it had an hundred years ago.

I do not know whether any attempt has ever been made to plate copper with tin instead of silver; I am aware of some difficulty, which might attend the operation; but yet it might, I think, be performed; and if it could, we might then have copper vessels covered with a coat of tin of any required thickness, which is the great desideratum in the present mode of tinning: but it ought to be remarked, that the thicker the coat of tin the more liable it would be to be melted off the copper by strong fires.

The art of plating copper has not been long practised in England; nor do I know whether it was practised at an early period in any other country; for the Roman method of silvering copper was different, I think, from that now in use. Thomas Bolsover of Sheffield, in the year 1742, was the first person in England who plated copper; it was applied by him to the purposes only of making buttons and snuff-boxes: soon after it was used for various other works: a person of the name of Hoyland, at Sheffield, was the first who made a plated candlestick.

What is commonly called French plate, is not to be confounded with the plated copper of which we have been speaking; for though both these substances consist of copper covered with a thin coat of real silver, yet they are not made in the same way. In making French plate, copper, or more commonly brass, is heated to a certain degree, and silver leaf is applied upon the heated metal, to which it adheres by being rubbed with a proper burnisher. It is evident, that the durability of the plating must depend on the number of leaves which are applied on the same quantity of surface. For ornaments which are not much used, ten leaves may be sufficient; but an hundred will not last long, without betraying the metal they are designed to cover, if they be exposed to much handling, or frequently washed. After the same manner may gold leaf be fixed, either on iron or copper. Gold is applied on silver, by coating a silver rod with gold leaf; and the rod being afterwards drawn into wire, the gold adheres to it; the smallest proportion of gold, allowed by act of parliament, is 100 grains to 5760 grains of silver; and the best double-gilt wire is said to have about twenty grains more of gold to the same quantity of silver*. It has been calculated, that when common gilt wire is flatted, one grain of gold is stretched on the flatted wire to the length of above 401 feet, to a surface of above 100 square inches, and to the thinness of the 492090th part of an inch: and M. de Reaumur says, that a grain of gold may be extended to 2900 feet, and cover a surface of more than 1400 square inches; and that the thickness of the gold, in the thinnest parts of some gilt wire, did not exceed the fourteen millionth part of an inch†. The gold, when thus applied, is thinner than when silver is gilt in the following manner, which is yet reckoned one of the cheapest ways, and is used in making various toys. Gold is dissolved in *aqua regia*; and linen rags being dipped into the solution, they take up some particles of gold; the rags being burned to ashes, and the ashes being rubbed on the silver, the gold adheres to it, and is rendered visible by being well burnished.

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* Lewis Com. Phil. p. 53. † Id. 60.

CHAP. V.

GILDING IN OR MOULU; USE OF QUICKSILVER IN EXTRACTING GOLD AND SILVER FROM EARTHS; EXPERIMENTS OF BOERHAAVE ON QUICKSILVER; SILVERING LOOKING-GLASSES, AND THE TIME WHEN THAT ART WAS DISCOVERED.

There is another method of applying gold on copper or silver, which is much practised; it is called gilding in *Or Moulu*. Quicksilver dissolves gold with great facility: if you spread a gold leaf (not what is called Dutch leaf, which is made of brass) on the palm of your hand, and pour a little quicksilver upon it, you will see the quicksilver absorbing the gold, just as water absorbs into its substance a piece of salt or sugar. Persons who have taken mercurial preparations internally, seldom fail to observe the readiness with which the mercury transudes through their pores, attaching itself to the gold of their watches, rings, sleeve-buttons, or ear-rings, and rendering them of a white colour. A piece of gold, of the thickness even of a guinea, being rubbed with quicksilver, is soon penetrated by it, and thereby made so fragile, that it may be broken between the fingers with ease: and if more quicksilver be added, the mixture will become a kind of paste, of different degrees of consistence according to the quantity of quicksilver which is used. A piece of this paste is spread, by ways well known to the artists, upon the surface of the copper which is to be gilded in or moulu, and the metal is then exposed to a proper degree of heat: quicksilver may be evaporated in a far less degree of heat, than what is required to melt either gold or copper; when therefore the mixture of gold and quicksilver is exposed to the action of fire, the quicksilver is driven off in vapour; and the gold, not being susceptible of evaporation, remains attached to the surface of the copper, and undergoing the operations of burnishing, &c. too minute to be described, becomes gilt. This method of gilding copper, by means of quicksilver and gold, was known to the Romans*. Quicksilver will not unite with iron, yet by an easy operation, iron may be gilded in the same way that copper or silver may. The iron is first to be made bright, and then immersed in a solution of blue vitriol, its surface will thereby become covered with a thin coat of copper, and it will then admit the gilding as if its whole substance was copper.

It is this property which quicksilver has of uniting itself with gold, and it does the same with silver, which has rendered it of such great use to the Spaniards in America. They reduce the earths or stones, containing gold or silver in their metallic states, into a very fine powder; they mix this powder with quicksilver; and the quicksilver, having the quality of uniting itself with every particle of these precious metals, but being incapable of contracting any union with any particle of earth, extracts these metals from the largest portions of earth. The quicksilver, which has absorbed either gold, or silver, or a mixture of both, is separated from the substance it has absorbed by evaporation; the quicksilver flies off in vapour, and the substance remains in the vessel used in the operation. We have no mines of mercury in England; Sir John Pettus, indeed, says, that a little cinnabar is now and then met with in our copper mines; and Mr. Pennant observes, that quicksilver has been found in its native state on the mountains of Scotland; and I have been shewn a piece of clay, said to have been dug near Berwick, in which there were some mercurial globules: but there are no works at present, where mercury is procured in any part of Great Britain; nor are there many mines of mercury in any part of the world. In the Philosophical Transactions for 1665, we have an account of the quicksilver mines of Idria, a town situated in the country anciently called Forum Julii, now Padria de Friouli, subject to the regency, and included in the circles of the lower Austria, in Germany. These mines have been constantly wrought for above 280 years, and are thought, one year with another, to yield above one hundred tons of quicksilver. In Hungary also, there are mines which yield quicksilver, but not so copiously now as formerly. Alonso Barba men-

* Æs inaurari argento vivo, aut certe hydrargyro, legititum erat. Plin. Hist. Nat. XXXIII. Pliny understood by argentum vivum, native quicksilver, which is found in a fluid state in many mines; and by hydrargyrum he understood quicksilver separated from its ore by fire; they are the same substance.

tions some quicksilver mines in America, near Potosi*, which, he says, God Almighty provided to supply the loss of this mineral, which is very considerable in extracting the silver from the earths and stones with which it is mixed: but the mines of Almaden in Spain are the richest, and probably have been wrought for the longest time of any in the world. Pliny speaks of the cinnabar which the Romans, with so much jealousy, annually fetched from Spain, and it is very probable that they had it from Almaden. M. Jussieu informs us †, that in 1717 there remained above 1200 tons of quicksilver in the magazines at Almaden, after a great deal had been sent to Seville in order to be exported to Peru, where the quicksilver, which is lost in extracting the silver, is said to be at least equal in weight to the silver which is extracted. From 1574, when they began to register the quicksilver, which came to Potosi upon the king of Spain's account, to the year 1640, there had been received, according to Alonso Barba, 204,600 quintals, besides a vast quantity irregularly brought in upon other accounts. This application of quicksilver to the extraction of gold and silver from the earths in which they are found, has rendered the consumption of it far more considerable since the discovery of the American mines, than it was amongst the ancients. Hoffman forms a calculation, and concludes, that fifty times as much gold as quicksilver was annually extracted from the bowels of the earth: Cramer ‡ admits the truth of this calculation, but insinuates a suspicion worth attending to—that mercury may often exist in minerals, and yet not be discovered by miners; since in the open fires in which minerals, whose properties are not known, are usually examined, the mercury would fly off in fume. Earths or minerals of any kind, containing mercury, are most accurately assayed by distilling them with iron filings; but whether a mineral contains mercury or not, may be easily discovered, by strewing it when powdered, on a plate of hot iron, or on a hot brick covered with iron filings, and inverting over it a glass of any kind; the mercury, if the mineral contains any, will ascend, and attach itself in small globules to the side of the glass. Mercury is divided, by the writers of systems of mineralogy, into native mercury, and mercury mineralized by sulphur: native mercury is found in its

* Treatise on Metals, &c. by Alonso Barba. Eng. Trans. p. 112.

† Hist. de l'Acad. des Scien. 1719. ‡ Ars Docim. Cram. Vol. I. p. 131.

running state, and quite pure, as it is said (though this may be doubted, from the facility with which mercury dissolves gold, and silver, and other metals), in the mines of Idria, Almaden, &c.; it is more frequently, however, imbedded in calcareous earths, or clays of different colours, from which it may be separated either by trituration and lotion, the smaller globules coalescing by mutual contact into larger; or by distillation. The running native mercury, which requires no process for its extraction is more esteemed, and thought to have some peculiar properties which do not belong to that obtained by simple distillation, though they both come under the denomination of virgin mercury. Mercury mineralised by sulphur, is called cinnabar, which some say is an African word denoting the blood of a dragon *. Cinnabar is the most common ore of mercury; it is found in an earthy form resembling red ochre, sometimes in an indurated state, and, though generally red, it hath been observed of a yellowish or blackish cast; it is mostly opaque, but some pieces are as transparent as a ruby. This ore consists of mercury and sulphur combined together in different proportions; some cinnabars yielding as far as seven, others not three parts in eight of their weight of mercury. Sulphur and mercury, being both volatile in a small degree of heat, would rise together in distillation, unless some substance, such as quicklime or iron filings, was added to the cinnabar, which by its superior affinity, unites itself with and detains the sulphur: whilst the mercury, not being able to support the heat, is elevated in vapour, and condensed in various ways in different works. It sometimes happens, that the coarser cinnabarine ores are so much mixed with calcareous earth, that they require no addition in order to effect the separation of mercury from sulphur; this is the case in the mines of Almaden. The finer kinds of cinnabar, bearing a much higher price than mercury itself, are never wrought for mercury, but either used in medicine, or, when levigated, under the name of vermilion, in painting; and often by the women as a substitute for carmine, which is prepared from cochineal. Native cinnabars are often mixed with small portions of arsenical, vitriolic, or earthy substances, whence they become of uncertain or dangerous efficacy in medicine; for this reason Geoffroy recommends the use of factitious cinnabar; and the native, though formerly in great repute, has been left out of modern dispensatories. The finest cinnabar we know of is brought from Japan, though there

* Valmont de Bomare.

is great reason to believe that the Dutch impose upon the world a home manufacture, under the name of Japan cinnabar: the trade for gold, copper, and cinnabar, to Japan is exceedingly lucrative, and I believe wholly, as to Europe, in the hands of the Dutch.

Those who are acquainted with the difficulty of making chemical experiments, will admire the great patience and industry with which Boerhaave investigated the nature of mercury. He was induced to undertake this task, from a desire of verifying or refuting the doctrines of the alchemists. These adepts had taught, that mercury was the matter of which all metals consisted; and that if it could be cleansed from some original impurities, with which, even in its virgin state, they held it to be polluted, it would then become fit nutriment for the seed of every metallic substance; for, according to them, every metal sprung from its peculiar seed, which, when it met with its proper *pabulum*, in a proper *matrix*, attended with a due fostering heat, by a vivifying principle multiplied itself, and received an augmentation of parts, in a manner similar to that by which plants and animals are dilated in their dimensions. The investigation of nature is infinite; every age adds somewhat to the common stock, which renders the labours of preceding ages wholly useless. We no longer trouble ourselves with the works of the alchemists which remain, nor do we regret such of them as have been devoured by time, or were burned by the order of Diocletian; nay, even the Herculean labours of Boerhaave are become less interesting to us, and probably never would have been undertaken by him, had he been aware, that mercury would, in a proper degree of cold, become, like other metals, solid and malleable. In the Transactions of our Royal Society, for the year 1733, we meet with Boerhaave's first dissertation upon mercury: his first experiments respect the change which the purest mercury undergoes from continual agitation; he included two ounces, which had been distilled above sixty times, in a clean bottle, and fastening the bottle to the hammer of a fulling mill which was almost constantly going, found in about eight months time above one eighth of the fluid, splendid, insipid mercury, changed into a black powder, of an acrid brassy taste. He next digested mercury in a gentle heat, (180° of Fahrenheit's thermometer), and found it, in a few months, changed into a powder, similar to what had been produced by agitation: both these powders in a greater degree of heat were revivified, or became running mercury again. He then inquired into the change which repeated distillation could produce; after each operation he found a red acrid powder remaining in the retort; and he observes, that this powder was as copiously separated, after the mercury had been above 500 times distilled, as at first; and thence reasonably concludes, that it ought rather to be attributed to a change of the mercury itself, than to any impurity contained in it. This powder, like the preceding, by a superior degree of heat became running mercury; except about a seventy-second part, which, though fixed in a strong fire, and vitrifiable with borax, could not support the action of lead, but vanished entirely, leaving no signs of any metallic substance upon the cupel; this shews the little probability of converting mercury into gold or silver by the action of a violent fire. In the following year he presented a memoir to the Royal Academy of Sciences, at Paris, upon the same subject. We there learn, that mercury, kept in digestion for fifteen years, with a constant heat of 100°, was not fixed, nor any how changed, except that a little black powder (which by simple grinding in a mortar became running mercury) was found floating upon its surface. Hence is inferred, the impossibility of mercury's being changed in the bowels of the earth into any other metal, the heat in mines scarcely ever amounting to 100°. Though it might be impossible to change mercury into a metal, yet the philosophers by fire contended, that mercury, united to a particular kind of sulphur, entered into the composition of all metals, and might by art be extracted from them; lead was of all others thought the most likely, and the experiment had been reported to succeed by Van Helmont, and others; but Boerhaave is positive, that nothing can be expected from its combination with salts, and lead, or tin. It was still thought by the alchemists, that mercury could never be freed from its original impurity, but by being joined to some pure body of the same nature with itself: this they thought gold and silver to be. Boerhaave, in order fully to subvert their high pretensions, gave in, to the Royal Society, another paper, in the latter end of the year 1736, containing an account of the unchangeableness both of mercury and gold, how often soever they were distilled together. He repeated the distillation of mercury from gold above 850 times; the mercury was not in any respect changed; its specific gravity was the same as at first, nor had it lost the property of being converted into a red powder by a due degree of heat. These were all the tracts which were published during the life-time of Boerhaave; he died in September, 1738, and left his papers to his two brothers, and after their deaths they fell into the hands of Charles Frederic Kruse, physician to the Empress of Russia; this gentleman hath published a short extract from Boerhaave's Diary, and promises a fuller account of still more laborious operations. We learn from this extract*, that Boerhaave had distilled the same mercury 1009 times, and its specific gravity was to that of water, as 13 $\frac{9}{100}$ to 1; whilst that which had been but once distilled was as 13 $\frac{57}{100}$ to 1; a difference which may easily be attributed to the different temperatures of the air when the experiments were made, or to other accidental circumstances, which the accuracy of Gravesande, with whom he made the experiment, could not provide against.

The mixture of quicksilver with gold, or silver, or lead, or tin, or copper, or any metallic substance with which it is capable of uniting, is called an *amalgam;* and the operation by which the union is effected, is called *amalgamation.* Authors are not agreed as to the derivation of the word amalgam; some think that it is composed of two Greek words, (αμα γαμειν), by which the intimate union, or marriage, as it were, of the two metals is denoted; others are of opinion, that it ought to be written a *malagma*, and that it is derived from a Greek word (μαλασσω) signifying to soften, inasmuch as the metal, be it what it may, is always softened by its union with the mercury. An amalgam, made of four parts of tin and one of quicksilver, in the form of a ball, is used by some under the pretence of purifying water; it cannot, I think, contribute in any manner to that end; but as the ball is always boiled in the water, the seeds of vegetables, or the fish spawn, or the animalcules, &c. with which water is often polluted, may be precipitated by the action of boiling. But there is another purpose to which a mixture of tin and quicksilver is applied with great utility—the silvering of looking-glasses.

Tin may be beat out into leaves not thicker than paper, called foils; on tin-foil, fitly disposed on a flat table, quicksilver is poured, and gently rubbed with a hare's foot; it soon unites itself with the tin, which then becomes very splendid, or, as the workmen say, is quickened: a plate of glass is then cautiously slid

* Novi Commen. Petrop. tom. ix.

upon the tin leaf, in such a manner as to sweep off the redundant quicksilver, which is not incorporated with the tin; leaden weights are then placed on the glass; and in a little time the quicksilvered tin-foil adheres so firmly to the glass, that the weights may be removed without any danger of its falling off. The glass thus silvered is a common looking-glass. About two ounces of quicksilver are sufficient for covering three square feet of glass.

It is generally believed, that the art of making looking-glasses, by applying to their back surface a metallic covering, is a very modern invention. Muratori expressly says, that glass *specula*, such he means as are now in use, are not of any great antiquity.—Seræ autem antiquitati novimus fuisse *specula*, quorum usus nunquam desiit; sed eorum fabricam apud Italos unice forsan Veneti per tempora multa servarunt et adhuc servant: quæ tamen alio translata nunc in aliis quoque regnis floret*.—The authors of the French Encyclopedie† have adopted the same opinion, and quoted a Memoir, printed in the twenty-third volume of the Academy of Inscriptions, &c.—Il est d'autant plus étonnant que les anciens n'aient pas connu l'art de rendre le verre propre à conserver la représentation des objets, en appliquant l'etain derriere les glaces, que les progrés de la découverte du verre furent, chez eux, poussés fort loin.—Mr. Nixon, in speaking of the glass specula of the ancients, says, "before the application of quicksilver, in the construction of these glasses, (which I presume is of no great antiquity), the reflection of images by such specula must have been effected by their being besmeared behind, or tinged through with some dark colour, especially black‡." I have bestowed more time in searching out the age in which the applying a metallic covering to one side of a looking-glass was introduced, than the subject, in the estimation of many, will seem to deserve; and, indeed, more than it deserved in my own estimation: but the *difficiles nugæ*, the *stultus labor ineptiarum*, when once the mind gets entangled with them, cannot be easily abandoned: one feels, moreover, a singular reluctance in giving up an unsuccessful pursuit. The reader would pardon the introduction of this reflection, if he knew how many musty volumes I turned over, before I could meet with any information which could satisfy me, in any degree, on this sub-

* Muratori Antiq. vol. ii. p. 392. † Art. Miroir.

‡ Phil. Trans. 1758. p. 602.

ject; I am not yet quite satisfied; though I take the liberty to say, in opposition to Muratori, and the other respectable authorities which I have quoted, that the applying a metallic covering to looking-glasses is not a modern invention; it is probable it was known in the first century, if not sooner; and it is certain, I apprehend, that it was known in the second.

The Romans, before the time of the younger Pliny, not only used glass, instead of gold and silver, for drinking vessels, but they knew how to glaze their windows with it, and they fixed it in the walls of their rooms to render their apartments more pleasant. Now a piece of flat glass, fixed in the side of a room, is a sort of looking-glass, and if the stucco into which it is fixed be of a dark colour, it will not be a very bad one. And hence I think the Romans could not fail of having a sort of glass specula in use: but this, though admitted, does not come up to the point; the question is, whether they covered the posterior surface of the glass with a metallic plate? It has been observed before, that the Romans knew how to make a paste of gold and quicksilver; and it appears from Pliny also, that they knew how to beat gold into thin leaves, and to apply it in that state both on wood and metal: now there is a passage in Pliny, from whence it may be collected, that the Romans began in his time to apply a coat of metal to glass specula, and that this coat was of gold. The passage occurs in the very place where Pliny professes to finish all he had to observe concerning specula*. An opinion, says he, has lately been entertained, that the application of gold to the back part of a speculum, renders the image better defined. It is hardly possible that any one should be of opinion, that a plate of gold put behind a metallic speculum, could have any effect in improving the reflected image; but supposing Pliny (whose transitions in writing are often abrupt) to have passed from the mention of metallic to that of glass specula, then the propriety of the observation relative to the improved state of the image is very obvious. If we suppose the Romans, in Pliny's age, to have simply applied some black substance to the back surface of the glass, or even to have known how to put tin behind it, yet the observation of the image being rendered more

* Atque ut omnia de speculis peragantur hoc loco—Optima apud majores fuerant Brundusina stanno et ære mixta. Prælata sunt argentea. Primus fecit Praxiteles, magni Pompeii ætate. Nuper credi cœptum certiorem imaginem reddi auro apposito aversis. Hist. Nat. l. xxxiii. s. xlv.

distinct by means of gold, might have been made with more justice than is generally supposed; for Buffon is of opinion, that a looking-glass made with a covering of gold and quicksilver, would reflect more light than one made in the ordinary way with tin and quicksilver *; and hence Pliny's expression, *certiorem imaginem reddi auro apposito aversis*, will be accurately true.

Alexander Aphrodiseus flourished towards the end of the second century; he wrote several works in Greek, and among the rest two books of Problems; one of his problems is this †:

> Δια τι τα ὑελινα κατοπἱρα λαμπεσι αγαν;
>
> Why are glass specula so very resplendent?

The only part of the answer which we are concerned with, is,

> Οτι ενδοθεν αυἱα χρισι κασσιτερῳ.
>
> Because they besmear the inside of them with tin.

The Greek word which I have here rendered besmear, does not clearly point out the manner in which the operation of fixing the tin upon the glass was performed. Pliny uses a Latin word (*illitum*) of exactly the same import as this Greek one, when he speaks of copper vessels being tinned; and as in that operation, tin is melted and spread over the surface of the copper, I see no difficulty in supposing, that the tin may have been, in the time of Alexander Aphrodiseus, melted and spread over the surface of the glass, when previously heated.

Having carried up the invention of covering glass specula with a metallic coating to the second century, we may be the more ready to admit that the Sydonians possessed this art, before Pliny wrote his Natural History: for in that work he not only praises them for their former ingenuity in various glass manufactures, but he adds— and they had invented specula also ‡.—Now there is some reason

* On pourroit trouver le moyen de faire un meilleur étamage, et je crois qu'on parviendroit en employant de l'or et du vifargent.—Hist. Nat. Buffon. Sup. tom. i. p. 451.

† ΑΛΕΞΑΝΔΡΟΥ ΑΦΡΟΔΙΣΕΩΣ ιατρικα απορηματα και φυσικα προϐληματα. Parisiis, 1511.—If there be any doubt concerning the authenticity of these problems, I leave it to be discussed by the critics.

‡ Aliud (vitrum) flatu figuratur, aliud torno teritur, aliud argenti modo cælatur, Sydone quondam iis officinis nobili, siquidem etiam specula excogitaverat.—Hist. Nat. l. xxxvi.

to think, that if the Sydonians had only invented the art of using a flat piece of glass as a speculum, without knowing how to give it a metallic coating, on which its excellency chiefly depends, they would not have merited the mention which Pliny makes of them; for their looking-glasses must have been inferior to the metallic mirrors then in use at Rome. There seems to be but one objection of any consequence to this conclusion:—had the method of giving a metallic covering to plates of glass been known at least to the Romans, (for it might have been known in Asia long before it was known in Italy), it seems probable, that the metallic specula would have fallen into general disuse, much sooner than there is cause to think they did, for it would have been much easier to make a looking-glass, than to polish a metallic mirror; and the image from the glass would have been superior to that from the metal, and on both accounts the mirrors would have become unfashionable.

The first mode of fixing a coat of tin on a looking-glass, I suspect to have beenthat of pouring the melted metal on the glass; and I have some reason, not now to be insisted on, to think, that this mode was not disused in the fourteenth century.—Baptista Porta lived in the fifteenth, and died towards the beginning of the sixteenth century; he gives us a very accurate description* of the manner in which looking-glasses were then silvered; it differs from that now in use only in this, that the tin-foil, when silvered, was taken up and gently drawn upon the glass. J. Maurice Hoffman published his Acta Laboratorii Chemici, in 1719; he there speaks† of a mixture of one part of tin with three of quicksilver, which some time ago, he says, was usually applied to the back surfaces of looking-glasses; although the Venetians did then make looking-glasses by pouring quicksilver upon tin-foil placed on the back surface of the glass.—This mode of silvering the glass was not then invented by the Venetians, as appears from what Baptista Porta had advanced above two hundred years before; though the mode of silvering the tin-foil, when laid upon the glass, was an improvement on that prescribed by Baptista Porta, just as the mode now in use is a great improvement on that practised by the Venetians in the time of Hoffman.

The men who are employed in silvering looking-glasses often

* Mag. Nat. l. iv. c. xviii. † Id. p. 245.

become paralytic, as is the case also with those who work in quicksilver mines; this is not to be wondered at, if we may credit Mr. Boyle, who assures us that mercury has been several times found in the heads of artificers exposed to its fumes*. In the Philosophical Transactions†, there is an account of a man, who having ceased working in quicksilver for six months, had his body still so impregnated with it, that by putting a piece of copper into his mouth, or rubbing it with his hands, it instantly acquired a silver colour. This, though a surprising, is not a fact of a singular nature; it is well known that sulphur, taken inwardly, will blacken silver which is carried in the pocket; and I have somewhere read of a man whose keys were rusted in his pocket; from his having taken, for a long time, large quantities of diluted acid of vitriol. I remember having seen, at Birmingham, a very stout man rendered paralytic in the space of six months, by being employed in fixing an amalgam of gold and quicksilver on copper; he stood before the mouth of a small oven strongly heated; the mercury was converted into vapour, and that vapour was inhaled by him. A kind of chimney, I believe, has of late been opened at the farther side of the oven, into which the mercurial vapour is driven, and the health of the operator is attended to. The person I saw was very sensible of the cause of his disorder, but had not courage to withstand the temptation of high wages, which enabled him to continue in a state of intoxication for three days in the week, instead of, what is the usual practice, two.

[*Bishop Watson.*

CHAP. VI.

METALLIC PLANTS, OR TREES.

Before we quit the very curious and interesting subject of metals, we may observe that many of these substances when minutely dissolved in a menstruum, and treated with a third substance that separates them wholly or in part from the fluid in which they are thus contained, crystallize into the appearances of very beautiful

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* Boyle's Works, vol. iii. p. 330. † 1665.

trees or plants, which are still usually known by the Latin name of *arbors;* as the *arbor Dianæ*, or SILVER-TREE; *arbor Martis*, or IRON-TREE; and *arbor Plumbi*, or LEAD-TREE. These experiments are simple as well as curious and entertaining, and we shall, therefore, subjoin the following as the easiest processes for working them.

Silver Tree.—Arbor Dianæ.

In this experiment the branches and figure of a tree are represented by an amalgam of silver and mercury, which appear to vegetate in a very beautiful manner. To obtain it, one part of silver, dissolved in nitrous acid to saturation, is mixed with twenty parts of clean water, and poured upon two parts of mercury. When left standing quietly, the desired crystallization will take place after some time. A cylindrical glass vessel is best suited for the purpose; and that the process may succeed, it is necessary that the ingredients be in their utmost purity.

Iron Tree.—Arbor Martis.

An apparent vegetation of iron, resembling a natural plant. It is formed by dissolving iron filings in diluted nitric acid, and adding to the solution a quantity of carbonate of potash in a deliquescent state, or what was formerly called oil of tartar per deliquium. The mixture swells considerably, and is no sooner at rest than the branches spring out on the surface of the glass.

Lead Tree.—Arbor Plumbi.

Is a beautiful vegetation of lead. To form it, two drams of acetite of lead (sugar of lead) are dissolved in six ounces of distilled water; the filtered solution is poured into a cylindrical glass, and a thin roll of zinc being hung in it, the whole is left standing at rest. The lead precipitates, adhering to the zinc in metallic leaves, in the form of a tree.

[*Editor.*

THE

GALLERY

OF

NATURE AND ART.

PART II.

A R T.

BOOK IV.

POLITE ARTS, or those connected with LITERATURE.

CHAP. I.

PAPER MAKING.

PAPER is well known to be a thin flexible leaf, usually white, artificially prepared of some vegetable substance, chiefly to write upon with ink.

The word is formed from the Greek ϖαπυρος, *papyrus*, the name of an Egyptian plant, called also βιϐλος, *biblus*, whereon the ancients used to write.

Various are the materials, on which mankind in different ages and countries have contrived to write their sentiments; as on stones, bricks, the leaves of herbs and trees, and their rinds or barks; also on tables of wood, wax, and ivory; to which may be added plates of lead, linen rolls, &c. At length the Egyptian papyrus was invented; then parchment, then cotton paper, and lastly, the common, or linen paper.

In some places and ages they have even written on the skins of fishes; in others, on the intestines of serpents; and in others, on the backs of tortoises. Mabill. de Re Diplom. lib. i. cap. 8. Fabric. Biblioth. Nat. cap. 21, &c. There are few sorts of plants but have at some time been used for paper and books: and hence the several terms, biblos, codex, liber, folium, tabula, tillura, philura, scheda, &c. which express the several parts on which they were written: and though in Europe all these disappeared upon the introduction of the papyrus and parchment, yet in some other countries the use of divers of them obtains to this day. In Ceylon, for instance, they write on the leaves of the talipot. And the Bramin MSS. in the Tulinga language, sent to Oxford from Fort St. George, are written on leaves of the ampana, or palma Malabarica: Hermannus gives an account of a monstrous palm-tree called codda palma, or palma montana Malabarica, which about the thirty-fifth year of its age rises to be sixty or seventy feet high, with plicated leaves nearly round, twenty feet broad, wherewith they commonly cover their houses, and on which they also write, part of one leaf sufficing to make a moderate book. They write between the folds, making the characters through the outer cuticle. Knox. Hist. Ceyl. lib. iii. Le Clerc. Bibl. Univ. tom. xxiii. p. 242. Phil. Trans. No. 226, p. 422, seq. Vide Hort. Ind. Malab. p. 3. Phil. Trans. No. 145, p. 108.

In the Maldive islands, the natives are said to write on the leaves of a tree called macaraquean, which are a fathom and a half long, and about a foot broad. And in divers parts of the East Indies, the leaves of the musa arbor, or plantain-tree, dried in the sun, served for the same use.

Egyptian paper was principally used among the ancients; being made of the papyrus, or biblus, a species of rush, which grew on the banks of the Nile: in making it into paper, they began with lopping off the two extremes of the plant, the head and the root: the remaining part, which was the stem, they cut lengthwise into two nearly equal parts, and from each of these they stripped the scaly pellicles of which it consisted. The innermost of these pellicles were looked on as the best, and that nearest the rind the worst: they were therefore kept apart, and made to constitute two different sorts of paper. As the pellicles were taken off, they extended them on a table, laying them over each other transversely, so that the fibres made right angles: in this state they were glued together by the muddy waters of the Nile; or, when those were not to be had, with paste made of the finest wheat flour, mixed with hot water and a sprinkling of vinegar. The pellicles were next pressed, to get out the water, then dried, and lastly flatted and smoothed, by beating them with a mallet: this was the Egyptian paper, which was sometimes further polished by rubbing it with a glass ball, or the like.

Bark paper was only the inner whitish rind, inclosed between the bark and the wood of several trees, as the maple, plane, beech, and elm, but especially the tilia, or linden-tree, which was that mostly used for this purpose. On this, stripped off, flatted, and dried, the ancients wrote books, several of which are said to be still extant.

Chinese paper is of various kinds; some is made of the rinds or barks of trees, especially the mulberry-tree and elm, but chiefly of the bamboo and cotton-tree. In fact, almost each province has its several paper. The preparations of paper made of the barks of trees may be instanced in that of the bamboo, which is a tree of the cane or reed kind. The second skin of the bark, which is soft and white, is ordinarily made use of for paper: this is beat in fair water to a pulp, which they take up in large moulds, so that some sheets are above twelve feet in length: they are completed by dipping them, sheet by sheet, in alum water, which serves instead of the size among us, and not only hinders the paper from imbibing the ink, but makes it look as if varnished over. The paper is white, soft, and close, without the least roughness, though it cracks more easily than European paper; is very subject to be eaten by the worms, and its thinness makes it liable to be soon worn out.

Cotton paper is a sort of paper which has been in use upwards of six hundred years. In the grand library at Paris are manuscripts on this paper, which appear to be of the tenth century; and from the twelfth century, cotton manuscripts are more frequent than parchment ones. Cotton paper is still made in the East Indies, by beating cotton rags to a pulp.

Linen or European paper appears to have been first introduced among us towards the beginning of the fourteenth century, but by whom this valuable commodity was invented is not known. The method of making paper of linen or hempen rags is as follows.

The first instrument is called the duster, made in the form of a cylinder, four feet in diameter, and five feet in length. It is altogether covered with a wire net, and put in motion by its connexion with some part of the machinery. A convenient quantity of rags before the selection are inclosed in the duster, and the rapidity of its motion separates the dust from them, and forces it through the wire. It is of considerable advantage to use the duster before selection, as it makes that operation less pernicious to the selectors.

The selection is then to be made; and it is found more convenient to have the tables for cutting off the knots and stitching, and for forming them into a proper shape, in the same place with the cutting-table. The surface, both of these and of the cutting-table, is composed of a wire net, which in every part of the operation allows the remaining part and refuse of every kind to escape.

The rags, without any kind of putrefaction, are again carried from the cutting-table back to the duster, and from thence to an engine, where, in general, they are in the space of six hours reduced to the stuff proper for making paper. The hard and soft of the same quality are placed in different lots; but they can be reduced to stuff at the same time, provided the soft is put somewhat later into the engine.

The engine is that part of the mill which performs the whole action of reducing the rags to paste, or, as it may be termed, of trituration. The number of engines depends on the extent of the paper-work, or the force of water, or on the construction of the machinery.

When the stuff is brought to perfection, it is conveyed into a general repository, which supplies the vat from which the sheets of paper are formed. This vat is made of wood; and generally about five feet in diameter, and two and a half in depth. It is kept in temperature by means of a grate introduced by a hole, and surrounded on the inside of the vat with a case of copper. For fuel to this grate, charcoal or wood is used; and frequently, to prevent smoke, the wall of the building comes in contact with one part of the vat, and the fire has no communication with the place where they make the paper.

Every vat is furnished on the upper part with planks closed inwards, and even railed in with wood, to prevent any of the stuff from running over in the operation. Across the vat is a plank which they call the trepan, pierced with holes at one of the extremities, and resting on the planks which surround the vat.

The forms or moulds are composed of wire cloth, and moveable frame. It is with these that they fetch up the stuff from the vat, in order to form the sheets of paper. The sides of the form are made of oak, which is previously steeped in water, and otherwise prepared to prevent warping. The wire cloth is made larger than the sheet of paper, and the excess of it on all sides is covered with a moveable frame. This frame is necessary to retain the stuff of which the paper is made on the cloth; and it must be exactly adapted to the form, otherwise the edges of the paper will be ragged and badly finished. The wire cloth of the form is varied in proportion to the fineness of the paper and the nature of the stuff.

The felts are pieces of woollen cloth spread over every sheet of paper, and upon which the sheets are laid to detach them from the adjoining, to prevent them from adhering together, to imbibe part of the water with which the stuff is charged, and to carry off the whole of it when pressed under the action of the press. The two sides of the felt are differently raised: that of which the hair is longest is applied to the sheets which are laid down; and any alteration of this disposition would produce a change in the texture of the paper. The stuff of which the felts are made should be sufficiently strong, in order that it may be stretched exactly on the sheets without forming into folds; and, at the same time, sufficiently pliant to yield in every direction without injury to the wet paper. As the felts have to resist the reiterated efforts of the press, it appears necessary that the warp be very strong, of combed wool, and well twisted. On the other hand, as they have to imbibe a certain quantity of water, and to return it, it is necessary that the woof be of carded wool, and drawn out into a slack thread. These are the utensils, together with the press, which are used in the apartment where the sheets of paper are formed.

The vat being furnished with a sufficient quantity of stuff and of water, two instruments are employed to mix them; the one of which is a simple pole, and the other a pole armed with a piece of board, rounded and full of holes. This operation is repeated as often as the stuff falls to the bottom. In the principal writing-mills in England, they use for this purpose what is called a hog; which is a machine within the vat, that, by means of a small wheel on the outside is made to turn constantly round, and keep the stuff in perpetual motion. When the stuff and water are properly mixed, it is easy to perceive whether the previous operations have been complete. When the stuff floats close, and in regular flakes, it is a proof that it has been well triturated; and the parts of the rags which have escaped the rollers also appear.

After this operation the workman takes one of the forms, furnished with its frame, by the middle of the short sides; and fixing the frame round the wire cloth with his thumbs, he plunges it obliquely four or five inches into the vat, beginning by the long side, which is nearest to him. After the immersion he raises it to a level: by these movements he fetches up on the form a sufficient quantity of stuff; and as soon as the form is raised, the water escapes through the wire cloth, and the superfluity of the stuff over the sides of the frame. The fibrous parts of the stuff arrange themselves regularly on the wire cloth of the form, not only in proportion as the water escapes, but also as the workman favours this effect by gently shaking the form. Afterwards, having placed the form on a piece of board, the workman takes off the frame or deckle, and glides this form towards the coucher; who, having previously laid his felt, places it with his left hand in an inclined situation, on a plank fixed on the edge of the vat, and full of holes. During this operation the workman applies his frame, and begins a second sheet. The coucher seizes this instant, takes with his left hand the form, now sufficiently dry, and, having laid the sheet of paper upon the felt, returns the form by gliding it along the trepan of the vat.

They proceed in this manner, laying alternately a sheet and a felt, till they have made six quires of paper, which is called a post: and this they do with such swiftness, that, in many sorts of paper, two men make upwards of twenty posts in a day. When the last sheet of the post is covered with the last felt, the workmen about the vat unite together, and submit the whole heap to the action of the press. They begin at first to press it with a middling lever, and afterwards with a lever about fifteen feet in length. After this operation, another person separates the sheets of paper from the felts, laying them in a heap; and several of these heaps collected together are again put under the press.

The stuff which forms a sheet of paper is received, as we have already said, on a form made of wire cloth, which is more or less fine in proportion to the stuff, and surrounded with a wooden frame, and supported in the middle by many cross bars of wood. In consequence of this construction, it is easy to perceive, that the sheet of paper will take and preserve the impressions of all the pieces which compose the form, and of the empty spaces between them.

The traces of the wire cloth are evidently perceived on the side of the sheet which was attached to the form, and on the opposite side they form an assemblage of parallel and rounded risings. As in the paper which is most highly finished the regularity of these impressions is still visible, it is evident that all operations to which it is submitted have chiefly in view to soften these impressions without destroying them. It is of consequence, therefore, to attend to the combination of labour which operates on these impressions. The coucher, in turning the form on the felt, flattens a little the rounded eminences which are in relievo on one of the surfaces, and occasions at the same time the hollow places made by the wire cloth to be partly filled up Meanwhile, the effort which is made in detaching the form produces an infinite number of small hairs on every protuberant part of the sheet.

Under the action of the press, first with the felts and then without them, the perfecting of the grain paper still goes on. The vestiges of the protuberances made by the wires are altogether flattened, and of consequence the hollows opposite to them disappear also; but the traces formed by the interstices of the wire, in consequence of their thickness, appear on both sides, and are rounded by the press.

The risings traced on each side of the paper, and which can be discovered by the eye on that which is most highly finished, form what is called the grain of paper. The different operations ought to soften, but not destroy it; which is effectually done by employing the hammer. This grain appears in the Dutch paper; which is a sufficient proof that though they have brought this part of the art to the greatest perfection, they have not employed hammers, but more simple and ingenious means. The grain of paper is often disfigured by the felts when they are too much used, or when the wool does not cover the thread. In this case, when the paper is submitted to the press, it takes these additional traces of the warp and the woof, and composes a surface extremely irregular.

The paper the grain of which is highly softened, is much fitter for the purposes of writing than that which is smoothed by the hammer: on the other hand, a coarse and unequal grain very much opposes the movements of the pen; as that which is beat renders them very uncertain. The art of making paper, therefore, should consist in preserving, and at the same time in highly softening, the grain: the Dutch have carried this to the highest perfection.

The exchange succeeds the operation last described. It is conducted in a hall contiguous to the vat, supplied with several presses, and with a long table. The workman arranges on this table the paper, newly fabricated, into heaps; each heap containing eight or ten of those last under the press, kept separate by a woollen felt. The press is large enough to receive two of them at once, placed the one at the other's side. When the compression is judged sufficient, the heaps of paper are carried back to the table, and the whole turned sheet by sheet, in such a manner that the surface of every sheet is exposed to a new one; and in this situation they are again brought under the press. It is in conducting these two operations to four or five times, or as often as the nature of the paper requires, that the perfection of the Dutch plan consists. If the stuff is fine, or the paper slender, the exchange is less frequently repeated. In this operation it is necessary to alter the situation of the heaps, with regard to one another, every time they are put under the press; and also, as the heaps are highest toward the middle, to place small pieces of felt at the extremities, in order to bring every part of them under an equal pressure. A single man, with four or five presses, may exchange all the paper produced by two vats, provided the previous pressing at the vats is well performed. The work of the exchange generally lasts about two days on a given quantity of paper.

When the paper has undergone these operations, it is not only softened on the surface, but better felted, and rendered more pliant in the interior parts of the stuff. In short, a great part of the water which it had imbibed in the operation of the vat is dissipated. By the felting of paper, is understood the approximation of the fibres of the stuff, and their adhering more closely together. The paper is felted in proportion as the water escapes, and this effect is produced by the management and reiterated action of the press. Were it not for the gradual operation of the press, the paper would be porous, and composed of filaments adhering closely together. The superiority of the Dutch over the French paper depends almost entirely on this operation.

If the sheets of paper are found to adhere together, it is a proof that the business of the press has been badly conducted. To avoid this inconveniency, it is necessary to bring down the press at first gently, and by degrees with greater force, and to raise it as suddenly as possible. By this means the water, which is impelled to the sides of the heaps, which has not yet escaped, returns to the centre; the sheets are equally dry, and the operation is executed without difficulty.

According to the state of dryness in which the paper is found when it comes from the apartment of the vat, it is either pressed before or after the first exchange. The operation of the press should be reiterated, and managed with great care; otherwise, in the soft state of the paper there is a danger that its grain and transparency are totally destroyed. Another essential principle to the success of the exchange is, that the grain of the paper is originally well raised. For this purpose the wire cloth of the Dutch forms is composed of a rounder wire than that used in France, by which they gain the greatest degree of transparency, and are in no danger of destroying the grain. Besides this, the Dutch take care to proportion the wires, even where the forms are equal, to the thickness of the paper.

Almost every kind of paper is considerably improved by the exchange, and receives a degree of perfection which renders it more agreeable in the use. But it is necessary to observe at the same time, that all papers are not equally susceptible of this melioration; on the contrary, if the stuff is unequal, dry, or weakened by the destruction of the fine parts, it acquires nothing of that lustre and softness, and appearance of velvet, which the exchange gives to stuff properly prepared.

The sheds for drying the paper are in the neighbourhood of the paper-mill, and are furnished with a vast number of cords, on which they hang the sheets both before and after the sizing. The sheds are surrounded with moveable lattices, to admit a quantity of air sufficient for drying the paper. The cords of the shed are stretched as much as possible; and the paper, four or five sheets of it together, is placed on them by means of a wooden instrument resembling a pick-axe. The principal difficulty in drying the paper, consists in gradually admitting the external air, and in preventing the cords from imbibing moisture. With regard to the first of these, the Dutch use very low sheds, and construct their lattices with great exactness. By this means the Dutch paper is dried equally, and is extremely supple before the sizing. They prevent the cords from imbibing the water by covering them with wax.

In using such cords, the moisture does not continue in the line of contact between the paper and the cord, which prevents the sheet from stretching in that particular place by its weight, and from the folds which the moisture in the subsequent operations might occasion. The Dutch also employ cords of considerable thickness, and place fewer of them under the sheets; by which means they diminish the points of contact, and give a freer and more equal circulation to the air.

The size for paper is made of the shreds and parings got from tanners, curriers, and parchment-makers. All the putrefied parts and the lime are carefully separated from them, and they are inclosed in a kind of basket, and let down by a rope and pulley into the cauldron. This is a late invention, and serves two valuable purposes. It makes it easy to draw out the pieces of leather when the size is extracted from them by boiling, or easy to return them into the boiler if the operation is not complete. When the substance is sufficiently extracted, it is allowed to settle for some time; and it is twice filtered before it is put into the vessel into which they dip the paper.

Immediately before the operation, a certain quantity of alum is added to the size. The work-man takes a handful of the sheets, smoothed and rendered as supple as possible, in his left hand, dips them into the vessel, and holds them separate with his right, that they may equally imbibe the size. After holding them above the vessel for a space of time, he seizes on the other side with his right hand, and again dips them into the vessel. When he has finished ten or a dozen of these handfuls, they are submitted to the action of the press. The superfluous size is carried back to the vessel by means of a small pipe. The vessel in which the paper is sized is made of copper, and furnished with a grate, to give the size when necessary a due temperature: and a piece of thin board or felt is placed between every handful as they are laid on the table of the press.

The Dutch are very careful in sizing their paper, to have every sheet in the same handful of equal dryness; because it is found that the dry sheets imbibe the size more slowly than those which retain some degree of moisture. They begin by selecting the padges in the drying-house; and after having made them supple, and having destroyed the adherence between the sheets, they separate them into handfuls in proportion to the dryness, each of them containing that number which they can dip at one time. Besides this precaution, they take care to apply two sheets of brown paper of an equal size to every handful. This brown paper, firm, solid, and already sized, is of use to support the sheets.

As soon as the paper is sized, it is the practice at some paper-mills to carry it immediately to the drying-house, and hang it before it cools, sheet by sheet, on the cords. The paper, unless particular attention is paid to the lattices of the drying-house, is apt to dry too fast, whereby a great part of the size goes off in evaporation: or, if too slow, it falls to the ground. The Dutch drying-houses are the best to prevent these inconveniences: but the exchange after the sizing, which is generally practised in Holland, is the best remedy. They begin this operation on the handfuls of paper, either while they are still hot, or otherwise as they find it convenient. But, after the exchange, they are careful to allow the heaps to be altogether cold before they are submitted to the press. Without this precaution the size would either be wholly squeezed out by the press of the exchange, or the surface of the paper become very irregular. It is of consequence that the paper, still warm from the sizing, grows gradually firm, under the operation of the exchange, in proportion as it cools. By this method it receives that varnish which is afterwards brought to perfection under the press, and in which the excellence of the paper either for writing or drawing chiefly consists. It is in consequence of the exchanging and pressing that the Dutch paper is soft and equal; and that the size penetrates into the body of it, and is extended equally over its surface.

The exchange after the sizing ought to be conducted with the greatest skill and attention, because the grain of the paper then receives impressions which can never be eradicated. When the sized paper is also exchanged, it is possible to hang more sheets together on the cores of the drying house. The paper dries better in this condition, and the size is preserved without any sensible waste, because the sheets of paper mutually prevent the rapid operation of the external air. And as the size has already penetrated into the paper, and is fixed on the surface, the insensible progress of a well-conducted drying-house renders all the good effects more perfect in proportion as it is slowly dried.

If to these considerations is added the damage done to the paper in drying it immediately after the press of the sizing-room, whether it is done in raising the hairs by separating the sheets, or in cracking the surface, it is evident that the trouble of the second exchange is infinitely overpaid by the advantage.

When the paper is sufficiently dry, it is carried to the finishing-room, where it is pressed, selected, examined, folded, made up into quires, and finally into reams. It is here put twice under the press; first, when it is at its full size, and secondly, after it is folded.

The principal labour of this place consists in assorting the paper into different lots, according to its quality and faults; after which it is made up into quires. The person who does this must possess great skill, and be capable of attention, because he acts as a check on those who separated the paper into different lots. He takes the sheets with his right hand, folds them, examines them, lays them over his left arm till he has the number requisite for a quire, brings the sides parallel to one another, and places them in heaps under the table. An expert workman, if proper care has been taken in assorting the lots, will finish in this manner near 6000 quires in a day.

The paper is afterwards collected into reams of 20 quires each, and for the last time put under the press, where it is continued for 10 or 12 hours, or as long as the demand of the paper-mill permits.

In different volumes of the Annales de Chimie we meet with some useful hints relative to the manner of re-manufacturing the paper of old books, or any letters or other paper already used for writing or printing, by MM. Deyeux, Pelletier, Molard, and Verkaven.

I. *Process for re-fabricating printed paper*:—All paper of the same quality should be collected, and separated from such as may have any writing on the pages; the edges of those leaves which may have become yellow, and also the backs of books, being cut off by the instrument used by book-binders. One hundred weight of paper is now to be put, sheet by sheet, into vats, sufficiently capacious to contain it, together with 500 quarts of hot water, but which ought to be filled about one-third: the whole is next stirred by two men for the space of one hour, who are gradually to add as much water as will rise about three inches above the paper; after which it is left to macerate four or five hours; the agitation being occasionally repeated, so as to separate, and at length to form the paper into a kind of paste.

The water is now drawn off by means of pipes, and the pulp conveyed to the mill, where it is to be coarsely ground for one hour; at the expiration of which it is boiled in a cauldron for a similar space, with a sufficient quantity of water to rise four or five inches above it. A short time before the mixture begins to boil, thirteen quarts of caustic ley of potash are to be added to every cwt. of paper. The ley alluded to is prepared by dissolving 100lbs. of potash in 300 quarts of boiling water, to which are to be added 20 lbs. of pulverized quick-lime; and the whole must be briskly agitated, till it become of an uniform consistence, when it is suffered to stand for 12 hours; at the end of this time it must be drawn off, and 75 quarts of boiling water added to the sediment, which being stirred for half an hour, and suffered to stand till it become clear, is to be mixed with the liquor first decanted.

When the paste has boiled in this ley for one hour, the fire is to be extinguished, and the matter suffered to macerate for 12 hours; after which it must be taken out, drained, put into bags, and submitted to the action of a strong press for a similar length of time, to deprive it of all moisture; and, if it appear white, so that the printer's ink be properly extracted, it may be re-manufactured in the usual manner.

II. *Process for the re-fabrication of written paper.*—The paper must be sorted; the yellow edges cut off; and the whole thrown, leaf by leaf, into a tub half full of boiling water, where it is to be agitated as before directed. After it has macerated four hours, the water should be drawn off; a fresh quantity of boiling water added; and the mixture stirred for half an hour: at the expiration of which the paper is again left to dissolve for three hours.

The fluid is now drawn off, and 260 quarts of cold water poured on each cwt. of paper; which being perfectly mixed, 6 lbs. of oil of vitriol are to be gradually added; and the whole strongly agitated for a considerable time, that the paper may thoroughly imbibe the liquor.

This composition is next suffered to macerate for twelve hours; the agitation being occasionally repeated, when the tub is to be filled up with cold water; and the mixture again stirred, to wash the paper, which will now be reduced to a perfect paste. Lastly, after drawing off the water, the pulp must be put into bags, pressed, and ground in a mill; after which it is conveyed to the vat, and worked in the manner practised with linen rags.

In the year 1801, a patent was granted to Mr. Koops, for extracting ink from printed paper, and restoring it to its original state. His process varies little from that above described; the paper being agitated in hot water to extract the size, and reduce it into a pulp: next, the adhesion of the ink is to be removed by a caustic alkali prepared of lime and potash, the quantities of which should be proportioned to those of the paper. After discharging the ink, he directs the pulp to be bleached by means of the oxygenated marine acid, in the proportion of 10 or 12 gallons to 140 lbs. of the material; and when sufficiently whitened, it is re-manufactured in the usual manner. According to the patentee's account, writing paper does not require so large a proportion, if any, of the caustic alkali; but is bleached by confining it in a wooden box, rendered air tight; into which the acid gass is thrown directly from the retort wherein it was produced.

The staining or dyeing of paper is performed by applying, with soft brushes, any of the colours used for tinging other substances, after tempering them properly with size or gum-water. Should the paper not be sufficiently hard to receive the tint without sinking, it will first be necessary to size it, or to employ a larger proportion of gum with the tinging matters. And if the paper is to be of an uniform colour, the latter must be fixed by several thin coatings, each being suffered to dry before another is applied; as the shade will otherwise appear unequal.

As writing paper is often imperfectly sized, in consequence of which the ink is apt to sink, it has been recommended to dissolve a small piece of Roman alum in a glass of pure water. This liquor should be gently spread over the suspected part, with a soft sponge; and, after becoming dry, it may be safely used for writing. Should there be any occasion to write on a printed book; or on paper that is too fresh and moist, it will only be necessary to mix a little gum with the ink. Lastly, in case any book or manuscript be stained with oil, or grease, it has been directed to calcine and pulverize the bones of sheep's trotters; and to apply a small portion of the powder to each side of the stain, which should be placed between two sheets of white paper, and the whole submitted for the space of twelve hours to the action of a press: if the stains do not disappear, the process should be repeated in a warm place.

[*Pantolog. Annales de Chimie.*

CHAP. II.

ORIGIN AND PROGRESS OF WRITING.

SECTION I.

On Hieroglyphic and Picture-writing.

THE desire of communicating ideas, seems to be implanted in every human breast. The two most usual methods of gratifying this desire, are, by sounds addressed to the ear; or, by representations or marks exhibited to the eye; or, in other words, by speech and writing. The first method was rendered more complete by the invention of the second, because it opened a door for communicating information, through the sense of sight as well as that of hearing. Speech may be considered as the substance; and writing, as the shadow which followed it.—These remarks may be illustrated, by stating a few observations concerning the former, which will naturally lead us to the origin of the latter.

One of the greatest advantages which we possess is that of speech, or the power of expressing the conceptions of the mind by articulate sounds. By this faculty we are capable of social intercourse, of enjoying the endearments of friendship and the communications of wisdom. Without language, we should have been solitary in the midst of crowds; excluded from every kind of knowledge but what fell under our immediate notice; and should have been confined to dull and tedious efforts of intimating our desires by signs and gestures: in short, without speech we should scarcely have been rational beings.

Two things are essential to speech; namely, mental conceptions, and sounds articulate. The former are, by far, the most excellent, because they originate in, and appertain to, the mind; whereas the latter are nothing more than the operations of certain organs of the body.

Human voice is produced by two semicircular membranes in the middle of the larynx, which form by their separation the aperture that is termed the glottis. The space between these membranes is not one-tenth of an inch, through which the breath, transmitted from the lungs, passes with considerable velocity: in its passage it is said to give a brisk vibratory motion to the membranous lips of the glottis, which produces the sound called voice, by an operation similar to that which produces sound from the two lips of a hautboy. Galen and others affirm, that both the larynx and the windpipe co-operate in rendering the breath vocal; but later authors do not agree in this opinion. It seems however necessary for the production of voice, that a degree of tenseness should be communicated to the larynx, or at least to the two membranes above mentioned. The voice thus formed is strengthened and mellowed by a reverberation from the palate, and other hollow places of the inside of the mouth and nostrils; and as these are better or worse shaped for this reverberation, the voice is said to be more or less agreeable; and thus the vocal organs of man appear to be, as it were, a species of flute or hautboy, whereof the membranous lips of the glottis are the mouth or reed, and the inside of the throat, palate and nostrils the body; the windpipe being nothing more than the tube or canal which conveys the wind from the lungs to the aperture of this musical instrument *.

The learned and ingenious author of Hermes †, with great strength of argument, shews, that language is founded in compact, and not in nature. His friend, lord Monboddo, with great learning and ingenuity, supports the same opinion, and insists that language is not natural to man; but that it is acquired: and, in the course of his reflections, he adduces the opinions not only of heathen philosophers, poets, and historians, but of christian divines both ancient and modern ‡.

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* See Dr. Beattie on the Theory of Language, p. 246, Lond. 1783, 4to.

† See Hermes, by James Harris, Esq. book iii. p. 314, 327.

‡ This author is of opinion that mankind took the hints of the most useful arts from the brute creation, " for," saith he, " it may be that men first learned to " build from the swallow; from the spider, to weave; and from the birds, to " sing." See Monboddo on the Origin and Progress of Language, books i. and ii. p. 237 and 375.

" The first words of men, like their first ideas," saith Mr. Harris, " had an " immediate reference to sensible objects; and, in aftertimes, when men began " to discover with their intellects, they took those words which they found al- " ready made, and transferred them, by metaphor, to intellectual conceptions." Hermes, p. 269.

Though language, as it is generally considered by grammarians, is a work of art; yet it is evident that vocal sounds are founded in nature; and man would vary those sounds, as impelled by his passions, or urged by his necessities. This exercise of the organs of speech would produce articulate voices, which are peculiar to the human species; vocal sounds, expressive of emotions, being natural to brutes as well as to men. These articulate voices are the first advances towards the formation of a language. The human organs are not, like those of most brutes, confined to particular sounds; but, as men are capable of learning to imitate the several sounds of the brute creation, by that means they acquire a greater variety of sounds than other animals. It is evident that children learn to speak by imitation; they acquire articulate sounds before they comprehend the ideas of which those sounds are significant.

It would be digressing from the subject immediately before us, to say more at present concerning the nature of speech, or audible language; our inquiry being into the origin of visible or written language.

It is obvious that men would soon discover the difficulty of conveying new ideas by sounds alone; for, as Mr. Harris observes *, "the senses never exceed their natural limits; the eye perceives "no sounds, the ear perceives no figures nor colours;" therefore it became necessary to call in the assistance of the eye where the ear alone was insufficient.

It will presently be demonstrated that men, even in their most uncivilized state, display a faculty of imitation †, which enables them to delineate objects and communicate information by rude pictures or representations.—For example, a man who had seen a strange animal, plant, or any other new object, for which he wanted a name, would have been almost mechanically led to illustrate his description by signs; and, if they were not readily comprehended, by a rude delineation in the sand, on the bark of a tree, on a slate, on a bone, or on such materials as first presented themselves: these being handed about, naturally suggested the hint of using this method of conveying intelligence to a distant friend. The exercise of this faculty of imitation, so eminently conspicuous in the human species, will be found, on an accurate investigation, to have been

* Hermes, p. 334.

† Aristotle says, man is the most imitative of all animals.

common to all nations, and perhaps coeval with the first societies or communities of mankind.

It is not probable that the art of picture-writing was brought to any degree of perfection by one man or nation, or even by one generation; but was gradually improved and extended, by the successive hands of individuals, in the societies through which it passed; and that more or less, according to the genius of each people, and their state of civilization; the ruder nations requiring fewer signs or representations, than the more cultivated. At first, each figure meant specifically what it represented. Thus, the figure of the sun expressed or denoted that planet only; a lion or a dog, simply the animals there depicted: but, in process of time, when men acquired more knowledge, and attempted to describe qualities, as well as sensible objects, these delineations were more figuratively explained; then the figure of the sun, besides its original meaning, denoted glory and genial warmth; that of the lion, courage; and that of the dog, fidelity.

A still further improvement in civilization occasioned these delineations to become too voluminous; every new object requiring a new picture, this induced the delineator to abridge the representations, retaining so much of each figure as would express its species. Thus, for example, instead of an accurate representation of a lion, a slight sketch, or more general figure of that animal was substituted; and for a serpent, either a spiral or crooked line like the letter S. Besides this, as there occurred a number of ideas, not to be represented by painting, for these it was necessary to affix arbitrary signs.

This transition was not so great as at first it may appear. In all probability, these signs were introduced slowly, and by degrees, and in such manner, as to be always explained by the context, until generally known and adopted.

That such was the origin and progress of this invention, history, and the journals of travellers, furnish us with a variety of proofs; hieroglyphics, in all their different stages being found in very distant parts of the globe. Of these we shall mention some instances.

Joseph d'Acosta relates, that on the first arrival of the Spanish squadron on the coast of Mexico, expresses were sent to Montezuma, with exact representations of the ships, painted on cloth; in which manner they kept their records, histories, and calendars;

representing things that had bodily shapes, in their proper figures; and those that had none, in arbitrary significant characters.—It is here to be observed, that the Mexicans had long been a civilized people; so that this kind of writing may be considered among them as almost advanced to its most perfect state.

Specimens of Mexican painting have been given by Purchas in sixty-six plates. His work is divided into three parts. The first contains the history of the Mexican empire, under its ten monarchs: the second is a tribute-roll, representing what each conquered town paid into the royal treasury; and the third is a code of their institutions, civil, political, and military *. Another specimen of Mexican painting has been published, in thirty-two plates, by the present archbishop of Toledo. To all these is annexed a full explanation of what the figures were intended to represent; which was obtained by the Spaniards from Indians well acquainted with their own arts. The stile of painting in all these is the same; and they may be justly considered as the most curious monuments of art, brought from the new world †.

* The originals are in the Bodleian library at Oxford, No. 3134, among Mr. Selden's MSS. In the same library, No. 2858, is a book of Mexican hieroglyphics painted upon thick skins, which are covered with a chalky composition, and folded in eleven folds. No. 3135, is a book of Mexican hieroglyphics painted upon similar skins, and folded in ten folds. No. 3207, is a roll containing Mexican hieroglyphics, painted on bark. These paintings are highly worthy the attention of the curious.

† Upon an attentive inspection of the plates above mentioned, we may observe some approach to the plain or simple hieroglyphic, where some principal part or circumstance of the subject, is made to stand for the whole. In the annals published by Purchas, the towns conquered by each monarch are uniformly represented in the same manner, by the rude delineation of a house; but, in order to point out the particular towns, which submitted to their victorious arms, peculiar emblems, sometimes natural objects, and sometimes artificial figures are employed. In the Tribute-roll, published by the archbishop of Toledo, the house, which was properly the picture of the town, is omitted; and the emblem alone is employed to represent it. The Mexicans seem even to have made some advances beyond this, towards the use of the more figurative and fanciful hieroglyphic. In order to describe a monarch who had enlarged his dominions by force of arms, they painted a target, ornamented with darts, and placed it between him and those towns which he had subdued. But it is only in one instance, the notation of numbers, that we discern any attempt to exhibit ideas which had no corporeal form. The Mexicans had invented artificial marks, or signs of delineation, for this purpose: by means of these they computed the years of their king's reigns, as well as the amount of tribute to be paid into the

Charlevoix and several other travellers testify, that this kind of writing, or rather painting, was used by the North American Indians, to record their past events, and to communicate their thoughts to their distant friends. The same kind of characters were found by Strahlenberg upon the rocks in Siberia; and the author of the book, intitled, De vet. Lit. Hun. Scyth. p. 15, mentions certain innkeepers in Hungary, who used hieroglyphic representations, not only to keep their acconnts, but to describe their debtors: so that if one was a soldier, they drew a rude kind of sword; for a smith or carpenter, a hammer or an axe; and, if a carter, a whip. See Histoire Générale des Voyages, Paris, 1754, 4to.

The inhabitants of the Friendly Islands, visited by Captain Cook, in 1779, made a great number of rude figures, to represent their deities. Captain King, who accompanied Captain Cook on his last expedition, brought from one of these islands a piece of cloth, made of bark, on which several rude representations, of men, birds, and ornaments of dress, are depicted. Besides these, there are some delineations, which have the appearance of arbitrary marks.

This cloth is divided into twenty-three compartments; in one of which, near the centre, is a rude figure, larger than the rest, perhaps of some deity, having a bird standing upon each hand: that on the right hand appears to be addressing itself to his ear. This figure is surrounded by three smaller ones, which may be intended as ministers or attendants. The great figure is much in the stile of the Mexican hieroglyphic paintings at Oxford *.

The Egyptians undoubtedly carried this art to its greatest extent; and this is one reason why they have been generally con-

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royal treasury: the figure of a circle represented a unit; and, in small numbers, the computation was made by repeating it. Larger numbers were expressed by peculiar marks; and they had such as denoted all integral numbers, from twenty to eight thousand. The short duration of their empire prevented the Mexicans from advancing farther in that long course, which conducts men, from the labour of delineating real objects, to the simplicity and ease of alphabetic writing.

Their records, notwithstanding some dawn of such ideas as might have led to a more perfect stile, can be considered as nothing more than a species of picture-writing, so far improved, as to mark their superiority over the savage tribes of North America; but still so defective, as to prove that they had not proceeded far beyond the first stage, in that progress which must be completed, before any people can be ranked among polished nations. See Dr. Robertson's Hist. of America, vol. ii. p. 286, and note 54, p. 472—482.

* This cloth is now in my possession.

sidered as the inventors of it; every species of hieroglyphics being recorded in their history.

Hieroglyphic writing, strictly so called, is a simple representation, or mere picture. The abridgments afterwards introduced may be divided into three kinds.

First, when the principal circumstance was made to represent the whole. In order to signify a battle, two hands were delineated; one holding a bow, another a shield: a tumult, or popular insurrection, was expressed by an armed man casting arrows; and a siege, by a scaling-ladder. This may be stiled a picture character; or, as the learned Dr. Warburton, bishop of Gloucester, called it, "a Curiologic Hieroglyphic."

The second, and more artificial method of contraction, was by putting the instrument for the thing itself. Thus, an eye in the clouds, or eminently placed, was designed to represent God's omniscience, as perceiving all things; an eye and sceptre, to represent a king; and a ship and pilot, the Governor of the universe. This may be called the Tropical Hieroglyphic.

The third, and still more artificial method of abridging picture-writing, was, by conversion, or making one thing stand for, or represent another: for example, the Bull Apis stood for Osiris, and not the picture or image of Osiris *. This hath been denominated the Symbolic Hieroglyphic †.

* Some authors have said, that, at first, symbols had some quaint resemblance of, or analogy to, what they represented. Thus, among the Egyptians, a cat stood for the moon; because the Egyptians held, that the pupil of her eye was enlarged at the full moon, and was contracted and diminished during its decrease: a serpent represented the divine nature, on account of its great vigour and spirit, its long age and revirescence.

† That these improvements are not imaginary, is proved from a fragment of Sanchoniatho, preserved by Eusebius, recording, "That Taautus, having imitated Ouranus's art of picture-writing, drew the portraits of the gods Cronus, "Dagon, and the rest; and delineated the sacred characters, which formed the "elements of this kind of writing. For Cronos, particularly, he imagined the "symbols of royalty: four eyes; two before, and two behind, of which two "were closed in slumber; and on his shoulders four wings; two stretched out, "as in the act of flying; and two contracted, as in repose. The first symbol "signified, that Cronus watched though he reposed, and reposed though he "watched. The second symbol of the wings, signified in like manner, that, even "when stationed, he flew about; and, when flying, he yet remained stationed. "To each of the other gods he gave two wings on their shoulders; as the "satellites, of Cronus, in his excursions; who had likewise two wings on his "head, to denote the two principles of the mind, reason and passion."—Here we see that Ouranus practised a kind of picture-writing, which Taautus afterwards improved.

This, and the enormous bulk of the picture volumes, produced a further change in writing; the figures were totally rejected; and, in their room, certain arbitrary marks were instituted, expressing not only visible objects, but mental conceptions. These of necessity must be exceedingly numerous, as is the case in the Chinese writings, in which some authors have asserted, they could still trace out the remains of the picture character.

The learned bishop of Gloucester, Dr. Warburton, in his Divine Legation of Moses *, observes, that all the barbarous nations upon earth, before the invention or introduction of letters, made use of hieroglyphics, or signs, to record their meaning. Such a general concurrence in the method of preserving events, could never be the effect of chance, imitation, or partial purposes; but must needs be esteemed the uniform voice of nature, speaking to the first rude conceptions of mankind; "for," adds the learned prelate, "not only the Chinese of the east, the Mexicans of the west, and the Egyptians of the south, but the Scythians likewise of the north, as well as those intermediate inhabitants of the earth, the Indians, Phenicians, Ethiopians, Etruscans, &c. all used the same way of writing, by picture and hieroglyphic."

We shall dismiss the present section, by endeavouring to impress the minds of our readers with a distinction which will be found to be of great importance in the present inquiry; namely, the difference between imitative characters and symbolic or arbitrary marks.

"Every medium," says Mr. Harris, in his Hermes, p. 331, 332, "through which we exhibit any thing to another's contemplation, is either derived from natural attributes, and then it is an Imitation; or else from accidents quite arbitrary, and then

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Taautus, or Thoth, was the Mercury, on which name and family all the inventions of the various kinds of writing, were very liberally bestowed; that here mentioned as the improvement of Taautus, being the very hieroglyphics above described; and that as before practised by Ouranus, the same with the simple American paintings.

Such then was the ancient Egyptian hieroglyphic; and this the second mode of invention for recording mens actions, not as hitherto thought a device of choice for secresy, but an expedient from necessity for general use. In process of time, their symbols and delineations, turning on the least obvious, or even perhaps on imaginary properties of the animal or thing represented, either to form or construe this, required no small degree of learning and ingenuity.

* Vol. iii. p. 97 to 305.

it is a Symbol." The former may be truly said to derive its origin from that imitative faculty which is so conspicuous in the human species; the latter is founded in necessity or convenience, and becomes significant by compact: the one hath only an immediate reference to sensible objects, which present themselves to the sight; the other to mental conceptions: in short, the former is applicable to hieroglyphic representations; the latter comprehends symbols and marks for sounds, significant of ideas by adoption. Hence we may conclude, that all representations, marks, or characters, which were ever used, by any nation or people, must have been either imitative or symbolic*.

[*Astle.*

SECTION II.

On the Origin of Letters, and the Invention of Alphabets.

The art of drawing ideas into vision, or of exhibiting the conception of the mind by legible characters, may justly be deemed the noblest and most beneficial invention of which human ingenuity can boast: an invention which hath contributed more than all others to the improvement of mankind.

This subject has engaged the attention and perplexed the sagacity, of many able and judicious persons for more than two centuries: some of the most respectable writers have reasoned upon erroneous principles, and, by their works, have ob-

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* Διαφέρει δὲ τὸ ΟΜΟΙΩΜΑ τῦ ΣΥΜΒΟΛΟΥ, καθόσον τὸ μὲν ὁμοίωμα τὴν φύσιν αὐτὴν τῦ πράγματος κατὰ τὸ δυνατὸν ἀπειχονίζεσθαι βύλεται, και ὐκ ἔστιν ἐφ' ἡμῖν αὐτὸ μεταπλάτας.—τὸ δε γε σύμβολον, ὅτοι σημεῖον τὸ ὅλον ἐφ' ἡμῖν εχει, ἅτε και ἐκ μόνης υφίςτάμενον τῆς ἡμετέρας ἐπινοίας·

A representation or resemblance differs from a symbol in as much as the resemblance aims as far as possible, to represent the very nature of the thing, nor is it in our power to shift or vary it: but a symbol or sign, is wholly in our power, as depending singly for its existence on our imagination. Ammon. in lib. de Interp. p. 17, b.

The above is the meaning to be annexed to the word symbol, the principal use of words being to explain things; but the great Lord Bacon truly observes, "That the first distemper of learning is, when men study words and not matter." Shaw's Bacon, vol. i. p. 25. That excellent writer was so strongly impressed with this sentiment, that he makes the same observation in different parts of his works. It is said of Plutarch, that, like a true philosopher, he regarded things, more than words.

scured the true path which might have led to the discovery of letters. Monsieur Fourmont, Bishop Warburton, and Monsieur Gebelin, have endeavoured to shew, that alphabets were originally made up of hieroglyphic characters ; but it will presently appear, that the letters of an alphabet were essentially different from the characteristic marks deduced from hieroglyphics, which last are marks for things and ideas, in the same manner as the ancient and modern characters of the Chinese ; whereas the former are only marks for sounds ; and, though we should allow it an easy transition, from the Egyptian hieroglyphics, to the characteristic marks of the Chinese, which have been demonstrated by Du Halde and others to be perfectly hieroglyphic, yet, it doth not follow, that the invention of an alphabet must naturally succeed these marks. It is true, there is a resemblance between the Mexican picture-writing, the Egyptian hieroglyphics, and the Chinese characters ; but these are foreign to alphabetic letters, and, in reality, do not bear the least relation to them.

The hieroglyphic characters of the Chinese, which are very numerous, are in their nature imitative, and do not combine into words, like arbitrary marks for sounds or letters, which are very few, and are of a symbolic nature. We shall shew, that these authors, whose learning and ingenuity entitle them to the highest respect, and whose writings have furnished many useful hints towards the discovery of alphabetic characters, have not filled up the great chasm between picture-writing and letters, which, though the most difficult, was the most necessary thing for them to have done, before they could attempt to account for the formation of an alphabet. We shall demonstrate, that letters do not derive their powers from their forms, and that originally their forms entirely depended on the fancy or will of those who made them *.—Other writers who have considered this difficult subject, have freely confessed that it was above their comprehension †.

Many learned men have supposed that the alphabet was of divine origin ; and several writers have asserted, that letters were

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* See Mons. Fourmont's Reflections Crit. sur les Hist. des Anc. Peuples, tom. ii. a Paris, 1735.—The Divine Legation of Moses, by the late Dr. Warburton, bishop of Gloucester, vol. iii. p. 121. Mons. Gebelin's Monde Primitif, vol. iii. Paris, 1775.

† Mr. Wise's Essay on the Origin of the Language and Letters of Europe, p. 92, 93. See Universal History, vol. xx. p. 18, n. H.

first communicated to Moses by God himself *; whilst others have contended, that the Decalogue was the first alphabetic writing.

It is highly proper for us to inquire how far these opinions are well founded; for, if they can be supported, there is an end of our pursuit; but if it shall appear that they are warranted neither by reason nor by scripture, we shall be at full liberty to pursue our inquiry: for the satisfaction therefore of those who have adopted those opinions, it is incumbent on us to have recourse to the Holy Scriptures themselves.

The first mention of writing recorded in Scripture, will be found in Exodus xvii. v. 14; "And the Lord said unto Moses, Write † this, for a memorial, in a book; and rehearse it in the ears of Joshua; for I will utterly put out the remembrance of Amalek from under heaven." This command was given immediately after the defeat of the Amalekites near Horeb, and before the arrival of the Israelites at Mount Sinai.

It is observable, that there is not the least hint to induce us to believe that writing was then newly invented; on the contrary, we may conclude, that Moses understood what was meant by writing in a book; otherwise God would have instructed him, as he had done Noah in building the ark ‡; for he would not have been commanded to write in a book, if he had been ignorant of the art of writing; but Moses expressed no difficulty of comprehension, when he received this command. We also find that Moses wrote all the words and all the judgments of the Lord, contained in the twenty-first and the two following chapters of the book of Exodus, before the two written tables of stone were even so much as promised §. The delivery of the tables is not mentioned till the

* Of these opinions were St. Cyril, Clement of Alexandria, Eusebius, and Isidore of Seville, amongst the fathers; and Mr. Bryant, Mr. Costard, Mr. Windar, with many others, among the moderns. See St. Cyril against Julian, book viii.; Clement of Alex. book i. stromat. cap 23; Euseb. Preparat. Evang. lib. ix. cap. 7; Isidore, Origin. lib. i. cap. 3; Mr. Bryant's Ancient Mythology; Mr. Costard's Letter to Mr. Halhed; and Mr. Windar's Essay on Knowledge, p. 2. ch. i. Univ. Hist. vol. iii. p. 212, Note T.

† The Hebrew word כתב, which word is generally used for drawing letters or literal characters; to write; Exod. xxiv. v. 4; and chap. xxxiv. v. 18.—See Parkhurst's Lexicon.

‡ Gen. vi. ver. 14, 15, 16.

§ "And Moses wrote all the words of the Lord, &c." Exod. xxiv. v. 4. "And he took the book of the covenant, and read it in the audience of the people; and they said, All that the Lord hath said we will do, and be obedient." Ibid. v. 7.

eighteenth verse of the thirty-first chapter, after God had made an end of communing with him upon the mount *, though the ten commandments were promulgated immediately after his third descent.

It is observable, that Moses no where mentions that the alphabet was a new thing in his time, much less that he was the inventor of it; on the contrary, he speaks of the art of writing as a thing well known, and in familiar use; for, Exodus xxviii. v. 21, he says, " And the stones shall be with the names of the children of Israel, twelve; according to their names, like the engravings of a signet, every one with his name, shall they be, according to the twelve tribes." And again, v. 36, " And thou shalt make a plate of pure gold, and grave upon it, like the engravings of a signet, Holiness to the Lord." Can language be more expressive? Would it not be too absurd to deny that this sentence must have been in words and letters? But writing was known and practised by the people in general in the time of Moses, as appears from the following texts, Deut. chap. vi. v. 9; chap. xi. v. 20; chap. xvii. v. 18; chap. xxiv. v. 1; chap. xxvii. v. 3, 8. By this last text, the people are commanded to write the law on stones; and it is observable, that some of the above texts, relate to transactions previous to the delivery of the law at Mount Sinai.

If Moses had been the inventor of the alphabet, or received letters from God, which till then had been unknown to the Israelites, it would have been well worthy of his understanding, and very suitable to his character, to have explained to them the nature and use of this invaluable art which God had communicated to him: and may we not naturally suppose, that he would have said, when he directed the workmen to engrave names and sentences on stones and gold †, " And in these engravings you shall use the alphabetic characters which God hath communicated to me, or which I have now invented, and taught you the use of?" But the truth is, he

* The different times of Moses' ascending and descending the Mount are distinguished in the following passages.

First ascent.	*Second ascent.*	*Third ascent.*	*Fourth ascent.*
Exod. xix. v. 3.	Exod. xix. v. 8.	Exod. xix. v. 20.	Exod. xxiv. v. 13.
First descent.	*Second descent.*	*Third descent.*	*Fourth descent.*
Exod. [illegible]. v. 7.	Exod. xix. v. 14.	Exod. xix. v. 25	Exod. xxxii. v. 15.

† See more texts on this subject in Genesis, chap. xxviii. verses 9, 10, 11; and chap. xxxix. v. 34; Deut. chap. xxviii. v. 58 and 61; and chap. xxix.

refers them to a model in familiar use, "like the engravings of a signet;" for the ancient people of the East, engraved names and sentences on their seals in the same manner as is now practised by the great Lama of Tartary, the princes in India, the Emperor of Constantinople, and his subordinate rulers.

In the State Paper office at Whitehall, are a great number of letters from eastern princes to the kings of England, the seals of which have not the likeness of any thing impressed npon them, but are inscribed with moral sentences. This custom is not peculiar alone to the princes who profess the Mahometan religion, but is common all over the East.

A letter from Shah Soleiman, King of Persia, to King Charles the Second, was inclosed in a silken bag, at the mouth of which is a signet or privy seal of wax, impressed with the following sentence, in the Persian language and characters, which are thus translated by Dr. Hyde: "Shah Soleiman is the servant of religion, 1667."

At the bottom of the letter is the great seal, which is stamped or printed on the paper with ink. Within a semicircle, on the upper part of the seal, is this sentence, in Persian: "Have God before thine eyes."

Round the seal, are words in Persian to the following purport: "Praise be to God who hath bestowed upon us his servants the virtue of justice, and hath turned away many evils from the successors of Mahomet and his family."

In the centre are the following words: "This is from Soleiman, and it is in the name of God gracious and merciful, 1668."

The seal of the Emperor of Morocco, stamped or printed on a letter from him to Queen Anne, written in the year 1706, is inscribed with words, in the Arabic language and characters, to the following purport: "The servant of the majesty of the mighty under God. Aly Ben Abdallah El Hamamy whom God establish." In my collection are two seals of the present great Lama of Tartary, inscribed with characters nearly Shanscrit. There are also in the Bodleian and Sloanian libraries, and at the India House, many seals of Asiatic princes and potentates, inscribed with sentences *.

* Pliny, lib. xxii. chap. 1. informs us, that the oriental nations, and the Egyptians, made use of letters only upon their signets. The industrious authors of the Nouveau Traité de Deplomatique (vol. iv. p. 75) say, that the ancient kings of Persia and the Turkish emperors did the like. The learned abbot of

If this art had been a new discovery in his time, he would probably have commemorated it, as well as the other inventions of music, &c.; nor is there any reason to suppose, that God was the immediate revealer of the art; for Moses could never have omitted to have recorded the history of so important a circumstance, as the memory of it would have been one of the strongest barriers against idolatry.

It is incumbent on us to mention, that several respectable prophane authors, attribute the discovery of letters to the gods, or to some divine man. Plato delivers his sentiments very plainly * upon this subject. Επειδη φωνῃ απειρον κατενοησεν ειτε τις Θεος ειτε και Θεος Ανθρωπος. The same author, in his Phædrus, makes the god Theuth or Mercury, the inventor of letters. Diodorus Siculus tells us, that Mercury invented the first characters of writing, and taught men the rudiments of astronomy †; and Cicero, in his Tusc. Quest. lib. i. delivers his opinion upon this subject in the following words: "Quid illa vis, quæ tandem est, quæ investigat occulta? aut qui sonos vocis, qui infiniti videbantur, paucis literarum notis terminavit?—Philosophia vero omnium mater artium, quid est aliud, nisi, ut Plato ait, donum, ut ego inventum Deorum?" The same author, in his Natura Deorum, lib. iii. says, that Hermes or the fifth Mercury, whom the Egyptians called Thoth, first communicated letters to that people. The Gentoos affirm, that letters were communicated to their ancestors by the Supreme Being, whom they call Brahmah ‡.

Although, from these authorities, we may infer that the art of writing is of great antiquity, yet they discover to us that the ancients had very imperfect ideas of its true origin; for Plato says §, "that some, when they could not unravel a difficulty, brought down a god, as in a machine, to cut the knot:" and the

Claraval, Monsieur du Pin, in his Universal Historical Library, p. 21, supports these authorities; and adds, that there is an infinite number of ancient and modern stones thus engraven, which were used for signets. That signets were used by the Hebrews, before they went into Egypt, we learn from Gen. chap. xxxviii. v. 18, where it appears, that Judah gave Thamar his signet, &c.: and it is reasonable to suppose, that this signet was similar to those used by the Israelites, and the other neighbouring nations.

* See vol ii. p. 18; edit. Serran.

† Lib. i. sect. 1.

‡ See Mr. Halhed's preface to the Gentoo Laws.

§ See the Cratylis edit. Fisc. p. 291.

learned bishop of Gloucester observes, that the ancients gave nothing to the gods, of whose original they had any records; but where the memory of the invention was lost, as of seed corn, wine, writing, civil society, &c. the gods seized the property, by that kind of right which gives strays to the lord of the manor *.

The holy scriptures having left this subject open to investigation, and the prophane writers having given us nothing satisfactory upon it, we are at liberty to pursue our inquiry into the origin of letters; but, in order to qualify ourselves for this task, it may be proper to enter into a philosophical contemplation of the nature of letters, and of their powers, which will best enable us to discover the true origin of their invention.

A little reflection will discover, that men, in their rude uncultivated state, had neither leisure, inclination, nor inducement, to cultivate the powers of the mind to a degree sufficient for the formation of an alphabet; but when a people arrived at such a state of civilization, as required them to represent the conceptions of the mind which had no corporeal forms, necessity, the mother of invention, would occasion further exertions of the human faculties, and would urge such a people to find out a more expeditious manner of transacting their business, and of recording their events, than by picture-writing; for the impossibility of conveying a variety of intellectual and metaphysical ideas, and of representing sounds by the emblematic mode of writing, would naturally occur, and therefore the necessity of seeking out some other that would be more comprehensive, would present itself.

These exertions would take place whenever a nation began to improve in arts, manufactures, and commerce; and the more genius such a nation had, the more improvements would be made in the notation of their language, whilst those people who had made less progress in civilization and science, would have a less perfect system of elementary characters; or would for ages advance no further in this art, than the marks or characters of the Chinese †. Hence it results, that the business of princes, and the manufactures

* Bishop Warburton's Divine Legation, vol. iii. p. 62.

† If it should be asked, why the Chinese still adhere to the ancient mode of writing; it may be answered, that their adherence to arbitrary marks, formed, and still continues to form, a part of the civil and religious policy of their country; in the same manner as the prohibition of printing, forms a part of the civil policy within the dominions of the emperor of Constantinople.

and commerce of each country, produced the necessity of devising some expeditious manner of communicating information to their subjects, or commercial correspondents at a distance. Such an improvement was of the greatest use, not only to the sovereign and the statesman, but to the manufacturer and the merchant.

We shall for the present, omit the mention of several modes of writing which were practised by different nations, in the course of their progress towards civilization, because such accounts would more properly come under the history of the writing of each country; particularly under that of Egypt, whose inhabitants displayed every species of writing in the course of their improvements. At present we shall pursue that part of our inquiry which relates to the formation of an alphabet.

Let us then in this place just premise, that arbitrary marks are of different kinds. First, those used by the Chinese; many of which were originally picture-characters. Secondly, those used by the notarii amongst the ancients, and by the present short-hand writers; and thirdly, marks for sounds; such as elementary characters or letters, and musical notes.

The marks of the first and second kind are very numerous, as will appear hereafter: those of the third are very few, as will presently be demonstrated.

It seems obvious, that whilst the picture or hieroglyphic presented itself to the sight, the writer's idea was confined to the figure or object itself; but when the picture was contracted into a mark, the sound annexed to the thing signified by such mark, would become familiar; and when the writer reflected, how small a number of sounds he made use of in speech to express all his ideas, it would occur, that a much fewer number of marks than he had been accustomed to use, would be sufficient for the notation of all the sounds which he could articulate. These considerations would induce him to reflect on the nature and power of sounds; and it would occur, that, sounds being the matter of audible language, marks for them must be the elements of words.

Aristotle justly observes, "that words are the marks of thoughts; and letters, of words." Words are sounds significant, and letters are marks for such sounds *.

The learned author of Hermes above quoted, informs us †,

* See Lord Bacon's Works by Shaw, vol. i. p. 137.

† Book iii. chap. 2. p. 334.

"That to about twenty plain elementary sounds, we owe that variety of articulate voices which have been sufficient to explain the sentiments of so innumerable a multitude, as all the present and past generations of men."

As there are but a small number of marks for sounds, called notes in music, so there are but a small number of distinct articulate sounds in every language. In different languages their number differs; and there are but few sounds in any two languages that are exactly the same; although by the great intercourse between the European nations, the sounds of different languages daily assimilate.

Mr. Sheridan says, that the number of simple sounds in our tongue is twenty-eight *. Dr. Kenrick says, we have eleven distinct species of articulate sounds, which even by contraction, prolongation, and composition, are increased only to the number of sixteen; every syllable or articulate sound in our language, being one of this number †. Bishop Wilkins, and Doctor William Holder, speak of about thirty-two or thirty-three distinct sounds.

It has been said, that among the Greeks and Romans, their written alphabet exactly accorded to the several distinct sounds and modes of articulation in their languages; so that each sound had its distinct mark, by which it was uniformly and invariably represented. Ten simple marks or characters, have been found sufficient for all the purposes of numerical calculations, which extend to infinity.

Seven notes comprise the whole of music: these, by their different arrangements, produce that variety of harmony which we so justly admire. If we would ascend higher than eight notes, we only begin another series of the same distances.—Again, the scale doth not admit of a division into equal parts: this must correspond with the laws of sound: as every piece of music is but these notes varied, it must come to a close in the lowest note, or its octave.

It is evident, that, from the confined nature of the organs, the simple natural sounds to be distinct must be few; and though artifice or affectation may invent a greater variety, they must be deficient in precision as they increase in number. Indeed, there are several sounds proceeding from inanimate objects; as the murmur-

* See Sheridan's Rhetorical Grammar, prefixed to his Dictionary, printed at London in 1780.

† See Dr. Kenrick's Rhetorical Grammar, prefixed to his Dictionary.

ing of a stream, &c. that are not adapted to the human organs of utterance.

It would be digressing too far from our subject, to enter into a discussion concerning the number of sounds that are known to exist, nor is this necessary; for as sounds are few, the marks for them need not be many; but marks for things are very numerous.

It is however requisite for our readers to distinguish between visible and audible language. This distinction is justly made by St. Augustine in the following words: "Signa sunt verba visibilia, verba signa audibilia."

The articulate sounds of vocal or audible language are resolvable into sentences, words, and syllables; and the analysis of language into elementary sounds, seems first to have led to the invention of symbols, or marks, for mental conceptions. This invention must have taken place much about the time that men began to reform the barbarous jargon they first spoke, and form a language; for which purpoŝe, the knowledge of elementary sounds and their powers, was absolutely necessary. The progress in this science, as has been already observed, must have been by degrees: men would begin no doubt, by distinguishing the sound of one word from that of another,—this would not be difficult; then they would resolve words into syllables, which would not be so easy: but it is likely that they stopt there for a long time, perhaps for ages, before they came to the last resolution of syllables into the distinct sounds of which they are composed. This was a very extraordinary work of art, which could only be performed by those who had considered the laws of sounds; and could not be the result of chance, as some speculatists have imagined; for this was in fact, the decomposition of a language into the sounds of which it was composed.

The next step towards the notation of language, would be the delineation of a separate mark or letter to denote or stand for each sound; which marks though few in number, would admit of so great a variety of arrangements and combinations, as would be capable of producing an infinity of articulate sounds, sufficient for the composition of syllables, words, and sentences; and consequently for the notation of language.

That able mathematician Tacquet informs us, that the various combinations of the twenty-four letters (without any repetition) will amount to 620,448,401,733,239,439,360,000. Thus it is evident, that twenty-four letters will admit of an infinity of combinations and arrangements, sufficient to represent not only all the conceptions of the mind, but all words in all languages whatever.

It is easy to conceive the astonishment of the human mind, at the first discovery of the doctrine and powers of combinations, which immediately led to the composition of written language, by the assistance of a small number of marks or letters; though the transferring of ideas by these means from the ear to the eye, was a very extraordinary effort of the human mind; yet if we suppose that the analysis of the sounds of language was already made, it was no more than finding out marks for what was known before: and we have already shewn, that symbols were in general use among mankind, before they knew the use of letters; and therefore the invention of the latter, was nothing more than the transferring the former method of representation, to the elements of sound. If the notation of music had been invented before letters, which might have happened, the discovery would have been just as great as that of letters.

As there are more sounds in some languages than in others, it follows of course that the number of elementary characters or letters, must vary in the alphabets of different languages. The Hebrew, Samaritan, and Syriac alphabets, have twenty-two letters; the Arabic twenty-eight; the Persic, the Egyptian or Coptic, thirty-two; the present Russian forty-one; the Shanscrit fifty; the Cashmirian and Malabaric are still more numerous.

Mr. Sheridan observes, that our alphabet is ill calculated for the notation of the English tongue, as there are many sounds for which we have no letters or marks; and there ought to be nine more characters or letters to make a complete alphabet, in which every simple sound ought to have a mark peculiar to itself. The reason of the deficiency is, that our ancestors adopted the Roman alphabet for the notation of our language, though it was by no means suited to it.

Every alphabet is to be considered as the elements of words, wherever it may be received by compact; for our readers must not forget, that all words, as well as symbols, letters, or elements of words, are significant only by habit or agreement.

As vocal or audible language is resolvable into sentences, words, and syllables; so written or visible language is composed of letters, syllables, words, and sentences.

A letter is an arbitrary mark, made to signify or stand for a particular sound significant by compact; and may be properly termed a mark for a certain known sound.

A determinate or established number of these marks, constitutes the elements or alphabet of written language. The combinations and arrangements of these elements or letters, as settled by consent or compact, compose the written languages of civilized nations.

The first step towards the composition of written language, is to convey an idea of some sound; either by a single mark or character, or by writing two or more of them, which form a syllable: one or more of these syllables make a word; which is a voice articulate, and significant by compact: a sentence is a compound quantity of sounds significant; of which certain parts are themselves also significant: several words make a sentence, and several sentences a memoir or discourse.

Writing then, may be defined by the art of exhibiting to the sight the conceptions of the mind, by means of marks or characters significant by compact of the sounds of language, which enable us to transfer ideas from the eye to the ear, and *vice versa.*

Thus it has been shewn how ideas may become the objects of vision, and be exhibited to the eye in legible characters; and that the notation of language may be performed, by making a sufficient number of marks for sounds, and by arranging and combining them properly.

The elements of all written language are divided into vowels and consonants; the former of which is defined to be a simple articulate sound, uttered by a single impulse of the voice, and forming an articulate sound by itself; whereas a consonant forms no articulate sound of itself, but only assists in forming a sound.

The vowels were probably invented first, but the consonants form the body of language, and are properly termed the bones and sinews thereof.

The consonants are divided into mutes, and liquids, which will seldom join together in the same syllable; nor will any two of the mutes associate in a syllable, either in English or in Latin. There are some exceptions as to the association of mutes.

The first composition of written language, is of letters into syllables; but it is observable, that all letters will not compound with all; the vowels will not only mix with each other, or form diphthongs; but they will compound in syllables with all the consonants so called, because they sound in company with the vowels. But this does not hold of the consonants with respect to one another; for only some of them sound together in syllables, whilst others cannot associate together in that way; the reason of which is, that the configuration of the mouth, and the action of its organs, are so different in the pronunciation of some of them, that they cannot be joined together in the same enunciation, nor without some rest or pause betwixt; so that there must be time to give a different configuration and action to the organs; whereas, when the pronunciation is not so different, the sounds may be so run together, as to incorporate in one syllable; and in this way, five, or even six consonants, may be joined in the same syllable, as in the English word, strength.

The next composition of articulate sounds, is of syllables into words; and the better the composers of such words were acquainted with the nature and harmony of sounds, the more harmonious would be their written language. On the contrary, a deficiency in the knowledge of sounds, is a considerable obstruction to the discovery of what consonants will incorporate with each other; and from this ignorance proceeds that redundancy and superfluity of letters, which is conspicuous in many languages.

It is observable, that many of the consonants, which admit of a junction in the same syllable, do not produce harmonious sounds. In truth, the manliness or effeminacy, the harmony or harshness, of a written language, will, in a great measure, depend on the proper or improper junction of letters in syllables. The proper arrangements and combinations of letters, constitute that branch of science called grammar, which consists of four parts; namely, orthography, prosody, etymology, and syntax.

Grammarians divide language into what they call parts of speech; but they differ as to the number of the parts, of which speech is composed. Mr. Harris clearly shews, that all words whatever, are either substantives, definitives, attributives, or connectives; the substantives may be called nouns; the attributives, verbs; the definitives, articles; and the connectives conjunctions. As to the pronouns, adverbs, prepositions, and interjections, he is of opinion, that they must be found included within the species abovementioned.

[*Astle.*

SECTION III.

Antiquity of Writing, and the Claims of different Nations to the Honour of its Invention.

THE art of writing is of great antiquity, and the written annals of ancient nations are so imperfect or fabulous, that it will be extremely difficult to decide to what nation or people the honour of the invention belongs; for, as Sir Isaac Newton justly observes, "there is the utmost uncertainty in the chronology of ancient kingdoms, arising from the vanity of each in claiming the greatest antiquity, while those pretensions were favoured by their having no exact accounts of time."

It has already been observed, that letters were the produce of a certain degree of civilization among mankind; and therefore it is most probable, that we shall obtain the best information, by having recourse to the history of those nations who appear to have been first civilized.

EGYPTIANS.

As a great number of authors have decided in favour of the Egyptians, who have an undoubted claim to an early civilization, we shall begin our inquiries with that people; and, as they displayed every species of writing in the course of their improvements, we shall pursue the thread of their history, which will reflect considerable light on what has been already advanced.

Dr. Warburton, bishop of Gloucester, affirms, that the Egyptians were the first people who discovered the knowledge of the divine nature; and amongst the first who taught the immortality of the soul *. In another place he gives us an account of the state of their learning and superstitions in the time of Moses. He contends, that Egypt was the parent of all the learning of Greece, and was resorted to by the Grecian legislators, naturalists, and philosophers. The same prelate, with great erudition, and

* Divine Legat. of Moses, vol. i. p. 165; vol. ii. p. 100 to 105; vol. iii. p. 17; ibid. p. 25 to 39. We are indebted to this prelate for great part of what is here said of the Egyptians.

strength of argument, endeavours to prove, that Egypt was probably one of the first civilized countries on the globe.

In order to give the reader a clear idea of the several kinds of Egyptian writing, it will be proper to observe, that this writing was of four kinds. The first, hieroglyphic; the second, symbolic; the third, epistolic; and, the fourth, and last, hierogrammic.

Porphyry *, speaking of Pythagoras, informs us, "That he sojourned with the priests in Egypt, and learnt the wisdom and language of the country, together with their three sorts of letters; the epistolic, the hieroglyphic, and the symbolic; of which, the hieroglyphic expressed the meaning of the writer, by an imitation or picture of the thing intended to be expressed; and the symbolic, by allegorical enigmas." Clemens Alexandrinus is larger and more explicit—"Now those who were instructed in the Egyptian wisdom, learnt, first of all, the method of their several sorts of letters; the first of which is called epistolic; the second, sacerdotal, as being used by the sacred scribes; the last, with which they conclude their instructions, hieroglyphical. Of these different methods, the one is in the plain and common way of writing by the first elements of words, or letters of an alphabet; the other, by symbols. Of the symbolic way of writing, which is of three kinds; the first is, that plain and common one, of imitating the figure of the thing represented; the second is, by tropical marks; and the third, in a contrary way, of allegorizing by enigmas.

Of the first sort, namely, by a plain and direct imitation of the figure, let this stand for an instance:—to signify the sun, they made a circle; the moon, a half circle. The second, or tropical way of writing, is by changing and transferring the object with justness and propriety: this they do sometimes by a simple change, sometimes by a complex multifarious transformation; thus they have engraven on stone and pillars, the praises of their kings, under the cover of theologic fables. Of the third sort, by enigmas, take this example; the oblique course of the stars, occasioned their representing them by the bodies of serpents; but the sun they likened to a scarabæus, because this insect makes a round ball of beast's dung, and rolls it circularly, with its face opposed to that luminary."

These two learned Greeks, though not quite correct in their de-

* De Vita Pythag. cap. xi. p. 15.

finitions of writing, prove, that the several kinds abovementioned were used by the Egyptians. Indeed, they reckon but three kinds of writing, when in fact, there were four. Porphyry names only three sorts, epistolic, hieroglyphic, and symbolic: and this was not much amiss; because the fourth, the hierogrammic or sacerdotal, not differing from the epistolic in its nature, he comprised it under the general term of epistolic.—It is observable, that Porphyry judiciously omits to explain epistolary writing, as supposing it to be well known: but Clement adds to epistolic the hierogrammic, which was alphabetic, but being confined to the use of the priests was not so well known: he with equal judgment explains the nature of these characters.

The Egyptians, as hath been observed, in the most early ages, wrote like all other infant nations, by pictures; of which rude original essays some traces are yet remaining amongst the hieroglyphics of Horapollo, who tells us, that the ancient Egyptians painted a man's two feet in water to signify a fuller; and smoke ascending to denote fire*. But to render this rude invention less incommodious, they soon devised the more artful and expeditious way of putting the principal part for the whole, or by putting one thing of resembling qualities for another. The former was the curiologic hieroglyphic; the latter, the tropical hieroglyphic; which last was a gradual improvement on the first, as appears both from the nature of the thing, and from the records of antiquity †.

These alterations in the manner of delineating hieroglyphic figures, produced and perfected another character, which hath been called the running hand of hieroglyphics, resembling the Chinese writing, which having been first formed by the outlines of each figure ‡, became at length a kind of marks: the natural effects of which were, that the constant use of them, would take off the attention from the symbol, and fix it on the thing signified; by which means the study of symbolic writing would be much abbreviated, because the writer or decypherer, would have then little to do, but

* Lib. i. c. 65; Lib. ii. c. 16.

† Many instances of this kind may be found in Horapollo, lib. i. c. 14 and 40. Plutarch Is. and Osir. Diod. Sic. lib. i.

‡ The inquisitive reader, by comparing Kircher's Account of Egyptian Hieroglyphics with those published by Purchas, will find that the former exactly resemble the Mexican, not only in their use, but, as Purchas (p. 69) and Diodorus Siculus (p. 124) say, in their forms and figures.

to remember the power of the symbolic mark: whereas before, the properties of the thing or animal delineated were to be learnt. This, together with their other marks by institution to design mental conceptions, would reduce the characters to the present state of the Chinese *; and these were properly what the ancients call hierographical. Dr. Robert Huntington, in his account of the Porphyry Pillars tells us, that there are yet some ancient monuments of this kind of writing remaining in Egypt †.

Apuleius ‡ describes the sacred book, or ritual of the Egyptians (as partly written in symbolic, and partly in these hierographic characters of arbitrary institution, resembling the Chinese) in the following manner. "He (the hierophant) drew out certain books from the secret repositories of the sanctuary, written in unknown characters, which contained the words of the sacred formula compendiously expressed, partly by figures of animals, and partly by certain marks or notes intricately knotted, revolving in the manner of a wheel, and crowded together, and curled inward like the tendrils of a vine, so as to hide the meaning from the curiosity of the profane." These hierographic characters are mixed with the symbolic in the ritual of Apuleius, and in the Bembine tables, as likewise on several of the obelisks, where they are found mixed both with the proper hieroglyphic and with the symbolic.

That letters were of great antiquity among the Egyptians, may reasonably be supposed, because we have indubitable proofs of their civilization; but there is strong evidence to induce us to believe they were not the first inventors of an alphabet.—Mr. Jackson §, with great learning endeavours to shew, that letters were not invented or carried into Egypt by Taaut, or Thoth, the first Hermes and son of Misraim, who lived about five hundred years after the deluge: but that they were introduced into that country by the second Hermes, who lived about four hundred years after the former. The second Hermes is by Plato called Theuth, who also styles him Counsellor and Sacred Scribe to King Thamus. Dio-

* These arbitrary marks, or marks by institution, seem to have led the way to what is called Notæ, or Short-hand. The notes of short-hand are marks for words, and the notes of hieroglyphics are marks for things.

† See his Account of the Porphyry Pillars, Philosoph. Transact. No. clxi. p. 624.

‡ Metamorphosis, lib. ii. where he speaks of his initiation into the mysteries of Isis.

§ See Chronological Antiquities, vol. iii. p. 93—95.

dorus relates, that this Egyptian Hermes was the inventor of grammar and music, and that he added many words to the Egyptian language: that he invented letters, rhythm, and harmony of sounds. This was the Hermes so greatly celebrated by the Greek writers, who knew no older Hermes than him.

Mr. Wise * insists, that Moses and Cadmus could not learn the alphabet in Egypt; and that the Egyptians had no alphabet in their time. He adduces several reasons to prove that they had no alphabet till they received what is called the Coptic, which was introduced either in the time of the Ptolomeys, or earlier, under Psammitichus or Amasis: and these letters, which are the oldest alphabetic characters of the Egyptians that can now be produced, are plainly derived from the Greek. It seems to us, that if the Egyptians used letters before the time mentioned by Mr. Wise, they were probably the characters of their neighbours the Phenicians.

Herodotus, the most ancient Greek historian, whose works have reached us †, seems very sincere in his Egyptian history; for he ingenuously owns, that all he relates before the reign of Psammitichus ‡ is uncertain; and that he reports the early transactions of that nation on the credit of the Egyptian priests, on which he did not much depend. Diodorus Siculus is also reported to have been greatly imposed upon by the priests in Egypt.

Manetho, the oldest Egyptian historian, translated out of the Egyptian into the Greek the Sacred Registers of Egypt, which are said, by Syncellus, to have been written in the sacred letters, and to have been laid up by the second Mercury in the Egyptian temples. This work was divided into three parts. The first, contained the history of the gods; the second, that of the demi-gods; the third, the dynasties, which ended in Nectanebus, King of Egypt, who was driven out by Ochus, three hundred and fifty years before Christ. This author seems to have written his dynasties about two hundred and fifty years before the christian æra, and, as

* See his Enquiries concerning the first inhabitants, language, &c. of Europe, p. 104—109.

† He wrote his history of the first year of the eighty-fourth olympiad; three hundred and ten after the foundation of Rome; and four hundred and forty-four before Christ.

‡ He reigned about six hundred and sixty years before the christian æra. Syncellus informs us, that the Greeks had very little commerce with the Egyptians till the reign of this king.

Syncellus tells us *, about ten years after Berosus had written his Chaldean History.—Manetho allows the Egyptian gods to have been mortal men; but his history was very much corrupted by the Greeks, and hath been called in question by several writers, from the account which he himself gave of it.

The objections to Manetho's Chronology are well founded; for his number of three thousand five hundred and fifty years, belongs wholly to the successors of Menes, though he is more modest than many other writers of the Egyptian history.—Eusebius, in his Canon †, omits the first sixteen dynasties of Manetho, and begins their chronology with the seventeenth.—After Cambyses had carried away the Egyptian records, the Egyptian priests, to supply their loss, and to keep up their pretensions to antiquity, began to write new records, wherein they not only unavoidably made great mistakes, but added much of their own invention, especially as to distant times.—Josephus, Plutarch, Porphyry, and Eusebius, speak well of Manetho. The curious fragments transcribed from him by Josephus, before his copies had been corrupted, seem to confirm the good opinion of these authors.

PHENICIANS.

We shall next consider the claim of the Phenicians to the invention of letters as we have the strongest proofs of the early civilization of this people.—Sanconiatho of Berytus, the most ancient, as also the most celebrated Phenician historian, compiled the Phenician history with great exactness, from the monuments and memoirs which he received from Jerobalus, priest of the god Jaco, and from their registers, which, Josephus says ‡, were carefully preserved in the inner parts of the temples; and in them were written the most memorable events, with regard to themselves and others.

Philo of Byblus, a famous grammarian, who lived in the reigns of Vespasian, Titus, Domitian, Trajan, and Adrian, translated Sanconiatho's history, out of the Phenician into the Greek tongue; and reduced it into eight books, but the original and the version are lost.—Eusebius who hath preserved several fragments of this history, gives the following account of it from Porphyry, who was

* Chronograph. p. 18.

† Chron. Græc. p. 89.

‡ See Josephus against Appion, book i.

a Phenician of Tyre, and excellently versed in all ancient learning, He says*, that Sanconiatho of Byrytus related, in his history, the Jewish affairs with great veracity:—that he dedicated his work to King Abibalus† and his history was allowed to be true, both by the king, and by those who were appointed by him to examine it.

This most ancient profane historian expressly relates, that letters were first invented in Phenicia, by Taaut, who lived in that country in the twelfth and thirteenth generations after the creation ‡. "Misor was the son of Hamyn. The son of Misor was Taaut, "who invented the first letters for writing." The Egyptians call him Tooth; the Alexandrians Thoyth, and the Greeks, Hermes, or Mercury.

Sanconiatho is said to have derived his first books, of the Origin of Gods and Men, from writings ascribed to Taaut the first Hermes; he makes Protogonus the first man, and Æon, or life, the first woman; of Protogonus and Æon were begot two children Genus and Genea, who dwelt in Phenicia, and in time of a drought, prayed to the Sun, and worshipped him, as the only God and Lord of heaven. From these two persons Taaut is lineally descended, as we have just mentioned (in note ‡); this author carries the worship of the Sun to the second man of human race. Philo observes, that the Greeks claimed most of Sanconiatho's history of the gods to themselves, to which they added many pleasing fables. Hence it was, saith he, that Hesiod, and the itinerary poets, sung about in their poems, generations of gods and battles of giants and Titans; and men being accustomed from their infancy to hear nothing but these fictions,

* See Eusebius Præparat. Evang. lib. i. c. 9, p. 30, &c.

† King Abibalus began to reign one thousand seventy-three years before Christ; he was the father of Hiram, who was Solomon's ally.

‡ The genealogy of Taaut, as given by Sanconiatho:

1 Protogonus,	5 Hypsuranius, or Memrumus,	9 Agroverus; (Noah),
2 Genus,	6 Agreus,	10 Amyn, (Hamyn, or Ham)
3 Ur, Phos,	7 Chrysor,	11 Misor, or Misraim,
4 Cassius,	8 Technites,	12 Taaut.

This author makes mankind live in Phenicia; and places Hypsuranius at Tyre. The plan of the history is quite different from that of Moses, and seems to be grounded upon a very different tradition relating to the first ages. Some writers have attempted to prove the works of this author spurious; but their arguments are so frivolous that they scarcely deserve an answer. See many curious particulars concerning the author and his writings, in the Univ. Hist. vol. i. preface, p. 10, and p. 23, 181, 187, 189, 303, to 320; vol. vi. p. 55; vol. xviii. p. 12, note D.—And Jackson's Chronol. Antiq. vol. iii. p 5 to 37.

which gained credit from long continuance, it was not easy to dispossess their minds of the belief of them. There is no doubt, but the Greeks received the history of the gods from the Phenicians and Egyptians, and applied them to their own either real or feigned heroes.

In the time of this Taaut or Hermes, Phenicia, and the adjacent country, was governed by Uranus; and, after him, by his son Saturn, or Cronus. He invented letters, saith Sanconiatho, either in the reign of Uranus, or Cronus; and staid in Phenicia, with Cronus, till the thirty-second year of his reign. Cronus, after the death of his father Uranus, made several settlements of his family *, and travelled into other parts; and, when he came to the south country, he gave all Egypt to the god Taautus, that it should be his kingdom.

Sanconiatho began his history with the creation, and ended it with placing Taautus upon the throne of Egypt. He doth not mention the deluge, but he makes two more generations in Cain's line, from Protogonus to Agroverus (or from Adam to Noah) than Moses.

As Sanconiatho has not told us in what reign, whether of Uranus or Chronus, Taaut invented letters, he might have invented them in either reign; "and we cannot err much," says Mr. Jackson, (in his Chronol. Antiq. vol. iii. p. 94), "if we place his invention of them five hundred and fifty years after the flood, or twenty years after the dispersion; and two thousand six hundred and nineteen years before the christian æra; and six, or perhaps ten years, before he went into Egypt. †"—Taaut, and his posterity, for fifteen generations, ruled in the upper Egypt, at Thebes, which was built by the Mezrites.

That letters were invented in Phenicia, doth not depend solely upon the testimony of Sanconiatho; for several Roman authors attribute their invention to the Phenicians.—Pliny says, the Phenicians were famed for the invention of letters, as well as for astro-

* "Out of Phenicia," (says Mons. Bochart, in his learned work, intitled, Canaan), "issued a vast number of tribes, who settled themselves in all parts of the world, in Egypt, Asia, Cyprus, the Isles of the Mediterranean, Sicily, Sardinia, the African coast, Spain, and several other countries."

† The author is supposed, by Mr. Astle, mistaken in this calculation.

nomical observations, and naval and martial arts *.—Curtius says, that the Tyrian nation are related to be the first, who either taught or learned letters †; and Lucan says, the Phenicians were the first who attempted to express sounds (or words) by letters ‡. To these authorities may be added that of Eusebius §, who tells us, from Porphyry, that "Sanconiatho studied with great application the writings of Taaut, knowing that he was the first who inventedlt ters;" and on these he laid the foundation of his history.

It is observable, that the Greek writers seem to have known no older Hermes than the second Hermes or Mercury, who is recorded to have lived about four hundred years after the Mezrite Taaut, or Hermes; which second Hermes, Plato calls Theuth, and counsellor and sacred scribe to king Thamus, but it is not said that he ever reigned in Egypt: whereas the Mezrite Taaut, or Athothes, as Manetho calls him, was the immediate successor of Menes, the first king of Egypt. The second Mercury, if we believe Manetho, composed several books of the Egyptian history, and many incredible things are attributed to him; who being more known, and more famous in Egypt than the Mezrite Hermes, and having improved both their language and letters, the Egyptians attributed the arts and inventions of the former, to him ||.

The Phenician language has been generally allowed to be, at least a dialect of the Hebrew; and though their alphabet doth not entirely agree with the Samaritan, yet it will hereafter appear, that there is a great similarity between them ¶. Arithmetic and Astronomy were much cultivated by them, in the most early ages **.

* Ipsa gens Phœnicum in gloria magna literarum inventionis et siderum, navaliumque ac bellicarum artium. Nat. Hist. lib. v. c. 12.

† Si famæ libet credere hæc (Tyriorum) gens literas prima aut docuit, aut didicit, lib. vi. c. 4.

‡ Phœnices primi, famæ si creditur, aussi,
Mansuram rudibus vocem signare figuris. Lib. iii. v. 220, 221.

§ De abstinent. lib. ii. sect. 56.

|| Concerning this second Hermes, see Du Pin's Universal Historical Library, vol. i. p. 34 and 52; and Jackson's Chronol. Antiq. vol. iii. p. 94.

¶ They had circumcision, as well as other customs, in common with the Hebrews, saith Herodotus.

** They were from the beginning, as it were, addicted to philosophical exercises of the mind; insomuch that a Sidonian, by name Moschus, is said to have taught the doctrine of Atoms, before the Trojan war; and Abdomenus of Tyre, challenged Solomon, though the wisest king upon earth, by the subtle questions he

Their fine linen, their purple, and their glass, were superior to those of any other people; and their extraordinary skill in architecture and other arts, was such, that whatever was great, elegant, or pleasing, whether in buildings, apparel, vessels, or toys, were distinguished by the epithet of Tyrian or Sidonian *.

The Sidonians or Phenicians were the first people who ventured out to sea in ships †; they were the greatest commercial people of all antiquity, and engrossed all the commerce of the western world. This very early and high degree of civilization, justly entitles them to urge the strongest pretensions to the first use of alphabetic characters ‡.

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proposed to him. Phenicia continued to be one of the seats of learning; and both Tyre and Sidon produced their philosophers of later ages; Boethus and Diodatus of Sidon, Antipater of Tyre, and Apollonius of the same place, gave an account of the writings and disciples of Zeno. Universal Hist. vol. ii. p. 346.

* Tyre and Sidon were the principal cities in Phenicia.—See the Treaty which king Solomon entered into with Hiram king of Tyre, for artificers, as it is recorded in 2 Chron. chap. ii. v. 7—16. Hiram began to reign in the one thousand three hundred and twenty-ninth year after the deluge, and one thousand and twenty years before the christian æra. Solomon also contracted with king Hiram, for ships to bring gold and precious stones for ornamenting his buildings. 2 Chron. v. 18, and chap. ix. v. 10 and 18.

† Sanconiatho says, that the Phenicians made ships of burden in which they sailed in the time of Saturn, or Cronus. And Dionysius says, the Phenicians were the first who ventured to sea in ships. Perieg. v. 907.

‡ The learned authors of the Nouveau Traité de Diplomatique, not only corroborate but illustrate this opinion.—Enfin, tout dépose exclusivement en faveur de l'antiquité de la langue Phénicienne. Par la Phenicie on n'entend pas seulement les villes de la côte maritime de la Palestine, mais de plus la Judée & les pays des Chananéens & des Hébreux. Hérodote lui-même, lib. ii. col. 104, par les Phéniciens désignoit évidemment les Hébreux ou les Juifs, puisque, selon lui, les Phéniciens se faisoient circoncire, & que les Tyriens, les Sidoniens, &c. n'étoient point dans cet usage. Par écriture Phénicienne, on entend donc, la Samaritaine, c'est-à dire l'ancien Hébreu, [*Soucit, Dissertation sur les Medailles Hebraique* p. 4;] different de l'Hébreu quarré ou Chaldaique, qui est le moderne, que les Juis ont adopté depuis la captivité de Babylone, ainsi que l'ont pensée S. Jérôme, S. Iréné, S. Clement d'Alexandrie, &c. &c.

Les auteurs qui adjugent l'antiquité à l'écriture Samaritaine sont sans nombre. Genebrard, Bellarmin, le Pere Morin, M. Huet, Dom. Montfaucon, Dom. Calmet, M. Renaudot, Joseph Scaliger, Grotius, Casaubon, Walton, Bochard, Vossius, Prideaux, Capelle, Simon, &c. &c. se sont hautement déclarés on faveur en ce sentiment; and ils sont appuyés sur les Auteurs anciens and sur l'analogies des caracteres Samaritains avec les caracteres Grecs; resemblance nécessaire pour obtenir la gloire de l'antiquité, puisque les derniers se perdent dans la nuit des temps, and que cependant ce n'est point eux qui les ont inventées.

En combinant la descendance des lettres, il en résultera beaucoup de jour sur

CHALDEANS.

With respect to the claim of the Chaldeans, the Jews, Arabians, and Indians, have it by tradition, that the Egyptians were instructed in all their knowledge by Abraham, who was a Chaldean. These traditions deserve, at least, as much credit as any traditions of the Egyptians, however credited and adopted by the Greeks ; because they are, in some degree, confirmed by most of the western writers, who ascribe the inventions of arithemetic and astronomy to the Chaldeans *. Josephus, lib. i. cap. 9. is very express that the Egyptians were ignorant of the sciences of arithmetic and astronomy before they were instructed by Abraham ; and it is probable that the relation of the Jewish historian, may have induced many succeeding writers to attribute the invention of letters to that celebrated patriarch †. Sir Isaac Newton admits that letters were known in the Abrahamic line for some centuries before Moses.

Though the cosmogony of the Chaldeans and Babylonians is deeply involved in fables, as is the case with all ancient nations, yet they evince that they cultivated the sciences in the most remote times.

The Chaldaic letters are derived from the ancient Hebrew, or Samaritan, which are the same, or nearly so, with the old Phenician ‡. The prophet Ezra is supposed to have exchanged the old Hebrew characters, for the more beautiful and commodious Chaldee, which are still in use.

Berosus, the most ancient Chaldean historian, was born (as he tells us himself) during the minority of Alexander the great ; he wrote in three books, the Chaldean and Babylonish history, which comprehended that of the Medes. He is allowed to have been a very respectable writer, but he does not mention that he believed the Chaldeans to have been the inventors of letters §.

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ce systême, et un nouvel appui pour le dernier sentiment. Dict. Dipl. tom. i. p. 416.

* After the flood, all mankind lived together in Chaldea, till the days of Peleg. See Univ. Hist. vol. iv. p. 332, 375 ; and Sir Isaac Newton's Chronology of Ancient kingdoms, London, 1728, 4to. The tower of Babel, and the city of Babylon, were in the province which is now called Erica Arabic.

† Abraham did not retire from Ur, in Chaldea, to settle at Haran in Canaan, till he was upwards of seventy years old.

‡ Univ. Hist. vol. iii. p. 217.

§ See an account of him and his works in the Univ. Hist. vol. i. pref. p. 13, and p. 29, 30 ; and the substance of th fragments of his history that are still remaining, at p. 192—195.

SYRIANS.

Let us briefly examine the pretensions of some other nations to the early use of letters.—The next nation that claims attention is the Syrian. The language of the Syrians is mentioned in the Universal History, vol. i. p. 347, 348; and was a distinct tongue in the days of Jacob. It was also the language of Mesopotamia and Chaldea.—As to the arts and learning of the Syrians, they were by some anciently joined with the Phenicians, as the first inventors of letters; but, without entering into this matter, certain it is, that they yielded to no nation in human knowledge, and skill in the fine arts. From their happy situation they may almost be said to have been in the centre of the old world; and, in the zenith of their empire, they enriched themselves with the spoils, tribute, and commerce, of the nations far and near, and arose to a great pitch of splendour and magnificence, which are the chief encouragers of ingenuity and industry *. Their language is pretended to have been the vernacular of all the oriental tongues, which was divided into three dialects: First, the Aramean, used in Mesopotamia, and by the inhabitants of Roha, or Edesa, of Harram, and the Outer Syria: Secondly, the dialect of Palestine, spoken by the inhabitants of Damascus, Mount Libanus, and the Inner Syria: Thirdly, the Chaldee or Nabathean dialect, the most unpolished of the three, and spoken in the mountainous parts of Assyria, and the villages of Irâc or Babylonia.

It hath been a received opinion, that no nation of equal antiquity had a more considerable trade than the ancient Syrians. They had many valuable commodities of their own to carry into other parts; and, by their vicinity to the river Euphrates, it is evident that they traded with the eastern nations upon that river very early. The easy and safe navigation of the Euphrates, when compared with that of the sea, may incline us to consider them, as older merchants than the Edomites, or even the Phenicians, who confessedly ingrossed the trade of the western world. The Syrians therefore are supposed to have been the first people who brought the Persian and Indian commodities into the west of Asia. It seems therefore that the Syrians carried on an inland trade, by engrossing the com-

* The altar at Damascus, which so ravished Ahaz king of Judah, serves as a noble specimen of the skill of their artificers.

merce of the Euphrates; whilst the Phenicians traded to the most distant countries.

Notwithstanding the above circumstances, which may seem to favour the claim of the Syrians, the oldest characters or letters of that nation that are at present known, are but about three centuries before the birth of Christ. Their letters are of two sorts: the Estrangelo, which is the more ancient; and that called the Fshito, the simple or common character, which is more expeditious and beautiful *.

INDIANS.

The period of time is happily arrived, when the study of oriental literature is not only become useful, but fashionable. The learned Sir William Jones greatly facilitated the attainment of the knowledge of the Persian language; Mr. Richardson that of the Arabic; and Doctor Woide, the Egyptian and the Coptic; by the publication of their respective grammars. Mr. Halhed, the editor of a work intitled the Gentoo Laws, hath written a grammar of the Shanscrit language †, which he informs us, is not only the grand source of Indian literature, but the parent of almost every dialect from the Persian gulph to the Chinese seas, and is a language of the most venerable antiquity; and, although at present shut up in the libraries of Bramins, and appropriated solely to the records of their religion, appears to have been once current over most of the oriental world, as traces of its original extent may still be discovered, in almost every district of Asia.

"There is," says Mr. Halhed, "a great similarity between the Shanscrit words and those of the Persian and Arabick, and even of Latin and Greek; and these, not in technical and metaphorical terms, which the mutation of refined arts and improved manners might have occasionally introduced, but in the main ground-works of language; in monosyllables, in the names of numbers, and the appellations of such things as would be first discriminated, on the immediate dawn of civilization. The resemblance which may be observed in the characters upon the medals and signets of various districts of Asia, the light which they reciprocally reflect upon each

* See these characters in the Univ. Hist. vol. ii. p. 294.

† This ingenious gentleman, assisted by Mr. Wilkins, a descendant of the learned bishop of that name, not only formed the types of the Gentoo alphabet, but printed this grammar, at Hoogly in Bengal, 4to. 1778.

other, and the general analogy which they all bear to the grand prototype, affords another ample field for curiosity.

That coins of Assam, Napaul, Cashmiria, and many other kingdoms, are all stampt with Shanscrit letters, and mostly contain allusions to the old Shanscrit mythology. The same conformity I have observed on the impressions of seals from Bootan and Thibet."

That part of Asia between the Indus and the Ganges, still preserves the Shanscrit language pure and inviolate, and offers a great number of books to the perusal of the curious, many of which have been religiously handed down from the earliest period of their civilization.

There are seven different sorts of Indian hand writings, all comprised under the general term of Naagoree, which may be interpreted writing. The elegant Shanscrit is stiled Daeb naagoree, or the writing of the immortals * ; which may not improbably be a refinement from the more simple Naagoree of the earliest ages. The Bengal letters are another branch of the same stock. The Bengalese Bramins have all their Shanscrit books copied in this national alphabet ; and they transpose into them all the Daeb-naagoree MSS. for their own perusal. The dialect called by us the Moorish, is that species of Hindostanic which owes its existence to the Mahometan conquests.

There are about seven hundred radical words in the Shanscrit language ; the fundamental part of which is divided into three classes.

First,	Dhaat—or roots of verbs.
Second,	Shubd—or original nouns.
Third,	Evya —or particles.

The Shanscrit alphabet contains fifty letters ; viz. thirty-four consonants, and sixteen vowels. The Indian Bramins contend, that they had letters before any other people ; and Mr. Halhed observes, that sufficient grounds still exist for conjecturing, that Egypt has but a disputable claim to its long boasted originality in civilization. The present learned Rajah of Kishinagur affirms, that he has in his possession Shanscrit books, where the Egyptians are constantly described as disciples, not as instructors, and as seeking that liberal education, and those sciences in Hindostan, which none of their own countrymen had sufficient knowledge to

* The Bramins say, letters were of divine original.

impart. Mr. Halhed hints, that the learning of Hindostan might have been transplanted into Egypt, and thus have become familiar to Moses *. However this may be, several authors agree in opinion, that the ancient Egyptians possessed themselves of the trade of the East by the Red Sea; and that they carried on a considerable traffic with the Indian nations before the time of Sesostris, who was contemporary with Abraham †.—The Red Sea was called by the ancients the Indian Sea; and they usually denominated the Ethiopians, and the rest of the nations under the torrid zone, Indians ‡.

A translation of the Indian book called Bagavadam, one of the eighteen Pouranam, or sacred books of the Gentoos, hath lately been published in France. This translation was made by Meridas Poullè, a learned man of Indian origin, and chief interpreter to the supreme council of Pondicherry; and was sent by him to M. Bertin, his protector, in 1769. This Bagavadam, or divine history, claims an antiquity of above five thousand years. Mousieur Poullè tells us, in his preface, that the book was composed by Viasser the son of Brahma, and is of sacred authority amongst the worshippers of Vischnow. The language of the original text is Shanscrit, but the translation was made from a version in Tamoul.

There are several traditions and relations of the Indians, calculated to ascertain the antiquity of this book, and they all tend to date its composition three thousand one hundred and sixteen years before the christian æra: but Mons. De Guines § hath not only invalidated these traditions, but proves also, that the pretensions of this book to such a remote antiquity are inconclusive and unsatisfactory. Hence we may conclude, that though a further inquiry into the literature of the Indian nations may be laudable, yet we must by no means give too easy credit to their relations concerning the high antiquity of their manuscripts, and early civilization.

PERSIANS.

The Persians had no great learning among them till the time of Hystaspes, the father of the emperor Darius Hystaspes. The for-

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* Preface to Gentoo Laws, p. 44.

† Rollin's Hist. p. 59, 60; and Univ. Hist. vol. i. p. 513.

‡ Preface to Gentoo Laws, p. 44.

§ See his reflections on this book, published in the 38th vol. of the Histoire de l'Academie Royal, &c. Paris, 1777.

mer, we are told, travelled into India, and was instructed in the sciences by the Bramins, for which they were at that time famed *. The ancient Persians contemned riches, and were strangers to commerce; they had no money amongst them, till after the conquest of Lydia †. It appears by several inscriptions taken from the ruins of the palace of Persepolis, which was built near seven hundred years before the christian æra, that the Persians sometimes wrote in perpendicular columns, after the manner of the Chinese. This mode of writing was first used upon the stems of trees, or pillars, or obelisks. As for those simple characters found upon the west side of the staircase at Persepolis, some authors have supposed them to be alphabetic; others, hieroglyphic; whilst others have asserted them to be ante-diluvian: but our learned Dr. Hyde pronounces them to have been mere whimsical ornaments, though a late writer ‡ supposes they may be fragments of Egyptian antiquity, taken by Cambyses from the spoils of Thebes. In the second volume of Niebuhr's Travels in Arabia, p. 25, several of the inscriptions at Persepolis are engraven. This author says, that they furnish three different alphabets, which have long been disused. They are certainly alphabetic, and not hieroglyphic or mere ornaments, as some writers have supposed. In fine, the learned seem generally agreed, that the ancient Persians were later than many of their neighbours in civilization: it was never pretended that they were the inventors of letters §.

ARABIANS.

The Arabs have inhabited the country they at present possess, for upwards of three thousand seven hundred years, without having been intermixed with other nations, or being subjugated by any foreign power. Their language must be very ancient. The two principal dialects of it, were those spoken by the Hamyarites, and other genuine Arabs; and that of the Koerish, in which Mahammed wrote the Koran. The first is stiled by the oriental writers, the Arabic of Hamyar; and the other, the pure, or defecated.—

* Univ. Hist. vol. v. p. 130.

† Ibid. p. 131.

‡ The author of Conjectural Observations on Alphabetic Writing.

§ See some remarks upon the old Persic letters in the Universal History, vol. xviii. p. 399.

Mr. Richardson, in his Arabic Grammar, observes, as a proof of the richness of this language, that it consists of two thousand radical words.

The old Arabic characters are said to be of very high antiquity; for Ebn Hashem relates, that an inscription in it was found in Yaman, as old as the time of Joseph. These traditions may have given occasion to some authors to suppose the Arabians to have been the inventors of letters; and Sir Isaac Newton * supposes, that Moses learned the alphabet from the Midianites, who were Arabians.

The Arabian alphabet consists of twenty-eight letters, which are somewhat similar to the ancient Kufic, in which characters the first copies of the Alcoran were written.

The present Arabic characters were formed by Ebn Moklah, a learned Arabian, who lived about three hundred years after Mahomet. We learn from the Arabian writers themselves, that their alphabet is not ancient.—Al Asmahi says, that the Koreish were asked, "From whom did you learn writing?" and that they answered, "From Hirah." That the people of Hirah were asked, "From whom did you learn writing?" and they said "From the Ambarites."—Ebn Al Habli and Al Heisham Ebn Admi relate, that Abi Sofian, Mahomet's great opposer, was asked, "From whom did your father receive this form of writing?" and that he said, "From Ashlam Ebn Sidrah;" and, that Ashlam being asked, "From whom did you receive writing?" his answer was, "From the person that invented it, Moramer Ebn Morrah;" and that they received this form of writing but a little before Islamism †.

OBSERVATIONS AND REFLECTIONS.

Before we conclude, we shall make a few reflections on the foregoing claims of different nations to the invention of letters. The vanity of each nation induces them to pretend to the most early civilization; but such is the uncertainty of ancient history, that it is difficult to decide to whom the honour is due. It however should seem, from what hath been advanced in the course of this part of our inquiry, that the contest may be confined to the Egyptians, the Phenicians, and the Chaldeans. The Greek writers, and most

* Chronology of Egypt, p. 205, 8vo. edit.

† Wise, on the first inhabitants, &c. of Europe, p. 99.

of those who have copied them, decide in favour of Egypt, because their information is derived from the Egyptians themselves. The positive claim of the Phenicians, doth not depend upon the sole testimony of Sanconiatho; the credit of his history is so well supported by Philo of Biblus his translator, Porphyry, Pliny, Curtius, Lucan, and other ancient authors, who might have seen his works entire, and whose relations deserve at least as much credit as those of the Egyptian and Greek writers. It must be allowed, that Sanconiatho's history contains many fabulous traditions; but does not the ancient history of the Egyptians, the Greeks, and most other nations, abound with them to a much greater degree? The fragments which we have of this most ancient historian, are chiefly furnished by Eusebius, who took all possible advantages to represent the Pagan writers in the worst light, and to render their theology absurd and ridiculous.

Cicero * distinguishes five Mercuries, two of which are Egyptian. Authors are much divided as to the ages in which they lived, but the most ancient is generally allowed to be the Phenician Taaut, who passed from thence to Egypt. It is probable that he might teach the Egyptians the use of letters; and that the second Taaut, Mercury, or Hermes Trismegistus, improved both the alphabet and language, as Diodorus and others have asserted. The Phenician and Egyptian languages are very similar, but the latter is said to be more large and full, which is an indication of its being of a later date.

The opinion of Mr. Wise, that the ancient Egyptians had not the knowledge of letters, seems to be erroneous: as they had commercial intercourse with their neighbours the Phenicians, they probably had the knowledge of letters, if their policy (like that of the Chinese at this day) did not prohibit the use of them.

The Chaldeans, who cultivated astronomy in the most remote ages, used symbols, or arbitrary marks, in their calculations; and we have shewn that these were the parents of letters. This circumstance greatly favours their claim to the invention, because Chaldea, and the countries adjacent, are allowed by all authors, both sacred and profane, to have been peopled before Egypt; and it is certain that many whole nations, recorded to be descended from Shem

* De Nat. Deor. lib. iii.

and Japhet, had their letters from the Phenicians, who were descended from Ham *.

It is observable, that the Chaldeans, the Syrians, the Phenicians, and Egyptians, all bordered upon each other; and as the Phenicians were the greatest, as well as the most ancient commercial nation, it is very probable, that they communicated letters to the Egyptians, the ports of Tyre and Sidon, and those of the Egyptians, being not far distant from each other.

Mr. Jackson is evidently mistaken, when he says, that letters were invented two thousand six hundred and nineteen years before the birth of Christ. The deluge, recorded by Moses, was two thousand three hundred and forty-nine years before that event; and if letters were not invented till five hundred and fifty years after, as he asserts, we must date their recovery only one thousand seven hundred and ninety-nine years before the christian æra, which is four hundred and ten years after the reign of Menes, the first king of Egypt, who (according to Geo. Syncellus and others) is said to have been the same person with the Misor of Sanconiatho, the Mizraim of the Scriptures, and the Osiris of the Egyptians; but whether this be true or not, Egypt is frequently called in the Scriptures, the land of Mizraim †.

This Mizraim, the second son of Amyn or Ham, seated himself near the entrance of Egypt at Zoan, in the year before Christ two thousand one hundred and eighty-eight, and one hundred and sixty years after the flood; he afterwards built Thebes, and some say Memphis. He is by Herodotus, by Diodorus, Eratosthenes, and Africanus, by Eusebius and Syncellus, called Menes ‡.

Before the time that Mizraim went into Egypt, Taaut his son had invented letters in Phenicia; and if this invention took place ten years before the migration of his father into Egypt, as Mr. Jackson supposes, we can trace letters as far back, as the year two thousand one hundred and seventy-eight before Christ, and one hundred and fifty after the deluge recorded by Moses; and beyond this period, the written annals of mankind, which have been hitherto trans-

* Misraim, the son of Ham, led colonies into Egypt, and laid the foundation of a kingdom, which lasted one thousand six hundred and sixty-three years; whence Egypt is, in the Holy Scriptures, called the land of Ham.

† Universal History, vol. v. p. 390.

‡ These authors say he went into Egypt twenty-one years sooner; but this account agrees best with the Scriptures. See Stackhouse's Hist. of the Bible p. 203.—Univ. Hist. vol. xxi. p. 3.

mitted to us, will not enable us to trace the knowledge of them; though this want of materials is no proof, that letters were not known, until a century and a half after the deluge.

As for the pretensions of the Indian nations, we must be better acquainted with their records, before we can admit of their claim to the first use of letters; especially as none of their MSS. of great antiquity have as yet appeared in Europe. That the Arabians were not the inventors of letters, hath appeared by the confession of their own authors.

Plato somewhere mentions Hyperborean letters, very different from the Greek; these might have been the characters used by the Tartars, or ancient Scythians.

ANTE-DILUVIAN WRITING.

It may be expected, that something should be said concerning those books, mentioned by some authors to have been written before the deluge *; but as Moses is silent upon the subject, we have no materials that will enable us to form an opinion. St. Jude, in his Epistle, v. 14, tells us, that Enoch prophesied; but this apostle might quote a Jewish tradition, for he does not say that Enoch wrote. The tales which have been told us concerning the books of this patriarch, are too absurd to deserve serious attention †. With respect therefore to Writings attributed to the ante-diluvians, it seems not only decent but rational, to say, that we know nothing concerning them; though it might be improper to assert, that letters were unknown before the deluge recorded by Moses.

As for the pillars, mentioned by Josephus to have been erected by the sons of Seth, whereon they wrote their invented sciences, we agree with the learned abbot of Claraval, that the bare reading of Josephus, is all that is requisite to prove them imaginary.

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* Amongst others, Dr. Parsons, who supposed that letters were known to Adam.—Remains of Japhet, p. 346, 359.—The Sabeans produced a book which they pretend was written by Adam. Univ. Hist. vol. i. p. 720, fol. edit.

† Origen reports, that certain books of Enoch were found in Arabia Felix, in the dominions of the queen of Saba. Tertullian roundly affirms, that he saw and read several pages of them; and, in his Treatise de Habitu Mulierum, he places these books among the canonical; but St. Jerome and St. Austin look upon them as hypocryphal. William Postellus pretended to compile his works, De Originibus, from the book of Enoch. Thomas Bangius published, at Copenhagen, in 1657, a work which contains many singular relations, concerning the manner of writing among the Ante-diluvians, wherein are contained several pleasant tales concerning the books of Enoch.

Upon the whole, it appears to us, that the Phenicians have the best claim to the honour of the invention of letters.

[*Astle.*

SECTION IV.

Instruments for writing with.

It is obvious, that when men wrote, or rather engraved, on hard substances, instruments of metal were necessary, such as the chisel and stylus; but the latter was chiefly used for writing upon boards, waxed tablets, or on bark; these were sometimes made of iron, but afterwards of silver, brass, or bone, called in Greek γραφιον, and in Latin stylus; though the Romans adopted the Greek word, as appears by this verse in Ovid:

> Quid digitos opus est graphium lassare tenendo?

The stylus was made sharp at one end to write with, and blunt at the other to deface and correct what was not approved; hence the phrase *vertere stylum* to blot out, became common among the Romans. The iron styles were dangerous weapons, and were prohibited by the Romans, and those of bone or ivory were used in their stead. Suetonius tells us, that Cæsar seized the arm of Cassius in full senate, and pierced it with his stylus. He also says that Caligula excited the people to massacre a Roman senator with their styles. And Seneca mentions that one Erixo, a Roman knight in his time, having scourged his son to death, was attacked in the forum by the mob, who stabbed him in many parts of his body, with the iron styles which belonged to their pugillares, so that he narrowly escaped being killed, though the emperor interposed his authority *. Prudentius very emphatically describes the tortures which Cassianus † was put to by his scholars, who killed him with their pugillares and styles:

> Buxa crepant cerata genis impacta cruentis,
> Rubetque ab ictu curva humens pagina;

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* De Clementia, lib. i. cap. 14.

† This Cassianus was the first bishop of Sibon, in Germany, where he built a church in 350; but he was driven away by the Pagans, and fled to Rome, where he commenced schoolmaster for a subsistence. In the year 365, he was, by the order of the Emperor Julian, exposed to the merciless rage of his scholars.

Inde alii stimulos, et acumina ferrea vibrant,
Quà parte aratis cera sulcis scribitur.

Περι ϛτεφανων, p. 93.

When the ancients wrote on softer materials than wood or metal, other instruments were used for writing with, of which reeds and canes seem to have been the first. Pliny says that Egypt furnished a great quantity of the kind of reeds which were used for writing with *: and Martial hath these words:

"Dat chartis habiles calamos Memphitica tellus†."

Reeds and canes are still used as instruments for writing with by the Tartars, the Indians, the Persians, the Turks, and the Greeks. Mr. Halhed tells me that the two first of these nations write with small reeds bearing the hand exceedingly lightly. Tavernier, in one of his voyages says the same of the Persians. Rauwolff, who travelled in 1583, relates, that the Turks, Moors, and eastern nations, use canes for pens, which are small and hollow within, smooth without, and of a brownish red colour ‡.

The canes in Persia are cut in March, which they dry in the smoak for about six months; those which are covered with a fine varnish of black and yellow, are esteemed the best for writing with.

The Indians more frequently write with the cane called bamboo, which is cut about the length and thickness of our pens.

Pencils made of hair are used by the Chinese for their writing: they first liquify their ink, and dip their pencils into it. The large capital letters were made with hair pencils from the time of the Roman emperors till the sixteenth century. After the invention of printing they were drawn by the illuminators.

Quills of geese, swans, peacocks, crows, and other birds have been used in these western parts for writing with, but how long is not easy to ascertain. St. Isidore of Seville, who lived about the middle of the seventh century, describes a pen made of a quill as used in his time. "Instrumenta scribæ calamus et penna; ex his

* Plin. Hist. l. xvi. c. 36.

† Lib. xiv. Epigr. 34.

‡ Rauwolff's Travels, p. 87.

enim verba paginis infiguntur; sed calamus arboris est, penna avis, cujus acumen dividitur in duo *."

Some of the instruments necessary for the occupation of a librarius or book-writer are delineated in a book of the four gospels in the Harleian library (No. 2820), written in Italy in the tenth century. The vellum, on which this book is written, is stained of different colours at the beginning of each gospel.

[*Astle.*

SECTION V.

Inks.

INK has not only been useful in all ages, but still continues absolutely necessary to the preservation and improvement of every art and science, and for conducting the ordinary transactions of life.

Daily experience shews, that the most common objects, generally prove most useful and beneficial to mankind. The constant occasion we have for ink, evinces its convenience and utility. From the important benefits arising to society from its use, and the injuries individuals may suffer from the frauds of designing men in the abuse of this necessary article, it is to be wished that the legislature would frame some regulation to promote its improvement, and prevent knavery and avarice from making it instrumental to the accomplishment of any base purposes.

Simple as the composition of ink may be thought, and really is, it is a fact well known, that we have at present none equal in beauty and colour to that used by the ancients; as will appear by an inspection of many of the MSS. above quoted, especially those written in England in the times of the Saxons. What occasions so great a disparity? Does it arise from our ignorance, or from our want of materials? From neither, but from the negligence of the present race; as very little attention would soon demonstrate, that we want neither skill nor ingredients to make ink as good now, as at any former period.

It is an object of the utmost importance that the records of parliament, the decisions and adjudications of the courts of justice, conveyances from man to man, wills, testaments, and other instruments, which affect property, should be written with ink of such

* Isid. Hisp. Orig. lib. vi. cap. 14.

durable quality, as may best resist the destructive powers of time and the elements. The necessity of paying greater attention to this matter may be readily seen by comparing the rolls and records, that have been written from the fifteenth century to the end of the seventeenth, with the writings we have remaining of various ages from the fifth to the twelfth centuries. Notwithstanding the superior antiquity of the latter, they are in excellent preservation; but we frequently find the former, though of more modern date, so much defaced, that they are scarcely legible.

Inks are of various sorts, as encaustic or varnish, Indian ink, gold and silver, purple, black, red, green, and various other colours: there are also secret and sympathetic inks.

The ink used by the ancients had nothing in common with ours, but the colour and gum. Gall nuts, copperas, and gum, make up the composition of our ink; whereas soot, or ivory black, was the chief ingredient in that of the ancients; so that very old charters might be suspected, if written with ink intirely similar to what we use; but the most acute and delicate discernment is necessary in this matter, for some of the inks formerly used were liable to fade and decay, and are found to have turned red, yellow, or pale: those imperfections are however rare in MSS. prior to the tenth century.

There is a method of reviving the writing, but this expedient should not be hazarded, lest a suspicion of deceit should arise, and the support depended on be lost.

Golden ink was used by various nations, as may be seen in several libraries, and in the archives of churches. Silver ink was also common in most countries. Red ink, made of vermilion, cinnabar, or purple, is frequently found in the MSS. but none are found written intirely with ink of that colour. The capital letters are made with a kind of varnish which seems to be composed of vermilion and gum. Green ink was rarely used in charters, but often in Latin MSS. especially in those of the latter ages: the guardians of the Greek emperors made use of it in signatures, till the latter were of age. Blue or yellow ink was seldom used but in MSS. The yellow has not been in use, as far as we can learn, for six hundred years.

Metallic and other characters were sometimes burnished. Wax was used as a varnish by the Latins and Greeks, but much more by the latter, with whom it continued a long time. This covering or varnish was very frequent in the ninth century.

COLOUR.

The colour of the ink is of no great assistance in authenticating MSS. and charters. There is, says Mr. Astle, in my library, along roll of parchment, at the head of which, is a letter that was carried over the greatest part of England by two devout monks, requesting prayers for Lucia de Vere, countess of Oxford, a pious lady, who died in 1199; who had founded the house of Henningham, in Essex, and done many other acts of piety. This roll consists of many membranes, or skins of parchment sewed together; all of which, except the first, contain certificates from the different religious houses, that the two monks had visited them, and that they had ordered prayers to be offered up for the countess, and had entered her name in their bead-rolls. It is observable, that time hath had very different effects on the various inks, with which these certificates were written; some are as fresh and black as if written yesterday, others are changed brown, and some are of a yellow hue. It may naturally be supposed that there is a great variety of hand-writings upon this roll; but the fact is otherwise, for they may be reduced to three.

The letter at the head of the roll is written in modern Gothic characters*: four-fifths of the certificates are Norman, which shews that this mode of writing had taken place of almost every other. Some of the certificates are in modern Gothic letters, which we conceive were written by English monks; and a very few are in Lombardic small letters. It may however be said in general that black ink of the seventh, eighth, ninth, and tenth centuries, at least amongst the Anglo-Saxons, preserves its original blackness much better than that of succeeding ages †; not even excepting the sixteenth and seventeenth, in which it was frequently very bad. Pale ink very rarely occurs before the four last centuries.

Peter Caniparius, Professor of Medicine at Venice, wrote a curious book concerning inks, which is now scarce, though there is an edition of it printed in London in 1660, 4to. The title is, "De Atramentis cujuscunque generis opus sanè novum. Hactenus

* The letter, with an account of it, is in Weever's Funeral Monuments, last edit. Lond. 1767, 4to. p. 379.

† The Texta Sancti Cuthberti in the Cottonian library, (Nero D. 4.) demonstrates the truth of this assertion.

à nemine promulgatum." This work is divided into six parts. The first of which treats generally of inks made from pyrites, stones, and metals.

The second treats more particularly of inks made from metals and calxes.

The third of ink made from soots and vitriols.

The fourth of the different kinds of inks used by the librarii or book-writers, as well as by printers and engravers, and of staining or writing upon marble, stucco or scaliolia, and of encaustic modes of writing; as also of liquids for painting or colouring of leather, cloths, linen, and woollen, and for restoring inks that have been defaced by time; as likewise many methods of effacing writing, restoring decayed paper, and of various modes of secret writing.

The fifth part treats of inks for writing, made in different countries, of various materials and colours; as from gums, woods, the juice of plants, &c. and also of different kinds of varnishes.

The sixth part treats of the various operations of extracting vitriol, and of its chemical uses.

This work abounds with a great variety of philosophical, chemical, and historical knowledge, and we conceive will give great entertainment to those who wish for information on this subject. Many curious particulars concerning ink will be found in Weckerus de Secretis*. This gentleman also gives recipes for making inks of the colour of gold and silver, composed as well with those metals as without them; also directions for making variety of inks for secret writing, and for defacing of inks. There are many marvellous particulars in this last-mentioned work, which will not easily gain credit with the judicious part of mankind.

[*Astle.*

The chief requisites for the making of good writing ink, are, 1. Limpidity, so that it may flow freely from the pen. 2. A deep uniform and black colour. 3. Durability, so that the letters be not liable to be effaced by age; and 4. It should be divested of any corrosive quality, by which the substance of the paper may be destroyed, or the writing rendered in any degree illegible. No ink however, hitherto used, possesses all these properties; hence several

* Printed at Basil in 1612, 8vo.

ingenious chemists have been induced to make experiments, in order to render it more perfect.

M. Ribaucourt, in the "Annales de Chimie," directs eight ounces of Aleppo galls, and four ounces of logwood, to be boiled in twelve pounds of water, till the quantity is reduced to one half; when the liquor should be strained through a linen or hair sieve into a proper vessel. Four ounces of sulphate of iron (green vitriol); three ounces of gum-arabic; one ounce of sulphate of copper (blue vitriol); and a similar quantity of sugar-candy, are now to be added: the liquid should be frequently shaken, to facilitate the solution of the salts. As soon as these ingredients are perfectly dissolved, the composition is suffered to subside for twenty-four hours; when the ink may be decanted from the gross sediment, and preserved for use in glass or stone bottles, well stopped.

This ink exhibits a purplish black colour in the bottles; but the writing performed with it is said to be of a beautiful black cast, which it retains, unaltered, for a considerable length of time. Each quart of the preparation contains:

	oz.	*drs.*	*grs.*
Of Galls - - - -	2	5	20
Green vitriol -	1	2	40
Logwood - -	1	2	40
Gum - - -	1	0	0
Blue vitriol -	0	2	40
Sugar-candy -	0	2	40

M. Ribaucourt is of opinion, that ink thus prepared, may be preserved several years in a state of perfection, without depositing either galls or iron.

The ink commonly used, is manufactured by stationers, according to Dr. Lewis's recipe; but it is ill calculated for keeping, as it deposits a black sediment, while the fluid itself is of a pale colour. Each quart of this ink contains:

	oz.	*drs.*	*grs.*
Of Galls - - - -	3	0	0
Green vitriol -	1	0	0
Logwood - -	0	5	24
Gum - - -	1	0	0

Neither blue vitriol nor sugar are employed in this preparation. As, however, both the ink made after the latter method, and that compounded according to other recipes, are not adapted to resist the effects of acids, and are consequently by no means fit for records, deeds, and other documents; M. Westrumb recommends the following ingredients, as being well calculated to remedy this inconvenience. He directs one ounce of Brazil-wood, and a similar quantity of gall-nuts, to be boiled in forty-six ounces (somewhat less than three pints) of water, till the whole be reduced to thirty-two ounces, or about two quarts.

This decoction is to be poured, while hot, upon half an ounce of copperas, or green vitriol; a quarter of an ounce of gum-arabic, and a similar quantity of white sugar. As soon as a perfect solution of these substances has taken place, one ounce and a quarter of indigo finely pulverized is to be added; together with three quarters of an ounce of the purest lamp black, previously diluted in one ounce of the best brandy. The whole is to be well incorporated; and, after it has subsided, M. Westrumb asserts that it will form an ink absolutely indestructible by acids.

A more simple composition, is that proposed by M. Bosse, who directs one ounce of Brazil-wood to be boiled in twelve ounces of water, with half an ounce of alum, till the liquid be reduced to eight ounces; when one ounce of calcined manganese is to be mixed with half an ounce of gum-arabic, and added to the liquor, which should be previously decanted, in order to render it perfectly limpid. This preparation is said to possess the property of being indelible by the use of any kind of acid, and to be superior to that proposed by M. Westrumb.

A durable ink may also be prepared by washing paper, parchment, &c. with the Prussic acid, which will not in the least injure either of these substances. The materials, thus prepared, may be written on with common ink, and a ground of Prussian blue will be formed beneath every stroke, which will remain long after the black has decayed by the influence of the air, or been destroyed by acids.

The latest, and perhaps most simple, preparation of black ink, is that contrived by Van Mons, who observed that sulphate of iron, or green vitriol, when calcined till it becomes white, uniformly afforded a very beautiful black precipitate. According to his experiments, the following ingredients produced an excellent writing ink: four ounces of galls, two ounces and a half of calcined vitriol of iron perfectly white, and two pints of water. The whole was infused in a cold place for twenty-four hours; adding ten drams of pulverized gum-arabic, and preserving it in a glass bottle, or glazed earthen vessel, slightly covered with paper.

Van Mous has applied the discoveries of Proust to the preparation of common writing ink. He has found that the sulphate of iron calcined to whiteness, always gives a most beautiful black precipitate. By the following mixture, he obtained excellent ink: galls 4 oz.; sulphate of iron, calcined to whiteness, $2\frac{1}{2}$ oz.; and two pints of water. The whole must be left to macerate cold for 24 hours: then add gum-arabic 10 drams, and preserve it in a stone jar open, or covered merely with paper. Chaptal has also employed the calcined sulphate, in connection with the decoction of gall nuts and logwood.

M. Desormeaux, Junr. of Vine court, Spitalfields, who has long been in the habit of preparing ink upon a large scale, has communicated to the Philosophical Magazine, a valuable paper on the subject, from which the following directions are extracted. In six quarts, beer-measure, of water, (it does not appear of importance whether it be rain, river, or spring water) boil four ounces of the best Campeachy logwood, chipped very thin across the grain (the boiling may be continued near an hour); adding from time to time a little boiling water, to compensate for weight by evaporation. Strain the liquor, while hot; suffer it to cool, and make up the quantity equal to five quarts, by the further addition of cold water. To this cold decoction, put one pound averdupois waste of blue galls, or 20 oz. of the best galls in sorts, which shonld be first coarsely bruised; 4 oz. of sulphate of iron, calcined to whiteness; $\frac{1}{2}$ oz. of the acetite of copper, which should be triturated in a mortar, moistened by a little of the decoction gradually added till it be brought to the form of a smooth paste, and then thoroughly intermixed with the whole mass. Three ounces of coarse brown sugar and six ounces of good gum Senegal, or Arabic, are also to be added. These several ingredients may be introduced one after the other immediately, contrary to the advice of some, who recommend the gum, &c. to be added when the ink is nearly made; as gum, however, is at present exorbitantly dear, three or four ounces will be found sufficient, with only one and a half ounce of sugar, unless, for particular purposes, it is wanted to bear a higher gloss than common. As the common writing inks are delible by many of the acids, especially the oxymuriatic, several chemists and others, particularly M. Pitel of Minden, Dr. Lentin, Wieglib, Westrumb, Thorey, M. Bosse, of Hamburgh, have endeavoured to discover a composition which would resist the action of this acid, and most of them have succeeded in the attempt. The two following methods are given by Bosse. 1. Boil 1 oz. of brazil-wood with 12 ozs. of water for a quarter of an hour; add $\frac{1}{2}$ oz. of alum; evaporate the whole to 8 ozs., and mix with the liquor 1 oz. of exceedingly soft finely pulverized manganese, mixed up with $\frac{1}{2}$ oz. of pulverized gum-arabic; or 2. Boil 4 oz. of Brazil wood, and 3 ozs. of coarsely pulverized galls, with 9 ozs. of vinegar aud as much water, for the space of eight minutes; in the liquor after being strained, dissolve $1\frac{1}{2}$ oz. of sulphet of iron, and 1 oz. of gum-arabic; and then add to the whole a solution of $\frac{1}{2}$ oz. of indigo in 1 oz. of concentrated sulphuric acid. M. Bosse also prepared an ink from the principal ingredients of common ink, but, instead of the usual liquids, he employed the expressed juice of some plant: those which he found most efficacious were obtained from the leaves of the caper spurge, *Euphorbia Lathyris*, *Linn.* the common holly, *Sambucus Niger*, and common grass.

Ink *Powder.* Common liquid ink, the method of making which we have already described, is not easily transported from one place to another; and, besides this inconvenience, it is apt to dry in the ink-holder. In bottles, unless well corked, it becomes decomposed and evaporates; and if the bottles happen to break, it may spoil clothes, or any other articles near it. For the convenience therefore of those who travel either by land or by sea, ink powder has been invented, which is nothing else than the substances employed in the composition of common ink, pounded and pulverized; so that it can be converted into ink in a moment, by mixing it up with a little water.

China *or* Indian Ink, which is employed for small drawings and plans, may easily be made by the following process. Take the kernels of the stones of apricots, and burn them in such a manner as to reduce them to powder, but without producing flame; which may be done by wrapping up a small packet of them in a cabbage leaf, and tying round it a bit of iron wire. Put this packet into an oven, heated to the same degree as that required for baking bread, and the kernels will be reduced to a sort of charcoal with which an ink may be made similar to that brought from China.

Pound this charcoal in a mortar, and reduce it to an impalpable powder, which must be sifted through a fine sieve, then form a pretty thick solution of gum-arabic in water, and, having mixed it with the powder, grind the whole on a stone, in the same manner as colour-men grind their colours. Nothing is then necessary, but to put the paste into some small moulds, formed of cards, and rubbed over with white wax, to prevent it from adhering to them.

In regard to the smell of the China ink, it arises from a little musk, which the Chinese add to the gum-water, and may easily be imitated. The figures seen on the sticks of China ink, are the particular marks of the manufacturers, who, as in all other countries, are desirous of distinguishing whatever comes from their hands.

Dr. Lewis thinks, from the information of Father du Halde, that China ink is composed of nothing but lamp black and animal glue. Having boiled a stick of China ink in several portions of water, in order to extract all the soluble parts; and having filtered the different liquors, which he evaporated in a stone vessel, he found that the liquors had the same odour as glue, and that they left, after evaporation, a pretty considerable quantity of a tenacious substance, which seemed to differ in nothing from common glue.

Coloured INKS. Few of these are used except red ink. The preparation of this is very simple, consisting either of decoctions of the different colouring or dying materials in water, and thickened with gum-arabic, or of coloured metallic oxides, or insoluble powders, merely diffused in gum water. The proportion of gum-arabic to be used, may be the same as for black writing ink. All that applies to the fixed or fugitive nature of the several articles used in dyeing, may be applied in general to the use of the same substances as inks.

Red INK is usually made by boiling about two ounces of Brazil wood in a pint of water, for a quarter of an hour, and adding to the decoction the requisite quantity of gum, and about half as much alum. The alum both heightens the colour and makes it less fugitive. Probably a little madder would make it more durable.

Blue INK may be made by diffusing Prussian blue or indigo throuh strong gum-water.

Yellow INK may be made by a solution of gambogo in gum-water.

Most of the common water-colour cakes diffused in water, will make sufficiently good coloured inks for most purposes.

Inks of other colours may be made from a strong decoction of the ingredients used in dying, mixed with a little alum and gum.

arabic. For example, a strong decoction of Brazil wood, with as much alum as it can dissolve, and a little gum, forms a good red ink. These processes consist in forming a lake, and retarding its precipitation by the gum.

On many occasions it is of importance to employ an ink indestructible by any process, that will not equally destroy the material on which it is applied. Mr. Close has recommended for this purpose 25 grains of copal in powder dissolved in 200 grains of oil of lavender, by the assistance of gentle heat, and then mixed with $2\frac{1}{2}$ grains of lamp black, and half a grain of indigo: or 120 grains of oil of lavender, 17 grains of copal, and 60 grains of vermilion. A little oil of lavender, or of turpentine, may be added, if the ink be found too thick. Mr. Sheldrake suggests, that a mixture of genuine asphaltum dissolved in oil of turpentine, amber, varnish, and lamp black, would be still superior.

When writing with common ink has been effaced by means of oxygenized muriatic acid, the vapour of sulphuret of ammonia, or immersion impregnated with this sulphuret, will render it again legible, Or if the paper that contained the writing be put into a weak solution of prussiate of potash, and when it is thoroughly wet a sulphuric acid be added to the liquor, so as to render it slightly acidulous, the same purpose will be answered.

Golden INK. As writing, before the invention of printing, was the only method of transmitting to posterity the works and discoveries of celebrated men, it became in the fourteenth and fifteenth centuries an art much cultivated, and in which many persons excelled. The manuscripts of those periods contain writing, the neatness and regularity of which are astonishing. Transcribers were even acquainted with a method of ornamenting the initial letters with gold, which they applied in such a manner as to preserve all its splendour. Writing, by the invention of printing, having become of less importance, soon degenerated, and the secret of applying gold to paper and parchment, like many other arts, was at length lost. The Benedictines however, rediscovered this secret, and specimens of the process, and parchment containing writing in gold letters, as brilliant as those so much admired in the ancient manuscripts, have been seen at the Abbey Saint-Germain-des-Pres, at Paris. This process may be exceedingly useful, and may further hints for improving some of the other arts, which are all connected, and mutually tend to promote each other.

Printer's INK. This is a very singular composition, partaking much of the nature of an oil varnish, but differing from it in the quality of adhering firmly to moistened paper, and in being to a considerable degree soluble in soap-water.

It is, when used by the printers, of the consistence of rather thin jelly, so that it may be smeared over the types readily and thinly, when applied by leather cushions, and it dries very speedily on the paper without running through to the other side, or passing the limits of the letter.

The method of making printer's ink is thus described by Dr. Lewis. Ten or twelve gallons of nut-oil are set over the fire in a large iron pot, and brought to boil. It is then stirred with an iron ladle, and whilst boiling, the inflammable vapour rising from it either takes fire of itself, or is kindled, and suffered to burn in this way for about half an hour, the pot being partially covered, so as to regulate the body of the flame, and consequently the heat communicated to the oil. It is frequently stirred during this time, that the whole may be heated equally, otherwise a part would be charred and the rest left imperfect. The flame is then extinguished by entirely covering the pot. The oil by this process has much of its unctuous quality destroyed,and when cold is of the consistence of soft turpentine, and is then called varnish. After this it is made into ink by mixture with the requisite quantity of lamp-black, of which about two ounces and a half are sufficient for sixteen ounces of the prepared oil. The oil loses by the boiling about an eighth of its weight, and emits very offensive fumes. Several other additions are made to the oil during the boiling, such as crusts of bread, onions, and sometimes turpentine. These are kept secret by the preparers. The intention of them is more effectually to destroy part of the unctuous quality of oil, to give it more body to enable it to adhere better to the wetted paper, and to spread on the types neatly and uniformly.

Besides these additions, others are made by the printers, of which the most important is generally understood to be a little fine indigo in powder, to improve the beauty of the colour.

Red printer's ink, is made by adding to the varnish, about half its weight of vermilion. A little carmine also improves the colour.

INK, *Sympathetic*, a liquor employed for writing on paper, so that it may retain its natural whiteness after the letters are formed, till it is held near the fire, rubbed with another liquor, or some other expedient is used to render the characters legible.

Sympathetic inks are prepared from various substances, such as bismuth, lead, &c. Thus, a solution of common sugar of lead in water, if employed with a clean pen, will remain concealed till it is wetted with a solution of the liver of sulphur, or is exposed to the vapours of such liquid; in which case it will assume a deeper or lighter brown shade, in proportion to the strength of the sulphureous gas. By the same process, words written with a solution of bismuth in spirit of nitre, will appear of a deep black colour.

Another sympathetic ink may be easily prepared, by diluting oil of vitriol with a sufficient quantity of water, to prevent the paper from being corroded. Letters drawn with this fluid are invisible when dry, but, on being held near the fire, they assume a perfect black colour. The juices of lemons or onions; a solution of sal ammoniac, &c. will answer a similar purpose, though their application is more difficult, and they afterwards require a greater degree of heat.

INK, *removing the stains of.* The stains of ink, on cloth, paper or wood, may be removed by almost all acids; but those acids are to be preferred, which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with five or six times its weight of water, may be applied to the spot, and, after a minute or two, may be washed off, repeating the application as often as may be found necessary. But the vegetable acids are attended with less risk, and are equally effectual. A solution of the oxalic, citric (acid of lemons), or tartareous acids, in water, may be applied to the most delicate fabrics without any danger of injuring them: and the same solutions will discharge writing but not printing-ink. Hence they may be employed in cleaning books which have been defaced by writing on the margin, without impairing the text. Lemon-juice, and the juice of sorrel, will also remove ink-stains, but not so easily as the concrete acids of lemons, or citric acid.

INK, *for marking Linen.* M. Haussman has given some compositions for marking pieces of cotton or linen, previous to their being bleached, which are capable of resisting every operation in the processes both of bleaching and dying, and consequently might be employed in marking linen for domestic purposes. One of these consists of asphaltum dissolved in about four parts of oil of turpentine, and with this is to be mixed lamp black, or black lead in fine powder, so as to make an ink of a proper consistence, for printing with types. Another, the blackish sulphate left after expelling oxygen gas from oxide of manganese with a moderate heat being dissolved and filtered, the dark grey pasty oxide left on the filter is to be mixed with a very little solution of gum tragacanth, and the cloth marked with this is to be dipped in a solution of potash or soda, mild or caustic, in about ten parts of water.

An ingenious correspondent, Mr. J. S. Gaskoin, has favoured us with the following receipt for the composition of the "Chemical Indelible Ink," sold for the purpose of marking linen. The linen, that the black colour may be produced and fixed, is first moistened with a mordant, which is a solution of soda, made thus; take of prepared soda 4 drams, distilled or common soft water 1 ounce, saffron 1 grain, gum-arabic 15 grs. The constituents of the ink are, lunar caustic 1 scruple, distilled water $1\frac{1}{2}$ dram; or, if common soft water be used, two drops of nitrous acid should be added to the solution. The mordant with which the linen has been moistened being suffered perfectly to dry by a gentle heat, the part where the linen has been moistened, is written upon with a clean pen dipped in the ink.

INK, *for the Rolling Press* is made of linseed oil burnt in the same manner as that for common printing ink, and then mixed with Francfort black, and finely ground. There are no certain proportions which can be determined in this kind of ink; every workman adding oil or black to his ink as he thinks proper, in order to make it suit his purpose. Some, however, mix a portion of common boiled oil which has never been burnt; but this must necessarily be a bad practice, as such oil is apt to go through the paper; a fault very common in prints, especially if the paper is not very thick. No soap is added; because the ink is not cleared off from the copper-plates with alkaline ley as in common printing, but with a brush dipped in oil.

[*Pantologia.*

SECTION VI.

Origin and Progress of Printing.

As the invention or rather the introduction of printing into Europe has been attended with the most beneficial advantages to mankind, some account of the origin and progress of that art may be acceptable.

It has not been pretended that the art of printing books was ever practised by the Romans, and yet the names they stamped on their earthen vessels were in effect nothing else but printing, and the letters on the matrices or stamps used for making these impressions were necessarily reversed, as printing types; several of these matrices are extant in the British Museum, and in other places, which are cut out of, or are cast in one solid piece of metal.

Many hundred pieces of the Roman pottery, impressed with these stamps have been found in the sands near Reculver in Kent, and on the eastern side of the Isle of Shepway, where they are frequently dragged up by the fishermen. The art of impressing legends upon coins is nothing more than printing on metals.

It is generally allowed, that printing from wooden blocks has been practised in China for many centuries. According to the accounts of the Chinese, and of P. Jovius, Osorius, and several other Europeans, printing began there about the year of Christ 927, in the reign of Ming-Tcoung, the second emperor under the dynasty of Heou-Thang: several of these blocks, which are cut upon ebony, or on wood exceedingly hard, are now in England. The Historia Sinensis of Abdalla, written in Persic in 1317, speaks of it as an art in very common use. Our countryman, Sir John Chardin, in his Travels, confirms these accounts.

Printing then may be considered as an Asiatic, and not a European invention.

The first printing in Europe was from wooden blocks, whereon a whole page was carved exactly in the same manner as is now practised by the Chinese, who print only on one side of their paper, because it is so exceedingly thin, that it will not bear the impression of their characters on both sides.

The earlier printers in Europe printed only on one side of the paper for some time after the introduction of the art; they pasted the blank sides together, which made them appear as one leaf.

The European blocks were carved upon beech, pear-tree, and other soft woods, which soon failed, and the letters frequently broke; this put them upon the method of repairing the block, by carving new letters, and gluing them in, which necessity, seems to have suggested the hint of moveable types of metal; these were not so liable to break as the soft European woods, which had been before used.

One great and obvious advantage of moveable types was, that by separating them they would serve for any other work; whereas the blocks of wood served only for one work: though the use of moveable metal types was a very fortunate discovery, yet they derived their origin rather from the imperfection or unfitness of our woods for printing blocks, than from any great ingenuity of those who first used them. In short, necessity, the mother of all arts, introduced moveable types.

It has been a matter of contest, who first practised the art of printing in Europe. Faust or Fust of Mentz, Guttenberg of Strasburgh, and Coster of Haerlem, have each their advocates. The pretensions in favour of Fust seem to be best supported; but we shall not trespass upon the patience of our readers by entering into a discussion of this matter, because such a discussion would, in our opinion, be of little importance, it having been generally agreed, that printing with moveable types was not practised till after the middle of the fifteenth century, although prints from blocks of wood are traced as far back as the year 1423.

It seems probable, that the art of printing might have been introduced into Europe by some European who had travelled into China, and had seen some of their printing tablets, as it is known that several Europeans had been over-land into China before this time; and what strengthens this probability is, the Europeans first printed on one side of the paper only, in the same manner as the Chinese do at present; but however this may be, the progress of the art was as follows:

First, pictures from blocks of wood without text.

Secondly, pictures with text.

Thirdly, whole pages of text cut on blocks of wood, sometimes for the explanation of prints which accompanied them. And,

Fourthly, moveable types. Specimens of all which are given in the Idée generalé des Estampes.

There are several ancient blocks extant which were used in the fifteenth century; some are in possession of Capt. Thompson, of Dulwich, in Kent.

I presented a block to Earl Spencer carved on a soft wood, which is the second in the "Historia Sancti Johannis Evangelistæ ejusque Visiones Apocalypticæ," generally called the Apocalypse.

Two of the copies of the book, to which the block referred to belongs, were formerly in the library of Mons. Gaignat: they are now in his majesty's library at the queen's house. These books are printed on one side of the paper only.

The Speculum Humanæ Salvationes is also printed on one side of the paper; a copy of it is in Earl Spencer's library, who has several of these early books printed on one side of the paper.

The History of the Old and New Testament in folio is also printed on one side of the paper. There is a complete copy of this work in his majesty's library, which was purchased from that of Mons. Gaignat. Earl Spencer has also a copy. Mr. Heineken says, there is one copy of this work in the library of the Senate of Leipsic, containing forty leaves; one was in that of the Duke de la Valliere, which has only twenty-two leaves; and one in the Electoral library at Dresden, besides several others.

The Ars Moriendi contains twelve leaves, printed on one side of the paper only; there is a copy of the first edition of this work in the library at Wolfenbuttel; and there are seven leaves of this edition in the public library at Memmingham. There are several other editions of this work; for an account of which see Heineken's Idée generalé d'Estampes, in which mention is made of other books printed on one side of the paper from carved blocks of wood without dates, which are supposed to have been printed between 1440 and 1450.

Fust and Guttenberg are reported to have printed the bible at Mentz, in 1450, or before the end of the year 1452, but several writers have doubted the fact, and assert, that the first edition of the bible was in 1462. Mons. de Bure says, that Fust and Guttenberg printed the bible in 1450, though it is without a date, and that there are different copies of it; one in the King of Prussia's library; one in the Benedictine convent near Mentz; and another was in the library of Cardinal Mazarine; but it is probable that they omitted the Colophon in several copies, in order to sell them as MSS. which Fust afterwards attempted, particularly at Paris in 1466. Fust and Guttenberg are also said to have used moveable types of wood, but I cannot believe that more than a few pages were ever printed by them with such types.

Guttenberg separated from Fust in 1455; and Fust with Schoeffer, his servant and son-in-law, printed a Psalter at Mentz, in 1457, with moveable types: the capitals were of wood, and the small letters of metal; but Meerman says, that these were cut types, and not the improved cast types; and asserts, that the first book printed with the latter, was Durandi Rationale, printed at Mentz, in 1459.

Heineken (p. 264) mentions several copies of the Psalter of Mentz, particularly a very fair one in the Imperial library at Vienna; at the end of which are the following words:

"Presens Psalmorum codex venustate capitalium decoratus rubricationibusque sufficienter distinctus, ab inventione artificiosa imprimendi ac characterisandi, absque calami exaracione sic effigiatus, ad Eusebiam dei industrie est consummatus per Joannem Fust civem Moguntinum, et Petrum Schoeffer de Gernszheim, Anno Domini Millesimo CCCCLVII. in Vigilia Assumptionis."

His majesty has lately procured a fine copy of this rare book for his noble library; and Earl Spencer has also one very fair; besides these, there are only four others known to be extant. Earl Spencer has also another edition of this Psalter, printed at Mentz in 1459. His lordship has also an Indulgence printed in moveable metal types in 1455, during the pontificate of Nicholas the Fifth.

In 1460 Fust and Schoeffer published with their improved types the Catholicon, which hath the following Colophon:

"Altissimi presidio, cujus nutu infantium lingue fiunt diserte. Quique numero sepe parvulis revelat, quod sapientibus celat. Hic liber egregius Catholicon, Dominice incarnationis annis M.CCCC.LX. alma in Urbe Moguntina Nationis inclite Germanice, quam Dei clementia tam alto ingenii lumine donoque gratuito, ceteris terrarum Nationibus præferre illustrareque dignatus est. Non calami, styli aut penne suffragio, sed mira patronarum formarumque concordia proportione et modulo impressus atque confectus est."

There is a fine copy of this edition in his majesty's library at the queen's house; another copy is in the Royal library at Paris.

In 1462 Fust and Schoeffer printed an edition of the Bible at Mentz in two volumes folio, in Gothic characters, which is justly esteemed a good performance; there are several copies of this edition extant, particularly one in his majesty's library, where there is a fair copy of the New Testament, of the same place and date, printed on vellum. If the pretended edition of 1450, without the Colophon was compared with this of 1462, the question, whether they are different editions or not, would be decided.

In 1465, Fust and Schoeffer priuted at Mentz an edition of Tully's Offices, and in the next year another edition of the same work. Some have asserted, that these were one and the same book, but both the editions are in his majesty's library, which I have seen. The Colophon to that first printed is as follows:

> Presens Marci Tullij clarissimu͞ opus. Johannes Fust, Mogu͞tinus civis. no͞ atrame͞to. plumali ca͞na neq͞ aerea. Sed arte quadam perpulcra. *Petri manu pueri mei* feliciter effeci finitum. Anno M. cccc. lxv.

The second edition hath this Colophon:

> Presens Marci Tullij clarissimu͞ opus. Johannes Fust Mogu͞tinus civis. no͞ atrame͞to, plumali ca͞na neq͞ aerea. Sed arte quadam perpulcra. *manu Petri de Gernshem pueri mei* feliciter effeci finitum. Anno M. cccc.lxvi. *quarta die mensis februarij, &c.*

From the year 1462 the art of printing spread very rapidly through Europe, and was encouraged by the sovereigns of every nation. In 1465 the Institutes of Lactantius, were printed in the Sublacensian monastery near Rome: this is said to have been the first attempt towards printing in Italy; a fair copy of this book is in his majesty's library; the letters are partly Gothic.

John Bember printed at Augsburg in 1466.

In 1467, printing was practised at Rome, by Sweynheim and Pannartz. Their first book was Cicero's Familiar Epistles. In the next year they printed several books. In 1469 they published an elegant edition of Aulus Gellius. In the same year John de Spira produced from his press at Venice his most beautiful edition of Pliny's Natural History; which is printed in elegant Roman types, in a manner which would do credit to the present times.

In the course of the next year Spira published an edition of Virgil, which though well printed is not to be compared with the book last mentioned.

In the year 1472 Nicholas Jenson printed at Venice a most elegant edition of Pliny's works; he seems to have endeavoured to excel his master Spira: both these beautiful editions of the works of Pliny are in the Royal library in the Queen's house, and also in earl Spencer's library, and they may be truly said to be in the perfection of the art. Jenson's edition of Aulus Gellius, printed in the same year, doth him great credit.

In 1470 printing was practised at Paris, Cologne, and Milan.

In the year 1471, Sixtus Riessenger printed at Naples, and Andrew Gallus at Ferrary. Henry Eggestein had a printing press at Strasburgh. There were also presses in this year at Bologna and at Lubec.

In 1472, Bernard and Dominic Cenini printed at Florence: in the same year printing presses were established at Padua, Parma, Mantua, and Verona: in this year printing was practised in Saxony, and in a few years afterwards in the most considerable parts of Europe.

Italy claims the honour of first printing in Greek characters. In the edition of Lactantius's Institutes above mentioned, which appeared in the 1465, the quotations from the Greek authors are in very neat Greek letters. Earl Spencer has a fair copy of this book.

The first whole book that was printed in that language, is supposed to have been the Grammar of Constantinus Lascaris in 4to, produced from the press of Dionysius Palavisinus at Milan in 1476. In 1481 the Greek Psalter was printed in that city, as were Æsop's Fables in 4to.

In 1486 two Greek books were printed at Venice, namely, the Psalter, and the Batrachomyomachia; the former by Alexander, the latter by Laonicus, both natives of Crete; these books are printed in uncommon characters, the latter of them with accents and spirits, and also with scholia. Earl Spencer has a fair copy of this work.

The folio edition of Homer's works, which was produced from the press of Demetrius, a native of Crete, who first printed Greek at Florence in 1488, eclipsed all former publications in this language. A fine copy of this edition is in the library of the Royal Society, and another in earl Spencer's, and two more in the British Museum.

In 1493, a fine folio edition of Isocrates was printed at Milan, by German and Sebastian. All the above works are prior in time to those of Aldus, who is erroneously supposed to have been the first Greek printer; but the beauty, correctness, and neatness of his editions place him in a much higher rank than his predecessors; and his characters in general were more elegant than any before used. He was born in 1445, and died in 1515, and was the inventor of the Italic characters, which are still used, called from him Aldine or Cursive. The Greek editions of the celebrated family of Stephens are much esteemed.

Printing in Hebrew was practised as early as 1477, when the Psalms appeared in that language. In 1482 the Pentateuch was printed. In 1484 the prior Prophets; the posterior, in 1486.—The Hagiographia, in 1487, and the whole Bible Text in one volume at Sancino with vowel points by Abraham fil. Babbi Hhaiim in 1488.

The first Polyglott work was printed at Genoa 1516, by Peter Paul Porrus, who undertook to print the Pentaglott Psalter of Augustin Justinian, bishop of Nebo. It was in Hebrew, Arabic, Chaldaic, and Greek, with the Latin verses, glosses, and scholia, which last made the eighth column in folio. In 1518 John Potken published at Cologne, the Psalter in Hebrew, Greek, Latin, and Ethiopic. In the year 1522 the Complutensian Bible, consisting of six large folio volumes, was printed under the auspices of that great man, cardinal Ximenes. A polyglott Pentateuch, was printed at Constantinople in 1546, and another in 1547.

In the year 1636 the congregation, *pro propaganda Fide*, at Rome, had types for the Samaritan, for the Syriac, both Fshito, and Estrangelo, for the Coptic, for the Armenian, and for the Heraclean or ancient language of the Chaldees. Since which time they have cast types for the Gentoo, Tartar, Bramin, Bengalese, Malabaric, and several other Asiatic languages.

Some years ago Ferdinand the late prince of Parma furnished that University which he re-established, with the types of twenty different eastern languages, which appear in a most magnificent book printed at Parma, at the Royal press in 1775, on the marriage of the prince of Piedmont with Mary Adelaide Clothilda of

France, in twenty-four languages. This book is in his Majesty's library.

OF PRINTING IN ENGLAND.

William Caxton hath been generally allowed to have first introduced and practised the Art of Printing in England in the reign of king Edward IV. He was born in the Weald of Kent, and was first a citizen and mercer of London; at length he became a reputable merchant, and in 1464 he was one of the persons employed by king Edward IV. in negociating a treaty of commerce with the duke of Burgundy, and was afterwards patronised by Margaret duchess of Burgundy, sister to that king. Caxton having received a good education in his youth, had a taste for learning, and made himself master of the Art of Printing. He tells us himself, that he began to print his translation of "Le Recueil des Histoirès de Troyes," at Bruges in 1468, that he continued the work at Ghent, and that he finished it at Cologne in 1471. A fair copy of this book is in his Majesty's library.

The first book, which Caxton printed in England, was the Game at Chess, which was finished in the Abbey of Westminster the last day of March 1474. In 1475 he printed the Book of Jason. In 1477 the Dictes and Sayinges of the Philosophers. For an account of the other books printed by Caxton, see Herbert's History of Printing.

The first letters used by Caxton were of the sort called Secretary, and of these he had two founts: afterwards his letters were more like the modern Gothic characters, written by the English Monks in the fifteenth century. Of these he had three founts of Great Primer, the first rude, which he used in 1474; another something better; and a third cut about the year 1488. Besides these he had two founts of English or Pica, the latest and best of which were cut about 1482; one of Double Pica, good, which first appeared in 1490; and one of Long Primer, at least agreeing with the bodies which have since been called by those names; all these resemble the written characters of that age, which have been distinguished by the name of Monkish-English. Those characters nearly resemble their prototypes used by the first printers in Germany.

In the year 1478 printing was first practised in the two Universities of Oxford and Cambridge; and two years afterwards we find a press at St. Alban's. Specimens of the first types used by Caxton, and by printers at the places above mentioned, may be seen in Herbert's History of Printing.

Caxton lived till the year 1491, when he was succeeded by Wynkyn de Worde, who had served him for many years, and was connected with him in business at the time of his death. Wynkyn made considerable advances in the Art of Printing, and enriched his foundery with a variety of new types; his letters were what are called the Old English (or Square English), which have been the pattern for his successors for black letter printing. He is said to have first brought into England the use of round Roman letters, though it does not appear that he ever printed in those letters. The first Roman, which I remember to have seen, is a marginal quotation in Pica, at the latter end of the second part of a book intituled, "the Extirpation of Ignorancy compyled by Sir Paule Bushe, Preeste, and Bonhome of Edyndon," printed by Pynson without a date; but in 1518 Pynson printed a book wholly in Roman types, as appears in Ames (p. 120). Pynson's contemporary, William Faques, in 1503 made a fount of English letters, equal, if not exceeding, in beauty, any which our founders at this day produce. The favourite characters of these times were large types, and particularly Great Primer. Although considerable progress was made in the Art of Printing in the fifteenth century, yet the English presses produced no works in the Greek, or in the Oriental languages till the sixteenth. The first Greek book I knew of, that was printed in England, is the Homilies set forth by Sir John Cheke, and printed at London in 1543, by Reg. Wolfe. It is true, that about the year 1523 Sibert of Cambridge printed a few Greek quotations interspersed among his Latin; but I do not find, that he printed any whole book in the Greek language.

About the year 1567 John Daye, who was patronised by archbishop Parker, cut the first Saxon types, which were used in England. In this year Asserius Mnenevensis was published by the direction of the archbishop in these characters; and in the same year archbishop Ælfric's Paschal Homily; and in 1571 the Saxon gospels. Daye's Saxon types far excel in neatness and beauty any which have been since made, not excepting the neat types cast for F. Junius at Dort, which were given by him to the University of Oxford.

Notwithstanding cardinal Wolsey founded a Hebrew lecture at

Cambridge in the beginning of the sixteenth century, no books were printed here in Hebrew characters before the year 1592, when Dr. Rhese published his Institutiones Linguæ Cambro-Britannicæ.

In the year 1657 the English Polyglott in six volumes folio was printed at London, under the auspices of archbishop Usher and bishop Walton. This magnificent work was begun in 1653, and contains the sacred text in the Hebrew, Samaritan, Syriac, Chaldean, Arabic, Persic, Æthiopic, Greek, and Latin languages, all printed in their proper characters. Besides the characters exhibited in the body of this great work, the Prolegomena furnish us with more; namely, the Rabbinical, the Hebrew, the Syriac duplices, Nestorian, and Estrangelan, the Armenian, the Egyptian, the Illyrian, both Cyrillian and Hieronymian, the Iberian, and the ancient Gothic. Most of the rare books above specified are to be found in his Majesty's library at the Queen's house, in the British Museum, or in that of earl Spencer.

The greatest difficulty, which the first letter-founders had to encounter, was the discovery of the necessary number of each letter for a font of types in any particular language; and in order to know this they would endeavour to find out how much oftener one letter occurred than another in such a language. Perhaps this discovery was made by casting off the copy, as the printers call it; which is by calculating the number of letters necessary for composing any given number of pages, and by counting the number of each letter which occurs in those pages; this would in some degree have pointed out the proportional number of one letter to another, but whether it was done by this, or by what other method, is not easy to discover: however it is generally supposed, the letter-founder's bill was made in the fifteenth century, but on what principle all writers are silent: the various ligatures and abbreviations used by the early printers made more types necessary than at present.

Printers divide a font of letters into two classes, namely, the upper-case and the lower-case. The upper-case contains large capitals, small capitals, accented letters, figures, and marks of references. The lower-case contains small letters, ligatures, points, spaces, and quadrates.

[*Astle.*

CHAP. III.

IMITATIVE ARTS, COMPRISING, DESIGNING, PAINTING, ENAMELLING, PRINTING, ENGRAVING, SCULPTURE, POTTERY, AND PORCELAIN-MODELLING.

SECTION I.

Knowledge of the Ancients in respect to the Imitative Arts.

It was not, to the philosophy of light, shade, and colours alone, that the ancients directed their attention. They made a practical use of them in the elegant arts of designing and painting, in all the different branches of which they acquired a degree of perfection which may well vie with that of later ages. Those who have studied the history of these arts, as anciently but satisfactorily compiled by Pliny, must be convinced, that there is scarcely a style of modern drawing or colouring which was not known to the Greeks; who united to these exquisite accomplishments all the collateral ramifications of embroidery, tapestry, brocading, damask-work, in the time of Homer denominated εμπαιστα, and every species of mosaic, which, according to the Roman annalist, had a different denomination assigned to each. Thus, we meet with one set of arranged and coloured stones which was called lithostrata; another, opus tesselatum; a third, musivum; fourth, emblematical; and a fifth, vermiculatum; many of several kinds of which are still carefully preserved in St. Peter's church at Rome, and contribute, in no small degree, to the splendour of that magnificent edifice. Their inlaid works, however, were not confined to stone and marble; they extended to horn, tortoise-shell, and ivory: and Pliny makes express mention of several exquisite proofs of their taste and ingenuity in inlaying tables, and other furniture, with a mixture of ivory, and woods or barks differently coloured, so as to produce the effect of a finished picture or medallion.

From whom the Greeks derived their first knowledge of designing we know not. According to Pliny, Telephanes of Sicyon and Ardices of Corinth equally contended for the honour; but the species of design he first adverts to, an invention, indeed, prior to the æra that can be ascribed to these artists, is the rude and incondite method of tracing the mere outline of the human shadow when projected upon a wall, a method which still exists among ourselves under the name of a *silhouette,—brâ hominis lineas circumducta.*

This species of drawing, and, probably, painting, strictly so called, must have been of very early origin indeed. Embroidery and tapestry, in which colours were introduced, we know to have been of high antiquity even among the Jews and Babyloneans; but both these arts presuppose the existence of outlines, or line drawings, for the artist necessarily worked from a pattern. The history of Pandion, king of Athens, and of his daughter Philomela, who informed Progné of her misfortunes by describing them on tapestry, may, perhaps, be fabulous. Be this, however, as it may, we know that this fable is of very remote origin, and as it is related by Apollodorus, was, probably, the production of one of the Cyclic poets, concerning whom the reader will find an account in Note on Book V. v. 339. of the present version. According to this admirable mythologist, Philomela did not indeed paint her history, but embroidered it in characters on a veil. Yet, at the period when this fable was invented, we can scarcely conceive, that embroidery was confined to the exhibition of characters alone; it was unquestionbly employed, and with more freedom, in the art of tracing and designing. In the time of Homer, however, we have undoubted proof of the application of tapestry to the dignity of historical subjects. Iris, in the third book of the Iliad, finds Helen occupied in representing on tapestry the evils which the Greeks and Trojans had suffered on her account in their battles. Such an undertaking, even supposing it were executed in cammeo, or with a single colour, evinces a considerable perfection of the art she was practising. But the Trojans are stated to have been also acquainted with the mode of intermixing different colours in their tapestries. When Andromache learned the death of Hector, she was at work in a retired part of her palace, and representing, in tapestry, flowers of a variety of tinctures,

> *Αλλ, ηγ' ιστον υφαιν μυχω δομου 'υψηλοιο,*
> *Διπλακα, μαρμαρεην, εν δε θρονα ποικιλλ' επασσε.*
>
> Il. K. 439.

Far in the close recesses of the dome
Pensive she ply'd the melancholy loom;
A growing work employed her secret views,
Spotted diverse with intermingled hues. Pope

To the mere outline or silhouette, the Corinthian or Sicyonian artist, according to Pliny, added strokes to its interior, —*jam tunc spargentes lineas intus;* a style which is yet retained whenever the quill or the crayon is employed; and some admirable drawings, in which are still preserved at Rome as the production of Polydore of Caravagio, a celebrated pupil of Raphäel; the mode of executing which is denominated by the Italians *al sgrafitto.* Our historian then advances to a second epoch, regarding the mere outline, and the outline with internal strokes as one and the same, although I cannot but agree with M. Levesque, in his very ingenious essay on this subject, (Mem. de l'Instit. Nat. Lit. et B. Arts, I.) that the former must, for a long period, have preceded the latter. This second epoch of Pliny comprises the use of a single colour alone, and its style was, in consequence, denominated by the Greeks, Monochromaton, and is still retained, in modern times, under the appellation of *cammeo.* For this improvement the Roman historian presents us with two competitors also, without deciding on the superiority of their pretensions; Philocles, whom he asserts to have been of Egypt, and Cleanthes of Corinth. This seems to have been a great improvement upon the style of stroke or linear drawing; for although the former may have been founded upon an observation of the effects of light and shade, and an attempt to introduce such effects upon paper, yet, every attempt must, in the first instance, and by the use of strokes alone, have been harsh and inharmonious; it must have wanted relief, and been incapable of exhibiting the gradual softness, recession, and rotundity which are every where to be met with in nature. This alone is to be obtained in any high degree, by the introduction of colour, although that colour be, as in the present instance a monochrome, or simple individual hue, diversified, as we must naturally suppose it to have been, by the gradual admixture of some other substance, which, without presenting any second hue, would progressively modulate its tones; as when black, for example, is the only tint resorted to, and its different shades are produced by different combinations of white. It is to these melodious combinations of tints, apparently opposite, in which the black alone maintains the supremacy, that the Italians have given the name of *chiaro-scuro*, or *clear obscure.* From this advantage gained to the art, it is easy to trace its ascent to the life and harmony of colouring properly so called—to the æras of Panænus, Polygnotus, and Zeuxis—to the exquisite paintings of the

Pæcile—and the meridian age of Appelles, who, in the language of Cicero, consummated this noble invention—"*jam perfecta*," said he, "*sunt omnia.*" To draw a comparison between these and others of equal celebrity, and the painters of modern times, would be as invidious as foreign to the plan I have prescribed to myself. It is enough to observe, that their excellence has been admitted, to its utmost extent, by Raphäel and Poussin; and we cannot err in applauding them after such antecedent panegyrics.

Upon the subjects of Grecian statuary and engraving, so nearly connected with painting, I have not space to enter. The perfection of the former art may be fully appreciated from the precious reliques which have descended to our own days; and that of the latter, from the description of the shields of their heroes as presented to us by their poets. But I ought not to forbear noticing, that amidst many other proofs of their ingenuity, which are totally lost to us, is to be enumerated their mode of encaustic painting as well in wax as on ivory. Of the inventors of these very curious arts we know nothing. The style of painting in wax was in common use at least as early as the age of Anacreon, who, as the friend of Polycrates of Samos, must have flourished upwards of five hundred years anterior to the Christian æra; for he expressly mentions it in several places, and particularly in Ode xxviii. in which he gives his direction to the painter, who was taking a likeness of his mistress.

> *Απεχει· βλεπω γαρ αυτην·*
> *Ταχα κηρε, και λαλησεις.*

> Enough—'tis she—her air, her cheek—
> O WAX! thou soon wilt learn to speak.

There was also another mode of employing wax in ship-painting, which was obviously invented for the sake of duration, but which is equally lost to us. The little with which we are acquainted of these different methods is preserved by Pliny in the following passage, xi. 41: Encausto pingendi duo fuisse antiquitus genera constat, cerâ et in ebore, cestro, id est, verculo; donec classes pingi cœpere. Hoc tertium adcessit, resolutis igni ceris penicello utendi; quæ pictura in navibus nec sole nec sale, ventisque corrumpitur. "There were formerly two modes of painting in encaustic, with wax, and on ivory, by the use of a cestrum, or graver, till, at length, ships began to be painted. A third mode was then invented, which consisted in employing a pencil brush with wax dissolved over a fire; which produced a painting for vessels that was never injured by the sun, the sea-water, or the winds." The passage is by no means perspicuous; and Pliny, who was no painter himself, does not appear to have been in the secret in either case. All we can collect is, that every mode was alike encaustic, or corrosive by means of fire: that, in the two former, a cestrum or pointed graver was employed; and, in the latter, a pencil-brush. M. Levesque observes, therefore, as has been observed also by M. Scheffer, (Graphice, par. 16.) that the painting upon ivory was less properly a painting than an engraving, the point of the graver being heated in the fire to a red heat—that the lines were of one colour alone, and this a black or a tawny. I know not, however, what reason these writers have for limiting the encaustic painting on ivory to any individual colour: those in wax, most assuredly comprehend every kind and combination of colour; for, in the ode of Anacreon above referred to, he makes express mention of black, white, blue, and red; and as the instrument employed in both these modes was the same, as they were both effected by a similar process of fire, and as Pliny does not inform us that there was any difference in the application of the instrument, we may as readily suppose that the encaustic on ivory admitted the introduction of different colours, as the encaustic in wax. M. le Compte de Caylus imagined he had recovered the Grecian mode of encaustic ship-painting a few years ago; but his method, though ingenious, is rather a new invention than a revival of that spoken of by Pliny; in the language of M. Levesque, it is an ustion rather than inustion; καυσις but not εγκαυσις.

[*Good's Translation of Lucretius, Note to book 5, v. 327.*

SECTION II.

Painting in Glass.

The ancient painting in glass was very simple: it consisted in the mere arrangement of pieces of glass of different colours in some sort of symmetry, and constituted what is now called Mosaic work. In process of time they came to attempt more regular designs, and also to represent figures heightened with all their shades: yet they proceeded no farther than the contours of the figures in black with water colours, and etching the draperies after the same manner on glasses of the colour of the object they designed to paint. For the carnation they used glass of a bright red colour; and upon this they drew the principal lineaments of the face, &c. with black. At length, the taste for this sort of painting improving considerably, and the art being found applicable to the adorning of churches, palaces, &c. they found out means of incorporating the colours in the glass itself, by heating them in a fire to a proper degree, having first laid on the colours. A French painter at Marseilles is said to have given the first notion of this improvement, upon going to Rome under the pontificate of Julius II; but Albert Durer and Lucas of Leyden were the first that carried it to any height.

This art, however, has frequently met with much interruption, and sometimes been almost totally lost; of which Mr. Walpole gives the following account in his Anecdotes of Painting in England: "The first interruption given to it was by the reformation, which banished the art out of churches; yet it was in some manner kept up in the escutcheons of the nobility and gentry in the windows of their seats. Towards the end of queen Elizabeth's reign, indeed, it was omitted even there; yet the practice did not entirely cease. The chapel of our Lady at Warwick was ornamented anew by Robert Dudley, earl of Leicester and his countess, and the cipher of the glass-painter's name yet remains, with the date 1574; and in some of the chapels at Oxford, the art again appears, dating itself in 1622, by the hand of no contemptible master,

"I could supply even this gap of 48 years by many dates on Flemish glass: but nobody ever supposed that the secret was lost so early as the reign of James I.; and that it has not perished since will be evident from the following series, reaching to the present hour.

"The portraits in the windows of the library at All Souls, Oxford. In the chapel at Queen's College there are twelve windows dated 1518. P.C. a cipher on the painted glass in the chapel at Warwick, 1574. The windows at Wadham-college; the drawing pretty good, and the colours fine, by Bernard Van Linge, 1622. In the chapel at Lincoln's Inn, a window, with the name Bernard, 1623. This was probably the preceding Van Linge. In the church of St. Leonard, Shoreditch, two windows by Baptista

Sutton, 1634. The windows in the chapel at University-college Henry Giles pinxit 1687. At Christ church, Isaac Oliver, aged 84, 1700. Window in Merton-chapel, William Price, 1700. Windows at Queen's New college and Maudlin, by William Price, the son, now living, whose colours are fine, whose drawing is good, and whose taste in ornaments and Mosaic is far superior to any of his predecessors; is equal to the antique, to the good Italian masters, and only surpassed by his own singular modesty.

"It may not be unwelcome to the curious reader to see some anecdotes of the revival of taste for painted glass in England. Price, as we have said, was the only painter in that stile for many years in England. Afterwards one Rowell, a plumber at Reading, did some things, particularly for the late Henry Earl of Pembroke; but Rowell's colours soon vanished. At last he found out a very durable and beautiful red; but he died in a year or two, and the secret with him. A man at Birmingham began the same art in 1756 or 1757, and fitted up a window for Lord Lyttleton in the church of Hagley, but soon broke. A little after him, one Peckitt at York began the same business, and has made good proficiency. A few lovers of that art collected some dispersed panes from ancient buildings, particularly the late Lord Cobham, who erected a gothic temple at Stowe, and filled it with arms of the old nobility, &c. About the year 1753, one Asciotti, an Italian, who had married a Flemish woman, brought a parcel of painted glass from Flanders, and sold it for a few guineas to the Hon. Mr. Bateman, of Old Windsor. Upon that I sent Asciotti again to Flanders, who brought me 450 pieces, for which, including the expence of his journey, I paid him 36 guineas. His wife made more journeys for the same purpose: and sold her cargoes to one Palmer, a glazier in St. Martin's lane, who immediately raised the price to one, two, or five guineas for a single piece, and fitted up entire windows with them, and with mosaics of plain glass of different colours. In 1761, Paterson, an auctioneer at Essex-house in the Strand, exhibited the two first auctions of painted glass, imported in like manner from Flanders. All this manufacture consisted in rounds of Scripture-stories, stained in black and yellow, or in small figures of black and white; birds and flowers in colours, and Flemish coats of arms."

The colours used in painting or staining of glass are very different from those used in painting either in water or oil colours.

For black, take scales of iron, one ounce; scales of copper, one ounce; jet half an ounce; reduce them to powder, and mix them. For blue, take powder of blue, one pound; nitre, half a pound; mix them and grind them well together. For carnation, take red chalk, eight ounces; iron scales, and litharge of silver, of each two ounces; gum-arabic, half an ounce; dissolve in water, grind altogether for half an hour as stiff as you can; then put it in a glass and stir it well, and let it stand to settle fourteen days. For green, take red lead, one pound; scales of copper, one pound; and flint, five pounds; divide them into three parts, and add to them as much nitre; put them into a crucible, and melt them with a strong fire; and when it is cold, powder it, and grind it on a porphyry. For gold colour, take silver, an ounce; antimony, half an ounce; melt them in a crucible; then pound the mass to powder, and grind it on a copper plate; add to it yellow ochre, or brick-dust calcined again, fifteen ounces; and grind them well together with water. For purple, take minium, one pound; brown stone, one pound; white flint, five pounds; divide them into three parts, and add to them as much nitre as one of the parts; calcine, melt, and grind it as you did the green. For red, take jet, four ounces; litharge of silver, two ounces; red chalk one ounce; powder them fine, and mix them. For white, take jet, two parts; white flint, ground on a glass very fine, one part; mix them. For yellow, take Spanish brown, ten parts; leaf-silver, one part; antimony, half a part; put all into a crucible, and calcine them well.

In all the windows of ancient churches, &c. there are to be seen the most beautiful and vivid colours imaginable, which far exceed any of those used by the moderns, not so much because the secret of making those colours is entirely lost, as that the moderns will not go to the charge of them, nor be at the necessary pains, by reason that this sort of painting is not now so much in esteem as formerly. Those beautiful works, which were made in the glass-houses, were of two kinds.

In some, the colour was diffused through the whole substance of the glass. In others which were far the most common, the colour was only on one side, scarce penetrating within the substance above one-third of a line; though this was more or less according to the nature of the colour, the yellow being always found to enter the deepest. These last, though not so strong and beautiful as the former, were of more advantage to the workmen, by reason that on the same glass, though already coloured, they could shew other kinds of colours where there was occasion to embroider draperies, enrich them with foliages, or represent other ornaments of gold, silver, &c.

In order to this, they made use of emery, grinding or wearing down the surface of the glass till such time as they were got through the colour to the clear glass. This done, they applied the proper colours on the other side of the glass. By these means, the new colours were hindered from running and mixing with the former, when they exposed the glasses to the fire, as will appear hereafter. When indeed the ornaments were to appear white, the glass was only bared of its colour with emery, without tinging the place with any colour at all; and this was the manner by which they wrought their lights and heightenings on all kinds of colour.

The first thing to be done, in order to paint or stain glass in the modern way, is to design, and even colour the whole subject on paper. Then they choose such pieces of glass as are clear, even, and smooth, and proper to receive the several parts; and proceed to distribute the design itself, or the paper it is drawn on, into pieces suitable to those of the glass, always taking care that the glasses may join in the contours of the figures, and the folds of the draperies; that the carnations and other finer parts may not be impaired by the lead with which the pieces are to be joined together. The distribution being made, they mark all the glasses as well as papers, that they may be known again: which done, applying every part of the design upon the glass intended for it, they copy or transfer the design upon this glass with the black colour diluted in gum-water, by tracing and following all the lines and strokes as appear through the glass with the point of a pencil.

When these strokes are well dried, which will happen in about two days, the work being only in black and white, they give it a slight wash over with urine, gum-arabic, and a little black: and repeat it several times, according as the shades are desired to be heightened; with this precaution, never to apply a new wash till the former is sufficiently dried. This done, the lights and risings are given by rubbing off the colour in the respective places with a wooden point, or the handle of the pencil.

As to the other colours above mentioned, they are used with gum-water, much as in painting in miniature; taking care to apply them lightly, for fear of effacing the outlines of the design; or even for the greater security, to apply them on the other side; especially yellow, which is very pernicious to the other colours, by blending therewith. And here to, as in pieces of black and white, particular regard must always be had not to lay colour on colour, or put on a new lay, till such time as the former is well dried.

When the painting of all the pieces is finished, they are carried to the furnace to anneal or bake the colours.

Having often been delighted with the grand effect produced by the windows of stained glass in old churches and monasteries, we have regretted that such fine and durable colouring should, in so many cases, have been prostituted upon wretched designs inferior to the productions of our sign post daubers. We have wished that some mode could be devised of copying and multiplying pictures upon glass—some mechanical mode, which should require the aid of the artist in the first instance only, and leave all the subsequent operations to be performed by inferior hands, as in the case of copper-plate printing. Portraits at least, on a single piece of glass which should perpetuate the features of great men and beautiful women, secure from that decay of colour and of canvas which has already begun to obliterate the finest paintings of the greatest artists whom the world has ever produced, might possibly be produced in the following way.

Suppose, after the outline of a likeness is drawn, that blocks were cut from it after the same manner as for callicoes, or paper-hangings, only with superior nicety, and in greater number for the purpose of multiplying and better blending the tints.

Enamellers must determine what shall be the proper substances for the different colours, and with what liquid they shall be moistened, that they may be readily taken up by the blocks, and thence transferred to another body by pressure.

From these blocks, and with these colours, let the figure be printed on paper: and, to prevent inaccuracy in bringing the separate parts, cut on the different blocks, to unite into a complete whole, let the paper be placed under a frame secured in an immoveable position during the operation. The blocks being accurately squared, all exactly of the same dimensions, and each nicely fitting the frame, cannot, in passing through it to deliver their several impressions, make the smallest deviation from their intended places, but must produce an exact picture—at least on the paper.

To transfer that impression to glass, is, indeed, a work of nicety and difficulty. Were it not for some smaller strokes which must necessarily be in wood, the entire impression might in the outset be made on the glass itself, without any intervention of paper; since experience has proved to the calico-printers, that the great masses of colour cannot be successfully delivered from wood; wherefore they are obliged, in those parts of their patterns, to use bits of smooth worn-out beaver-hat, which might very well be pressed on the glass-plate.

However, from what we every day see effected in the case of prints affixed to glass without any of the paper remaining, and also of copper-plate embellishments upon porcelain and queen's ware, we doubt not that the picture, while fresh, may, by well managed pressure, be transferred from the paper to an even plate of ground glass coated with a proper gluten which shall not, at least not materially, offuscate its transparency; and experiment must determine whether the paper may afterward be gently drawn or peeled off, or must be burned away, or destroyed by a corrosive liquid, if any such can be found which will not injure the colours.

Suppose, however, the operation of removing the paper to be satisfactorily performed, proceed we now to secure the indelibility of the picture.

Let a square plate of cast-iron, an inch or two in thickness, and as level and smooth as possible, be furnished on every side with a metal ledge rising an inch or more in height, which ought to be in two separate pieces, the one permanently fastened to the plate, the other capable of being removed at pleasure, for the purpose of laying in and taking out the glass without violence.

Within that ledge let the glass be fitted, closely touching it on every side, and lying with the painted surface uppermost. Upon this lay another plate of glass, fitted in the same manner.

Let, now, the metal frame, with the inclosed glasses, be exposed to the action of fire until the glass plates, without being melted to absolute fluidity, shall nevertheless become sufficiently soft to coalesce into one body under a strong pressure. The body which conveys the pressure, and lies in immediate contact with the glass, must equally fit and completely fill the entire space between the ledges, that there be no room for the soft glass to spread in any direction.

Those who have witnessed the process pursued in softening tortoise-shell in the fire, and pressing it into the various shapes of snuff-boxes, *étuis*, &c. &c. will not conceive much difficulty in this use of the glass. It may be managed by the aid of a machine somewhat similar to, but more powerful than, a common printing press, with a solid metal platine, to fit and fill the frame, as above; though much better contrivances may be found among the multifarious engines employed at Birmingham for the purposes of coining, and striking the heavy dies, than any we can possibly suggest. In whatever manner the two glasses may be pressed into union, the united body may be afterward ground and polished.

[*Pantologia. Walpole.*

SECTION III.

Enamelling.

The delicate and beautiful art of enamelling consists in the application of a smooth coating of vitrified matter (transparent or opaque, and with or without colour, figures and other ornaments), to a bright polished metallic substance. It is, therefore, a kind of varnish made of glass, and melted upon the substance to which it is applied, and affording a fine uniform ground for an infinite variety of ornaments which are also fixed on by heat.

The general principles on which enamelling is founded, are on the whole very simple, but, perhaps, there is none of all the chemico-mechanical arts which requires, for the finer parts, a greater degree of practical skill and dexterity, and of patient and accurate attention to minute processes.

The concealment observed by those who profess this art, is proportioned to the difficulty of acquiring it; the general chemist must, therefore, content himself with the general principles of enamelling, and the detail of those particulars that are commonly known.

Though the term enamelling is usually confined to the ornamental glazing of metallic surfaces, it strictly applies to the glazing of pottery or porcelain, the difference being only that in the latter the surface is of baked clay. With regard to the composition of coloured enamels (which are all tinged by different metallic oxyds) a very general account of the substances used will suffice in this place, the rest of the subject having been treated of in the article of coloured glass. The enamelling on metals, therefore, will only be noticed in this place. The only metals that are enamelled, are gold and copper; and with the latter the opaque enamels are only used. Where the enamel is transparent and coloured, the metal chosen should be of that kind, as not only to have its surface unalterable when fully red hot, but also to be in no degree chemically altered by the close contact of melted glass, containing an abundance of some kind of metallic oxyd. This is the chief reason why coloured enamelling on silver is impracticable, though the brilliance of its surface is not impaired by mere heat, for if (for example) an enamel made yellow with oxyd of lead, or antimony is laid on the surface of bright silver, and kept melted on it for a certain time, the silver and the enamel act on each other so powerfully, that the colour soon changes from a yellow to an orange, and lastly to a dirty olive. Copper is equally altered by the coloured anamels, so that gold is the only metal which can bear the long contact of the coloured glasses at a full red heat, without being altered by them.

The simplest kind of enamel is that fine white opaque glass, which is applied to the dial plate of watches. The process of laying it on (which may serve as a general example of the art) is the following.

A piece of thin copper sheet, hammered of the requisite convexity, is first accurately cut out, a hole drilled in the middle for the axis of the hands, and both the surfaces made perfectly bright with a scratch brush.

A small rim is then made round the circumference, with a thin brass band rising a little above the level, and a similar rim round the margin of the central hole. The use of these is to confine the enamel when in fusion, and keep the edges of the plate quite neat and even. The substance of the enamel is a fine white opaque glass, the material of which will be presently mentioned. This is bought in lump by the enamellers, and is first broken down with a hammer, then ground to a sufficiently fine powder, with some water, in an agate mortar; the superfluous water being then poured off, the pulverised enamel remains of about the consistence of wetted sand, and is spread very evenly over the surface of the copper-plate by many dexterous manipulations. On most enamellings, and especially on this, it is necessary also to counter enamel the under concave surface of the copper plate, to prevent its being drawn out of its true shape, by the unequal shrinking of the metal and enamel on cooling. For this kind of work, the counter enamel is only about half the thickness on the concave as on the convex side. For flat plates, the thickness is the same on both sides.

The plate, covered with the moist enamel powder, is warmed and thoroughly dried, then gently set upon a thin earthen ring, that supports it only by touching the outer rim, and put gradually into the red hot muffle of the enameller's furnace. This furnace is constructed somewhat like the assay furnace, but the upper part alone of the muffle is much heated, and some peculiarities are observed in the construction, to enable the artist to govern the fire more accurately.

The precise degree of fire to be given here as in all enamelling, is that at which the particles of the enamel run together into an uniform pasty consistence, and extend themselves evenly over the surface, shewing a fine polished face, carefully avoiding on the other hand so great a heat as would endanger the melting of the thin metallic plate. When the enamel is thus seen to sweat down, as it were, to an uniform glossy glazing, the piece is gradually withdrawn and cooled, otherwise it would fly by the action of the cold air.

A second coating of enamel is then laid on and fired as before, but this time the finest powder of enamel is taken, or that which remains suspended in the washings. It is then ready to receive the figures and division marks, which are made of a black enamel, ground in an agate mortar, with much labour, to a most impalpable powder, worked up on a pallet with oil of lavender, or spike, and laid on with an extremely fine hair brush. The plate is then stoved to evaporate the essential oil, and the figure burnt in as before. The polishing with tripoli, and minuter parts of the process, need not be here mentioned.

If the enamel be chipped off a dial plate (which may be done with the utmost ease, by bending it backwards and forwards, as the adhesion between the metal and glazing is very slight) the part immediately in contact with the copper will be found deeply and nearly uniformly browned, which shews how unfit copper alone would be for the transparent enamels.

The regulation of the fire appears to be the most difficult of all the parts of this nice process, particularly in the fine enamelling of gold for ornamental purposes, of designs, miniatures, and the like, where three, four, or sometimes five separate firings are required. If the heat is too low, the enamel does not spread and vitrify as it ought; if too high, it may be enough to melt the metal itself, whose fusing point is but a small step above that of the enamel, or else (what is an equal mortification to the artist) the delicate figures, laid on with so much care and judgement, melt down in a moment, and the piece exhibits only a confused assemblage of lines, and fragments of designs.

The exact composition of the opaque white enamel, is a matter of considerable importance, and is procured by the enamellers from persons whose business it is to prepare it. A good enamel of this kind, fit to be applied to porcelain and metals, should be of a very clear fine white, so nearly opaque, as only to be translucent at the edges; and at a moderate red heat it should run into that kind of paste, or imperfect fusion which allows it to extend itself freely and uniformly, and to acquire a glossy even surface, without, however, fully melting into a thin glass. The opaque white of this enamel is given by the oxyd of tin, which possesses, even in a small proportion, the property of rendering vitrescent mixtures white and opaque, or in still less proportion, milky; and when otherwise coloured, opalescent. The oxyd of tin is always mixed with three or four times its quantity of oxyd of lead; and it appears necessary that the metals should be previously mixed by melting, and the alloy then calcined. The following are the directions given by Clouet for the composition of this enamel. Mix 100 parts of pure lead with from 20 to 25 of the best tin, and bring them to a low red heat in an open vessel. The mixture then burns nearly as rapidly as charcoal, and oxidates very fast. Skim off the crusts of oxyd, successively formed, till the whole is thoroughly calcined. It is better then to mix all the skimmings, and again heat as before, till no flame arises from them, and the whole is of an uniform grey colour. Take 100 parts of this oxyd, 100 of sand, and 25 or 30 of common salt, and melt the whole in a moderate heat. This gives a greyish mass, often porous and apparently imperfect, but which, however, runs to a good enamel when afterwards heated. This is the enamel used for porcelain, but for metals and finer works the sand is previously calcined in a very strong heat with a fourth of its weight, or, if a more fusible compound is wanted, as much of the oxyd of tin and lead as of salt is taken, and the whole melted to a white porous mass. This is then employed instead of the rough sand as in the above-mentioned process. The above proportions, however, are not invariable, for if more fusibility is wanted, the dose of oxyd is increased, and that of the sand diminished, the quantity of common salt remaining the same. The sand employed in this process, according to Mr. Clouet, is not the common sort, however fine, but a micaceous sand, in which the mica forms about one-fourth of the mixture.

Neri, in his valuable treatise on glass-making, has given long ago the following proportions for the common material of all the opaque enamels, which Kunckel and other practical chemists have confirmed. Calcine 30 parts of lead, with 33 of tin, with the precautions mentioned above. Take of this calcined mixed oxyd 50 pounds, and as much of powdered flints (prepared by being thrown into water when red hot, and then ground to powder), and eight ounces of salt of tartar; melt the mixture in a strong fire kept up for ten hours, after which reduce the mass to powder. This is the common material for the opaque enamels, and is of a grey white. To make this fine enamel quite white, mix six pounds of this material with 48 grains of the best black oxyd of manganese, and melt in a clear fire. When fully fused, throw it into cold water, then re-melt and cool as before two or three times, till the enamel is quite white and fine. Kunckel observes on this process, that he tried it without the oxyd of manganese, but the enamel, instead of being milk white, was blueish and not good, so that there is no doubt but that this oxyd is highly important. If too much is used, the enamel becomes of a rose purple. For further observations on this subject, see the article Glass. Coloured enamels are composed of a common basis, which is a fusible mixture of vitrifiable materials, and of some metallic oxyd. In general, the coloured enamels are required to be transparent, in which case, the basis is a kind of glass, composed of borax, sand, and oxyd of lead, or other vitrescent mixtures, in which the proportion of saline or metallic flux is more or less according to the degree of heat that the colouring oxyd will bear without decomposition. When the coloured enamel is to be opaque, or opalescent, a certain portion of the white opaque enamel, or of the oxyd of tin, is added to the mixture. The most beautiful and costly colour known in enamelling, is an exquisitely fine rich red, with a purplish tinge, given by the salts and oxyds of gold, especially the purple precipitate, formed by tin in one form or other, and nitro muriat of gold, and also by the fulminating gold. This beautiful colour requires much skill in the artist to be fully brought out. It is said, that when most perfect, it should come from the fire quite colourless, and afterwards receive its colour by the flame of a candle. Gold colours will not bear a violent fire.

Other and common reds are given by the oxyd of iron, but this requires the mixture of alumine, or some other substance refractory in the fire, otherwise at a full red heat the colour will degenerate into black.

Yellow is given either by the oxyd of silver alone, or by the oxyds of lead and antimony, with similar mixtures to those required for iron. The silver is as tender a colour as gold, and readily injured or lost in a high heat.

Green is given by the oxyd of copper, or it may also be procured by a mixture of blue and yellow colours.

Blue is given by cobalt ? and this seems of all enamel colours the most certain, and easily manageable.

Black is produced by a mixture of cobalt and manganese.

The reader may conceive how much the difficulties of this nice art are increased, when the object is not merely to lay an uniform coloured glazing on a metallic surface, but also to paint that surface with figures and other designs, that require extreme delicacy of outline, accuracy of shading, and selection of colouring. The enamel painter has to work, not with actual colours, but with mixtures, which he only knows from experience will produce certain colours after the delicate operation of the fire ; and to the common skill of the painter, in the arrangement of his pallet and choice of his colours, the enameller has to add an infinite quantity of practical knowledge of the chemical operation of one metallic oxyd on another, the fusibility of his materials, and the utmost degree of heat at which they will retain not only the accuracy of the figures which he has given, but the precise shade of colour which he intends to lay on.

Painting in enamel requires a succession of firings; first of the ground which is to receive the design, and which itself requires two firings, and then of the different parts of the design itself. The ground is laid on in the same general way as the common watch face enamelling already described. The colours are the different metallic oxyds, melted with some vitrescent mixture, and ground to extreme fineness. These are worked up with an essential oil (that of spike is preferred, and next to it oil of lavender) to the proper consistence of oil colours, and are laid on with a very fine hair brush. The essential oil should be very pure, and the use of this, rather than any fixed oil, is probably that the whole may evaporate completely in a moderate heat, and leave no carbonaceous matter in contact with the colour when red hot, which might affect its degree of oxidation, and thence the shade of colour which it is intended to produce. As the colour of some vitrified metallic oxyds (such as that of gold) will stand only at a very moderate heat, whilst others will bear, and even require, a higher temperature to be properly fixed, it forms a great part of the technical skill of the artist to supply the different colours in proper order; fixing first those shades which are produced by the colours that will endure the highest heat, and finishing with those that demand the least heat. The outline of the design is first traced on the enamel, ground and burnt in; after which, the parts are filled up gradually with repeated burnings, to the last and finest touches of the tenderest enamel.

Transparent enamels are scarcely ever laid upon any other metal than gold, on account of the discoloration produced by other metals, as already explained. If, however, copper is the metal used, it is first covered with a thin enamel coating, over which gold leaf is laid and burnt in. so that, in fact, it is still this metal that is the basis of the ornamental enamel. With regard to the vast number of important minutiæ in the selection and order of applying the colours, the management of the fire, &c. &c. almost the whole of what is known on this subject is confined to the practical artist, nor could this knowledge, if obtained, interest the general reader.

[*Pantolog. Clouet. Kunckel.*

SECTION IV.

Encaustic painting.

We have already observed* that this is an art upon which the ancients highly prided themselves: invented to fix by fire the colours made use of by the artist, who employed wax to give them a gloss, and preserve them from being injured by the air.

* Section 1, of the present Chapter.

This ancient art, after having been long lost, was restored by count Caylus, a member of the Academy of Inscriptions in France; and the method of painting in wax was announced to the Academy of Painting and Belles Letters, in the year 1753; though M. Bachelier, the author of a treatise De l'Histoire & du Secret de la Peinture en Cire, had actually painted a picture in wax in 1749; and he was the first who communicated to the public the method of performing the operation of inustion, which is the principal characteristic of the encaustic painting. The count kept his method a secret for some time, contenting himself with exhibiting a picture at the Louvre in 1754, representing the head of Minerva, painted in the manner of the ancients, which excited the curiosity of the public and was very much admired. In the interval of suspense, several attempts were made to recover the ancient method of painting. The first scheme adopted was that of melting wax and oil of turpentine together, and using this composition as a vehicle for mixing and laying on the colours. But this method did not explain Pliny's meaning, as the wax is not burnt in this way of managing it. In another attempt, which was much more agreeable to the historian's description of encaustic painting, the wax was melted with strong lixivium of salt of tartar, and with this the colours were ground. When the picture was finished, it was gradually presented to the fire, so as to melt the wax; which was thus diffused through all the particles of the colours, so that they were fixed to the ground, and secured from the access of air or moisture. But the method of count Caylus is much more simple: the cloth or wood which he designed for the basis of his picture is waxed over, by only rubbing it simply with a piece of bees-wax; the wood or cloth, stretched on a frame, being held horizontally over, or perpendicularly before, a fire, at such a distance, that the wax might gradually melt, whilst it is rubbed on, diffuse itself, penetrate the body, and fill the interstices of the texture of the cloth, which, when cool, is fit to paint upon; but as water colours, or those that are mixed up with common water, will not adhere to the wax, the whole picture is to be first rubbed over with Spanish chalk or white, and then colours are applied to it; when the picture is dry, it is put near the fire, whereby the wax melts and absorbs all the colours.

Mr. J. H. Muntz, in a treatise on this subject, has proposed several improvements in the art of encaustic. When the painting is on cloth, he directs it to be prepared by stretching it on a frame and rubbing one side several times over with a piece of bees-wax, or virgin-wax, till it is covered with a coat of wax of considerable thickness. In fine linen this is the only operation necessary previous to painting; but coarse cloth must be rubbed gently on the unwaxed side with a pumice stone, to take off all those knots which would prevent the free and accurate working of the pencil. Then the subject is to be painted on the unwaxed side with colours prepared and tempered with water; and when the picture is finished it must be brought near the fire, that the wax may melt and fix the colours. This method, however, can only be applied to cloth or paper, through the substance of which the wax may pass; but in wood, stone, metals or plaster, the former method of count Caylus must be observed.

Mr. Muntz has also discovered a method of forming grounds for painting with crayons, and fixing these, as well as water-colours, employed with the pencil. On the unwaxed side of a linen cloth, stretched and waxed as before, lay an even and thick coat of the colour proper for the ground; having prepared this colour by mixing some proper pigment with an equal quantity of chalk, and tempering them with water. When the colour is dry, bring the picture to the fire that the wax may melt, pass through the cloth, and fix the ground. An additional quantity of wax may be applied to the back of the picture, if that which was first rubbed on should not be sufficient for the body of colour; but as this must be laid on without heat, the wax should be dissolved in oil of turpentine, and applied with a brush, and the canvas be again exposed to the fire, that the fresh supply of wax may pass through the cloth, and be absorbed by the colour; and thus a firm and good body will be formed for working on with the crayons. If cloth and paper are joined together, the cloth must be first fixed to the straining frame, and then the paper must be pasted to it with a composition of paste made with wheaten flour, or starch, and water, and about a twelfth part of its weight of common turpentine. The turpentine must be added to the paste when it is almost sufficiently boiled, and the composition well stirred, and left to simmer over the fire for five or six minutes; let wax be dissolved in oil of turpentine to the consistence of a thin paste; and when the cloth and paper are dry, let them be held near a fire; and with a brush lay a coat of the wax and turpentine on both sides of the joined cloth and paper, to such a degree of thickness, that both surfaces may shine throughout without any appearance of dull spots. Then expose the cloth to the fire or to the sun; by which means the oil will evaporate, and the wax become solid, and be fit to receive any composition of colour proper for a ground, which is to be laid on as above directed in the case of cloth without paper.

Almost all the colours that are used in oil-painting may be also applied in the encaustic method. Mr. Muntz objects, indeed, to brown light pink, and unburnt terra di Sienna; because these, on account of their gummy or stony texture, will not admit such a cohesion with the wax as will properly fix them; but other colours which cannot be admitted in oil-painting, as red lead, red orpiment, crystals of verdigris, and red precipitate of mercury, may be used here. The crayons used in encaustic painting are the same with those used in the common way of crayon painting, excepting those that in their composition are too tenacious; and the method of using them is the same in both cases.

The encaustic painting has many peculiar advantages; though the colours have not the natural varnish or shining which they acquire with oil, they have all the strength of paintings in oil, and all the airiness of water-colours, without partaking of the apparent character or defects of either; they may be looked at in any light and in any situation, without any false glare: the colours are firm, and will bear washing; and a picture, after having been smoked, and then exposed to the dew, becomes as clean as if it had been but just painted. It may also be retouched at pleasure, without any detriment to the colours: for the new colours will unite with the old ones, without spots, as is the case in common size painting; nor is it necessary to rub the places to be retouched with oil as in oil pictures; it is not liable to crack, and easily repaired, if it should chance to suffer any injury. The duration of this painting is also a very material advantage; the colours are not liable to fade and change; no damp can affect them, nor any corrosive substance injure them; nor can the colour fall off in shivers from the canvas. However, notwithstanding all these and other advantages enumerated by the abbé Mazeas and Mr. Muntz, this art has not yet been much practised. Many of these properties belong to a much higher species of encaustic painting afterwards discovered in England, the colours of which are fixed by a very intense heat; nor are the colours or grounds on which they are laid liable to be dissolved or corroded by any chemical menstrum; nor, like the glassy colours of enamel, to run out of the drawing on the fire. This method is described in the second part of the xlixth volume of the Philosophical Transactions, No. 100. Yet, notwithstanding the ingenuity of this communication, we find the ancient or some similar method of painting in wax remained a desideratum upwards of twenty-five years; and till, in 1787, a method was communicated to the Society of Arts by Miss Greenland. The ground of her information she received at Florence, through the acquaintance of an amateur of painting, who procured her the satisfaction of seeing some paintings in the ancient Grecian style, executed by signora Parenti, a professor of that place, who had been instructed by a Jesuit at Pavia, the person who made the farthest discoveries in that art. Miss Greenland's friend, knowing she was fond of painting, informed her what were the materials the paintress used, but could not tell her the proportions of the composition; however, from her anxiety to succeed in such an acquisition, she made various experiments, and at last obtained such a sufficient knowledge of the quantities of the different ingredients as to begin and finish a picture, which she afterwards presented to the society for their inspection.

Her method is as follows: "Take an ounce of white wax, and the same weight of gum mastich powdered. Put the wax in a glazed earthen vessel over a very slow fire; and when it is quite dissolved, strew in the mastich, a little at a time, stirring the wax continually until the whole quantity of gum is perfectly melted and incorporated: then throw the paste into cold water, and when it is hard, take it out of the water, wipe it dry, and beat it in one of Mr. Wedgewood's mortars, observing to pound it at first in a linen cloth to absorb some drops of water that will remain in the paste, and would prevent the possibility of reducing it to a powder, which must be so fine as to pass through a thick gauze. It should be pounded in a cold place, and but a little while at a time, as after long beating the friction will in a degree soften the wax and gum, and instead of their becoming a powder they will return to a paste.

"Make strong gum arabic water, and when you paint, take a little of the powder, some colour, and mix them together with the gum water. Light colours require but a small quantity of the powder, but more of it must be put in proportion to the body and darkness of the colours; and to black there should be almost as much of the powder as colour.

"Having mixed the colours and no more than can be used before they grow dry, paint with fair water, as is practised in painting with water colours, a ground on the wood being first painted of some proper colour prepared in the same manner as is described for the picture; walnut-tree and oak are the sorts of wood commonly made use of in Italy for this purpose. The painting should be very highly finished; otherwise, when varnished, the tints will not appear united.

"When the painting is quite dry, with rather a hard brush, passing it one way, varnish it with white wax, which is put into an earthen vessel, and kept melted over a very slow fire till the picture is varnished, taking great care that the wax does not boil. Afterwards hold the picture before a fire, near enough to melt the wax, but not to make it run; and when the varnish is entirely cold and hard, rub it gently with a linen cloth. Should the varnish blister, warm the picture again very slowly, and the bubbles will subside. When the picture is dirty, it need only be washed with cold water."

The opinion given by the society upon the above is. The method made use of by Miss Greenland provides againt all inconveniencies; and the brilliancy of the colours in the picture painted by her, and exhibited to the society, fully justifies the opinion, that the art of painting in wax, as above described, highly merited the reward of a gold pallet voted to her on this occasion.

Another lady, Mrs. C. J. Hooker, of Rottingdean, near Brighton, laid before the Society of Arts, in 1807, the following method of preparing and applying a composition for painting in imitation of the ancient encaustic painting.

"Put into a glazed earthen vessel four ounces and a half of gum arabic, and eight ounces (or half a pint wine measure) of cold spring water; when the gum is dissolved, stir in seven ounces of gum-mastich, which has been washed, dried, picked, and beaten fine. Set the earthen vessel containing the gum-water, and gum-mastich, over a slow fire, continually stirring and beating them hard with a spoon, in order to dissolve the gum-mastich: when sufficiently boiled, it will no longer appear transparent, but will become opaque, and stiff like a paste. As soon as this is the case, and the gum-water and mastich are quite boiling, without taking them off the fire, add five ounces of white wax, broken into small pieces, stirring and beating the different ingredients together, till the wax is perfectly melted and has boiled. Then take the composition off the fire, as boiling it longer than necessary would only harden the wax, and prevent its mixing so well afterwards with water. When the composition is taken off the fire, and in the glazed earthen vessel, it should be beaten hard, and whilst hot (but not boiling) mix with it by degrees a pint (wine measure) or sixteen ounces more of cold spring water, then strain the composition, as some dirt will boil out of the gum-mastich, and put it into bottles: the composition, if properly made, should be like a cream, and the colours when mixed with it as smooth as with oil. The method of using it is to mix with the composition, upon an earthen palette, such colours in powder as are used in painting with oil, and such a quantity of the composition to be mixed with the colours as to render them of the usual consistency of oil colours; then paint with fair water. The colours when mixed with the composition may be laid on either thick or thin, as may best suit your subject, on which account, this composition is very advantageous, where any particular transparency of colouring is required, but in most cases it answers best, if the colours be laid on thick, and they require the same use of the brush as if painting with body colours, and the same brushes as used in oil painting. The colours, if grown dry, when mixed with the composition, may be used by putting a little fair water over them; but it is less trouble to put some water when the colours are observed to be growing dry. In painting with this composition the colours blend without difficulty when wet, and even when dry the tints may easily be united by means of a brush and a very small quantity of fair water. When the painting is finished, put some white wax into a glazed earthen vessel over a slow fire, and when melted, but not boiling, with a hard brush cover the painting with the wax; and when cold take a moderately hot iron, such as is used for ironing linen, and so cold as not to hiss if touched with any thing wet, and draw it lightly over the wax. The painting will appear as if under a cloud till the wax is perfectly cold, as also whatever the picture is painted upon is quite cold: but if, when so, the painting should not appear sufficiently clear, it may be held before the fire, so far from it as to melt the wax but slowy; or the wax may be melted by holding a hot poker at such a distance as to melt it gently, especially such parts of the picture as should not appear sufficiently transparent or brilliant; for the oftener heat is applied to the picture, the greater will be the transparency and brilliancy of colouring; but the contrary effect would be produced if too sudden or too great a degree of heat was applied, or for too long a time, as it would draw the wax too much to the surface, and might likewise crack the paint. Should the coat of wax put over the painting when finished appear in any part uneven, it may be remedied by drawing a moderately hot iron over it again as before mentioned, or even by scraping the wax with a knife: and should the wax by too great or too long an application of heat form into bubbles at particular places, by applying a poker heated, or even a tobacco-pipe made hot, the bubbles would subside; or such defects may be removed by drawing any thing hard over the wax, which would close any small cavities.

"When the picture is cold, rub it with a fine linen cloth. Paintings may be executed in this manner upon wood (having first pieces of wood let in behind, across the grain of the wood, to prevent its warping) canvas, card, or plaster of Paris. The plaster of Paris would require no other preparation than mixing some fine plaster of Paris in powder with cold water the thickness of a cream; then put it on a looking-glass, having first made a frame of bees-wax on a looking-glass the form and thickness you would wish the plaster of Paris to be of, and when dry take it off, and there will be a very smooth surface to paint upon. Wood and canvas are best covered with some gray tint mixed with the same composition of gum-arabic, gum-mastich, and wax, and of the same sort of colours as before mentioned, before the design is begun, in order to cover the grain of the wood or the threads of the canvas. Paintings may also be done in the same manner with only gum-water and gum-mastich, prepared the same way as the mastich and wax; but instead of putting seven ounces of mastich, and when boiling, adding five ounces of wax, mix twelve ounces of gum-mastich with the gum-water, prepared as mentioned in the first part of this receipt: before it is put on the fire, and when sufficiently boiled and beaten, and is a little cold, stir in by degrees twelve ounces, or three quarters of a pint (wine measure) of cold spring water, and afterwards strain it. It would be equally practicable painting with wax alone, dissolved in gum-water in the following manner. Take twelve ounces, or three quarters of a pint, wine measure, of cold spring water, and four ounces and a half of gum-arabic; put them into a glazed earthen vessel, and when the gum is dissolved, add eight ounces of white wax. Put the earthen vessel with the gum-water and wax upon a slow fire, and stir them till the wax is dissolved and has boiled a few minutes: then take them off the fire and throw them into a bason, as by remaining in the hot earthen vessel the wax would become rather hard; beat the gum-water and wax till quite cold. As there is but a small proportion of water in comparison to the quantity of gum and wax, it would be necessary in mixing this composition with the colours, to put also some fair water. Should the composition be so made as to occasion the ingredients to separate in the bottle, it will become equally serviceable if shaken before used to mix with the colours.

"I had lately an opportunity of discovering that the composition which had remained in a bottle since the year 1792, in which time it had grown dry and become as solid a substance as wax, returned to a cream-like consistence, and became again in as proper a state to mix with colours as when it was first made, by putting a little cold water upon it, and suffering it to remain on a short time. I also lately found some of the mixture composed of only gum-arabic water and gum-mastich, of which I sent a specimen to the Society of Arts in 1792; it was become dry, and had much the appearance and consistency of horn. I found, on letting some cold water remain over it, that it became as fit for painting with as when the composition was first prepared."

[*Caylus. Mantz. Pantolog. Transactions of the Society of Arts, Commerce, and Manufactures.*

SECTION V.

Painting of Paper Hangings.

THERE are three methods of effecting this. The first by printing on the colours; the second by using the stencil; and the third by laying them on with a pencil, as in other kinds of painting. When the colours are laid on by printing, the impression is made by wooden prints, which are cut in such a manner that the figure to be expressed is made to project from the surface by cutting away all the other part; and this, being charged with the colours tempered with their proper vehicle, by letting it gently down on the block, on which the colour is previously spread, conveys it from thence to the ground of the paper, on which it is made to fall more forcibly by means of its weight, and the effort of the arm of the person who uses the print. It is easy to conclude that there must be as many separate prints as there are colours to be printed. But where there are more than one, great care must be taken, after the first, to let the print fall exactly in the same part of the paper as that which went before; otherwise the figure of the design would be brought into irregularity and confusion. In common paper of low price, it is usual, therefore, to print only the outlines, and lay on the rest of the colours by stencilling, which both saves the expence of cutting more prints, and can be practised by common workmen, nor requiring the great care and dexterity necessary to the using several prints. The manner of stencilling the colours is this: the figure, which all the parts of any particular colour make in the design to be painted, is to be cut out in a piece of thin leather or oil-cloth, which pieces of leather, or oil-cloth, are called stencils; and being laid flat on the sheets of paper to be printed, spread on a table or floor, are to be rubbed over with the colour, properly tempered by means of a large brush. The colour passing over the whole, is consequently spread on those parts of the paper where the cloth or leather is cut away, and give the same effect as if laid on by a print. This is nevertheless only practicable in parts where there are only detached masses or spots of colours; for where there are small continued lines, or parts that run one into another, it is difficult to preserve the connection or continuity of the parts of the cloth, or to keep the smaller corners close down to the paper; and therefore, in such cases, prints are preferable. Stencilling is indeed a cheaper method of ridding coarse work than printing; but without such extraordinary attention and trouble as render it equally difficult with printing, it is far less beautiful and exact in the effect. For the outline of the spots of colour want that sharpness and regularity that are given by prints, besides the frequent extralineations, or deviations from the just figure, which happens by the original misplacing of the stencils, or the shifting the place of them during the operation. Pencilling is only used in the case of nicer work, such as the better imitations of the India paper. It is performed in the same manner as other paintings in water or varnish. It is sometimes used only to fill the outlines already formed by printing, where the price of the colour, or the exactness of the manner in which it is required to be laid on, render the stencilling or printing it less proper; at other times it is used for forming or delineating some parts of the design, where a spirit of freedom and variety, not to be had printed in outlines, are desirable in the work. The paper designed for receiving the flock is first prepared with a varnish-ground with some proper colour, or by that of the paper itself. It is frequently practised to print some Mosaic, or other small running figure in colours, on the ground, before the flock be laid on; and it may be done with any pigment of the colour desired, tempered with varnish, and laid on by a print cut correspondently to that end. The method of laying on the flock is this: a wooden print being cut, as is above described, for laying on the colour in such manner that the part of the design which is intended for the flock may project beyond the rest of the surface, the varnish is put on a block covered with leather or oil-cloth, and the print is to be used also in the same manner, to lay the varnish on all the parts where the flock is to be fixed. The sheet, thus prepared by the varnished impression, is then to be removed to another block, or table, and to be strewed over with flock, which is afterwards to be gently compressed by a board, or some other flat body, to make the varnish take the better hold of it: and then the sheet is to be hung on a frame till the varnish be perfectly dry, at which time the superfluous part of flock is to be brushed off by a soft camel's-hair brush, and the proper flock will be found to adhere in a very strong manner. The method of preparing the flock is, by cutting woollen rags or pieces of cloth with the hand, by means of a large bill or chopping-knife; or by means of a machine worked by a horse-mill. There is a kind of counterfeit flock-paper, which, when well managed, has very much the same effect to the eye as the real, though done with less expence. The manner of making this sort is, by laying a ground of varnish on the paper, and having afterwards printed the design of the flock in varnish, in the same manner as for the true; instead of the flock, some pigment or dry colour, of the same hue with the flock required by the design, but somewhat of a darker shade, being well powdered, is strewed on the printed varnish, and produces nearly the same appearance.

Mr. John Middleton lately communicated some improvements in the printing of paper-hangings, to the Society of Arts. They are intended to facilitate the conveyance of the paper over the printing-table, and to give a greater pressure than usual to the block, when printing dark grounds.

To facilitate the conveyance of the paper, two cords 36 feet long, are stretched from the printers table to the other end of the room, through rings, where they are kept tight by a weight appended to their extremities. The paper to be printed is rolled up on a wooden roller at one side of the table, and its ends brought across the table, and fastened between two flat ledges that are connected at one end by an hinge, and at the other by a sliding ring; these ledges slide along the two cords on pullies placed at each end of them, and serve to draw forward the paper as it is printed; from the middle of these ledges a cord proceeds to the end of the room, between the other two cords, where it passes over a pulley, and thence returns to a roller under the table; the circle of this roller extends beyond the table, and there has a wheel fastened to it, from which projects three pins, each about four inches long, by pressing on which with the foot, the wheel is turned round, and with it the roller; by means of which, the paper is drawn forward on the cords a space corresponding to the distance between the pins in the wheel.

The contrivance for giving an extraordinary pressure to the block, consists of a long and a short lever, projecting from one side of an axle, placed over head, above the printers' table, which levers and the matters supported by them, are balanced by a weight appended to an arm which proceeds from the other side of the axle; from the long lever a cord falls to the ground, where a treadle is attached to it: a long pole is jointed to the end of the short lever, and descends from it directly over the place of the block, on which it is made to press, by standing on the treadle whenever it is thought proper, and is put out of the way when not wanted, by placing the end of it behind a piece of wood, which projects upwards from the back of the table for that purpose.

[*Pantologia.*

SECTION VI.

Calico-printing.

This ingenious art consists in dyeing cloth with certain colours and figures upon a ground of a different hue; the colours, when they will not take hold of the cloth readily, being fixed to them by means of intermedes, or mordants, as they were formerly called, constituting materials that have a chemical affinity or attraction for both the materials that form the colour, and the cloth to which the colour is to be applied. It was long ago supposed that these intermedes corroded their way into the interior of the cloth, and carried the colouring matter along with them, and it was on this account they were called *mordants;* but since the science of chemistry has been better studied and understood, it has been sufficiently ascertained, that they only act or hold the dye and the cloth together, by a mutual affinity or attraction.

The mordant which is principally used in the general process is a preparation of alum, called in the new nomenclature acetate of argil. It is prepared by dissolving 3lbs. of alum and 1lb. of acetate of lead in 8lbs. of warm water. An exchange of the principles of these salts takes place: the sulphuric acid of the alum combines with the oxide of lead, and the compound thus formed being insoluble, is precipitated, the acetic acid remains united with the argil of the alum in solution. There are added at the same time two ounces of the potash of commerce, and two ounces of chalk; the principal use of which appears to be, to neutralize the excess of acid that might act on the colouring matter and alter its shade.

The superiority of this acetate of argil as a mordant to the cheaper sulphat of argil or alum, arises principally from two circumstances; from the affinity between its principles being weaker, in consequence of which, the argil more easily separates from the acid, and unites with the cloth and the colouring matter; and, 2dly, from the acetic acid disengaged in the process not acting with the same force on the colouring matter as the sulphuric acid would do. The acetate being also very soluble, and having little tendency to crystallize, can be more equally mixed and applied. The discovery of this mordant, so essential in the art of calico-printing, was altogether accidental, or rather empirical. The recipes of the calico-printers were at one time very complicated: different articles were from time to time omitted or changed, until at length the simple mixture of alum and acetate of lead was found to answer as a mordant, equally with compositions more complicated.

After the mordants have been applied, the cloth must be completely dried. It is proper for this purpose to employ artificial heat, which will contribute something towards the separation of the acetous acid from its base, and towards its evaporation, by which the mordant will combine in a greater proportion, and more intimately with the cloth.

When the cloth is sufficiently dried, it is to be washed with warm water and cow-dung, till all the flour, or gum, employed to thicken the mordants, and all those parts of the mordants which are uncombined with the cloth, are removed. The cow-dung serves to entangle these loose parts of the mordants, and to prevent them from combining with those parts of the cloth which are to remain white. After this, the cloth is thoroughly rinsed in clean water.

Almost the only dye-stuffs employed by calico-printers are indigo, madder, and quercitron bark, or weld. This last substance, however, is but little used by the printers of this country, except for delicate greenish yellows. The quercitron bark has almost superseded it, because it gives colours equally good, and is much cheaper and more convenient, not requiring so great a heat to fix it. Indigo, not requiring any mordant, is commonly applied at once, either with a block or a pencil. It is prepared by boiling together indigo and potash made caustic by quick lime, and orpiment; the solution is afterwards thickened with gum. It must be carefully secluded from the air, otherwise the indigo would soon be regenerated, which would render the solution useless. Dr. Bancroft has proposed to substitute coarse brown sugar for orpiment: it is equally efficacious in decomposing the indigo, and rendering it soluble; while it likewise serves all the purposes of gum.

Let us now give an example or two of the manner in which the printers give particular colours to calicoes. Some calicoes are only printed of one colour, others have two, others three or more, even to the number of eight, ten, or twelve. The smaller the number of colours, the fewer in general are the processes.

1. One of the most common colours on cotton prints is a kind of nankeen yellow, of various shades down to a deep yellowish brown, or drab. It is usually in stripes or spots. To produce it,

the printers besmear a block, cut out into the figure of the print, with acetic of iron, thickened with gum or flour; and apply it to the cotton, which, after being dried and cleansed in the usual manner, is plunged into a potash ley. The quantity of acetite of iron is always proportioned to the depth of the shade. 2. For yellow, the block is besmeared with acetite of alumina. The cloth, after receiving this mordant, is dyed with quercitron bark, and then bleached. 3. Red is communicated by the same process; only madder is substituted for the bark. 4. The fine light blues which appear so often on printed cottons, are produced by applying to the cloth a block besmeared with a composition, consisting partly of wax, which covers all those parts of the cloth which are to remain white. The cloth is then died in a cold indigo vat; and after it is dry, the wax composition is removed by hot water. 5. Lilac, flea brown, and blackish brown, are given by means of acetite of iron: the quantity of which is always proportioned to the depth of the shade. For very deep colours, a little sumach is added. The cotton is afterwards dyed in the usual manner with madder, and then bleached. 6. Dove-colour and drab, by acetite of iron and quercitron bark.

When different colours are to appear in the same print, a greater number of operations are necessary. Two or more blocks are employed, upon each of which that part of the print only is cut, which is to be of some particular colour. These are besmeared with different mordants, and applied to the cloth, which is afterwards died as usual.

Mr. Henry Maudeslay has a patent press for calico-printing: it is described in No. 54, Rep. of Arts, N. S., and No. 7, Retrospect of Discoveries.

In the towns of Manchester, Glasgow, Paisley, &c. many thousands of industrious hands are employed in the manufacture of this article; which, according to its different degrees of fineness, is sold from 6d. to 6s. and upwards a yard.

Cotton cloth is an intermediate substance between that made of flax and animal wool; but by no means deserves to be commended as a substitute for flannel, next the skin. Calico imbibes and retains the perspired humours, unless it be as frequently changed as linen; while flannel admits a free evaporation through its numerous pores.

[*Bancroft. Chaptal. Gregory. Nicholson.*

SECTION VII.

Engraving.

This curious and valuable art is for the most part of modern invention, having its rise no earlier than the middle of the fifteenth century. The ancients, indeed, practised engraving on precious stones and crystals with very good success; and there are still many of their works remaining equal to any production of the later ages. But the art of engraving on plates and blocks of wood, to afford prints or impressions, was not known till after the invention of painting in oil. Of these last, the most ancient mode is that on wood, the first impressions on paper having been taken from carved wooden blocks. For this invention we are indebted to the *brief-malers*, or makers of playing cards, who practised the art in Germany about the beginning of the fifteenth century. From the same source may perhaps be traced the first idea of moveable types, which appeared not long after; for these brief-malers did not entirely confine themselves to the printing and painting of cards, but produced also subjects of a more devout nature; many of which, taken from holy writ, are stlll preserved in German libraries, with the explanatory text facing the figures, the whole engraved in wood. Thus a species of books was formed; such as, Historia Sancti Johannis, ejusque Visiones Apocalypticæ; Historia Veteris et Novi Testamenti, known by the name of the Poor Man's Bible. These short mementos were printed only on one side; and two of them being pasted together, had the appearance of a single leaf. The earliest date on any of these wooden cuts in 1423. The subject is St. Christopher carrying the infant Jesus over the sea, preserved in a convent at Buxheim near Menningen. It is of a folio size, illuminated in the same manner as the playing cards; and at the bottom is this inscription,

> "Cristoferi faciem die quacunque tueris.
> Illa nempe die morte mala non morieris.
> Millesimo CCCC° XX° tertio."

Upon the invention of moveable types that branch of the brief-malers business, so far as it regarded the making of books, was gradually discontinued; but the art itself of engraving on wood continued in an improving state; and towards the end of the fifteenth century and the beginning of the sixteenth century, it became customary for almost every one of the German engravers on copper to engrave on wood also. The works of Albert Durer in this style of engraving are justly held in the highest esteem. Italy, France, and Holland, have produced many capital artists of this kind; but for boldness and spirit we must see the prints of Christopher Jegher, who worked under the direction of Rubens, and was without doubt assisted by that great master. The invention of that species of engraving distinguished by the appellation of *chiaro-scuro*, seems also to be justly claimed by the Germans, and first practised by Mair; one of whose prints of this kind is dated 1499. Many excellent works in chiaro-scuro have been produced in France; and in Italy it was honoured with the performances of Titian and Parmegiano; but the attempts of Jackson, Kirkall, and others in England, have not been successful. A set of excellent prints in this way have lately been published by J. Skippe, esq. a connoisseur and dillettante. In Germany, about A. D. 1450, prints from engraved copper first made their appearance. The earliest date of a copperplate print is indeed only 1461; but however faulty this print may be with respect to the drawing, or defe tive in point of taste, the mechanical part of the execution of it has by no means the appearance of being one of the first productions of the graver. We have also several other engravings evidently the work of the same master; in which the impressions are so neatly taken from the plates, and the engravings so clearly printed in every part, that according to all appearance, they could not be executed in a much better manner in the present day, with all the conveniencies which the copperplate printers now possess, and the additional knowledge they must necessarily have acquired in the course of more than three centuries. Hence we may fairly conclude, that if they were not the first specimens of the engraver's workmanship, they were much less the first efforts of the copperplate printer's ability. It is likewise to be observed, that Martin Shoen, who is said to have worked from 1460 to 1486, was apparently the scholar of Stoltzhirs; for he followed his style of engraving, and copied from him a set of prints, representing the passion of our Saviour. Now, allowing Stoltzhirs to have preceded his disciple only ten years, this carries the era of the art back to 1450, as was said above. There is no ground to suppose that it was known to the Italians till at least ten years afterwards. The earliest prints that are known to be theirs are a set of the seven planets, and an almanac by way of frontispiece; on which are directions for finding Easter from 1465 to 1517 inclusive: and we may be assured that the engravings were not antedated, as the almanac would have thus been less valuable. These prints must therefore have been executed in 1464, which is only four years later than the Italians claim. The three earliest Italian engravers are Finiguerra, Boticelli, and Baldini. If we are to refer these prints to any of the three, we shall naturally conclude them to be the work of Finiguerra or Baldini; for they are not equal either in drawing or composition to those ascribed to Boticelli, which we know at least were designed by him; and as Baldini is expressly said to have worked from the designs of Boticelli, it will appear most probable that they belong to Finiguerra. With respect to the invention of etching, it seems to be not well known to whom it is to be ascribed. One of the most early specimens is the print by Albert Durer, known by the name of the Cannon, dated 1518, and thought by some, with little foundation, to have been worked on a plate of iron. Another etching by the same artist is Moses receiving the tables of the law, dated 1524. It was also practised in Italy soon after this by Parmegiano, in whose etchings we discover the hand of the artist working out a system as it were from his own imagination, and striving to produce the forms he wanted to express. We see the difficulty he laboured under, and cannot doubt, from the examination of the mechanical part of the execution of his works, that he had no instruction; and that it was something entirely new to him. If the story is true, that he kept an engraver by profession in his house, the novelty of the art is rendered so much the more probable. He died in 1540. As to that species of engraving in which the modes of etching and cutting with the graver are united, it must have been found necessary immediately upon the invention of etching; it was, however, first carried to perfection by G. Audran, and is now almost universally practised, whether the work is in strokes or in dots. Engraving in dots, the present fashionable method, is a very old invention, and the only mode discovered by the Italians. Agostino de Musis, commonly called Augustine of Venice, a pupil of Marc Antonio, used it in several of his earliest works, but confined it to the flesh, as in the undated print of an old man seated upon a bank, with a cottage in the back ground. He flourished from 1509 to 1536. We also find it in a print of a single figure standing, holding a cup and looking upwards, by Giulio Campagnola, who engraved about the year 1516. The back ground is executed with round dots, made apparently with a dry point. The figure is outlined with a stroke deeply engraved, and finished with dots, in a manner greatly resembling those prints which Demarteau engraved at Paris in imitation of red chalk. The hair and beard are expressed by strokes. Stephen de Laulne, a native of Germany, followed the steps of Campagnola; and many of his slight works are executed in dots only. John Boulanger, a French artist, who flourished in the middle of the last century, and his contemporary Nicholas Van Plattenberg, improved greatly on this method, and practised it with much success. It is only, however, of late, that it has been considered as an object worthy of general imitation. John Lutma executed this kind of work with a hammer and a small punch or chisel. Engraving in mezzotinto was invented about the middle of the seventeenth century; and the invention has generally been attributed to prince Rupert. Engraving in aquatinta is quite a recent invention, and seems at once to have been carried to perfection by Sandby, and other artists of the present age. Engraving with the tool was the kind originally practised, and it is yet retained for many purposes. For though etching be more easy, and other advantages attend it; yet where great regularity and exactness of the stroke or lines are required, the working with the graver is much more effectual: on which account it is more suitable to the precision necessary in the execution of portraits; as there every thing the most minute must be made out and expressed according to the original subject, without any licence to the fancy of the designer in deviating from it, or varying the effect either by that masterly negligence and simplicity in some parts, or those bold sallies of the imagination and hand in others, which give spirit and force to history-painting.

Historical engravings for the port folio and furniture seemed at one period to advance rapidly towards perfection, to which the late alderman Boydell lately contributed; but the death of Strange, Hall, and Woollet, have been almost fatal to the hopes of the amateur, which rest, in a great measure, upon Heath, Sharp, Bromley, and a few others, as in this particular instance we do not include those eminent foreigners who have, or do at present reside in England. Whatever deficiencies we may discover in the prosecution of the arts in this country, is fortunately not to be attributed to want of genius, or relaxation from study in the artist; the chill of apathy in the rich, who view a wretched coloured aquatint with the same or more pleasure than the most laboured production of the graver, is the baleful cause of the languishing state of historical engraving. When persons capable of affording patronage are taught discrimination, future Woollets will fascinate the best judges of engraving. We have, however, some very fine engravers, in different departments, among whom it would be unjust not to specify the names of Milton, Scott, Lowry, and Mrs. Griffiths.

[*Walpole. Phil. Trans. Pantol.*

A very ingenious process has of late years been employed on the continent to answer at the same time both the purposes of designing and engraving; or, in other words, to produce an engraving by the art of designing. This art or process is called *lithography* or *stone-engraving:* and among the German artists, who have recourse to it, *chemische druckery*, or *chemical printing.* From Germany it has spread into our own country, and still more lately into France and Italy. It consists in being first provided with a few small blocks of marble, about the size of Dutch tiles, or larger, according to the intended dimensions of the print; the thickness should be about two inches. The landscape, or other subject, is then to be traced over with a pencil; and the pencil lines to be afterwards at leisure retraced with a particular ink which was at first a great secret. It is now, however, known to consist of a solution of lac in potash, coloured black by soot from burning wax. When the design has been gone over with this ink, it is left to dry, which commonly takes about two hours, though this will depend upon the temperature and dryness of the atmosphere. The face of the marble being, after this process, washed with nitric acid more or less diluted according to the degree of relief desired, the whole surface will be corroded except where defended by the resinous ink. The operation is now completed, and to obtain printed copies nothing more is necessary than to wash the marble clean; to distribute over it, by means of printers' balls, an ink similar to that commonly used by printers; and to press down upon the design, by a copper roller or copper-plate press, a sheet of paper properly disposed in a frame.

A few of such marble tiles or blocks are now frequently taken by travellers through picturesque scenery, who produce at one and the same time the drawing and the engraving, and the latter with far more correctness to the former than can possibly be obtained by copying. And as soon as a sufficient number of prints have been struck off, nothing more is necessary than to replane and repolish the marble tiles, when they will be immediately ready for other subjects. A particular account of this process, drawn up by M. Marcel de Serres, will be found in the Annales de Chemie, vol. lxxii.

[*Editor.*

SECTION VIII.

Sculpture.

Engraving is occasionally called working *en creux*, sculpture working in *relievo* : yet in its most comprehensive range the word sculpture has been applied to both these.

The studies necessary for the young sculptor, towards the attainment of his art, are so similar to those which form the painter (with the obvious exceptions arising from the difference of materials employed in the two arts), that very little remains here to be enlarged on, under the head of studies. The principal acquisitions to which the student must direct his endeavours are, a knowledge of composition, form (including anatomy), and expression; to which, as in painting, must be added the difficult study of grace.

The method of study most recommended to young sculptors is, to begin with copying, and to end with rivalling, the forms of the Greek statues.

——" Vos exemplaria Græca
Nocturnâ versate manu, versate diurnâ;"

says Du Fresnoy: nor can it be questioned that the sculptors are, generally speaking, the safest guides to the study of nature. But it should not pass unnoticed, that although the forms of the Greek sculpture are, in general, not only more beautiful, but more appropriately so than any other; yet in some instances they have been surpassed by modern sculptors, as in the forms of infants by Flamingo.

The method of execution in the Greek statues and other works of sculpture, seems to have been extremely different from that which is generally in use among modern artists. In the ancient statues, we frequently find striking proofs of the freedom and boldness that accompanied each stroke of the chisel, and which resulted from the artist's being perfectly sure of the accuracy of the method which he pursued. Even in the most minute parts of the figure, no indication of timorousness or diffidence appears: nothing that can induce us to believe, that the artist feared he might have occasion to correct his strokes. It is difficult to find, even in the second-rate productions of the Grecian artists, any marks of a false or a random touch. This firmness and precision of the Grecian chisel were certainly derived from a more determined and perfect set of rules, than those of which we are masters.

Besides studying, therefore, in the productions of the Grecian masters, their choice and expression of select nature, whether beautiful, sublime, or graceful, together with that sedate grandeur and simplicity which pervade all their works, the artist will do well to investigate the manual and mechanical part of their operations, as they may lead to the perception of their mode of progress.

As soon as the artist has rendered himself familiarly acquainted with the beauties of the Grecian statues, and formed his taste on the admirable models they exhibit, he may then proceed with advantage and assurance to the imitation of nature. The ideas he has already formed of the perfection of nature, by observing her dispersed beauties combined and collected in the composition of the ancient artists, will enable him to acquire with facility, and to employ with advantage, the detached and partial ideas of beauty which will be exhibited to his view in a survey of nature, in her actual state. When he discovers these partial beauties, he will be capable of combining them with those perfect forms of beauty, with which he is already acquainted. In a word, by having always present to his mind the noble models already mentioned, he will form an accurate judgment of the powers of his art, and will draw rules from his own mind.

There are, however, two ways of imitating nature. In the one, a single object occupies the artist, who endeavours to represent it with precision and truth; in the other, certain lines and features are taken from a variety of objects, and combined and blended into one regular whole. All kinds of copies belong to the first kind of imitation; and productions of this sort must necessarily be executed in a confined and servile manner, with high finishing, and little or no invention. But the second kind of imitation leads directly to the investigation and discovery of true beauty, of that beauty whose perfect idea is only to be found within the mind.

Of the different modes of process in sculpture.—Works of of sculpture are performed, either by hollowing or excavating, as in metals, agates, and other precious stones, and in marbles of every description; or by working in relief, as in bas-reliefs in the materials just mentioned, or in statues of metal, clay, wood, wax, marble, or stone.

The excavation of precious stones forms a particular branch of art called intaglio, which, together with the working them in relievo, when the term camayeu is applied to them, belongs to the art of seal-engraving.

The excavation of metals consitutes the art of engraving, in its various branches, on metal of any kind; and its relief comprises enchasing, casting in bronze, &c.

The process of hollowing hard stone or marble will need no particular description; especially as it is now wholly in disuse, except for the forming of letters in monumental or other inscriptions.

In working in relief the process is necessarily different, according to the materials in which the work is performed.

As not only the beginning of sculpture was in clay, for the purpose of forming statues, but as models are still made in clay or wax, for every work undertaken by the sculptor; we shall first consider the method of modelling figures in clay or wax.

Few tools are necessary for modelling in clay. The clay being placed on a stand or sculptor's easel, the artist begins the work with his hands, and puts the whole into form by the same means. The most expert practitioners of this art seldom use any other tool than their fingers, except in such small or sharp parts of their work as the fingers cannot reach. For these occasions, they are provided with three or four small tools of wood, about seven or eight inches in length, which are rounded at one end, and at the other flat and shaped into a sort of claws. These tools are called by the French *ebauchoirs*. In some of these the claws are smooth, for the purpose of smoothing the surface of the model; and in others are made with teeth, to rake or scratch the clay, which is the first process of the tool on the work, and in which state many parts of the model are frequently left by artists, to give an appearance of freedom and skill to their work.

If clay could be made to preserve its original moisture, it would undoubtedly be the fittest subtance for the models of the sculptor; but when it is placed either in the fire, or left to dry imperceptibly in the air, its solid parts grow more compact, and the work shrinks, or loses a part of its dimensions. This diminution in size would be of no conséquence, if it affected the whole work equally, so as to preserve its proportions. But this is not always the case: for the smaller parts of the figure drying sooner than the larger; and thus losing more of their dimensions in the same space of time, than the latter do; the symmetry and proportions of the work inevitably suffer.

This inconvenience, however, is obviated by forming the model first in clay, and moulding it in plaister of Paris before it begins to dry, and the taking a plaister cast from that mould, and the repairing it carefully from the original work; by which means you have the exact counterpart of the model in its most perfect state; and you have, besides, your clay at liberty for any other work.

In order to model in wax, prepare the wax in the following manner: to a pound of wax add half a pound of scammony (some mix turpentine also), and melt the whole together with oil of olives; putting more or less oil as you would have your modelling wax harder or softer. Vermillion is sometimes mixed with this composition, to give it a reddish colour, in imitation of flesh.

In modelling in wax, the artist sometimes uses his fingers, and sometimes tools of the same sort as those described for modelling in clay. It is at first more difficult to model in wax than in clay, but practice will render it familiar and easy.

Of the use of the model.—Whatever considerable work is undertaken by the sculptor, whether bas-relief, or statue, &c. it is always requisite to form a previous model, of the same size as the intended work; and the model being perfected, according to the method before described, whether it is in clay, or in wax, or a cast in plaister of Paris, becomes the rule, whereby the artist guides himself in the conduct of his work, and the standard from which he takes all its measurements. In order to regulate himself more correctly by it, he puts over the head of the model an immoveable circle, divided into degrees, with a moveable rule fastened in the centre of the circle, and likewise divided into parts. From the extremity of the rule hangs a line with a lead, which directs him in taking all the points, which are to be transferred from the model to the marble; and from the top of the marble is hung also a line, tallying with that which is hung from the model; by the correspondence of which two lines, the points are ascertained in the marble.

Many eminent sculptors prefer measurements taken by the compasses to the method just described; for this reason, that if the model is moved but ever so little from its level, the points are no longer the same.

This method, however, offers the best means, by which mechanical precision may be attained; but it is manifest, that enough yet remains to exercise and display the genius and skill of the artist. For, first, as it is impossible, by the means of a straight line, to determine with precision the procedure of a curve, the artist derives from this method no certain rule to guide him, as often as the line which he is to describe deviates from the direction of the plumb-line. It is also evident, that this method affords no certain rule to determine exactly the proportion, which the various parts of the figure ought to bear to each other considered in their mutual relation and connections. This defect, indeed, may be partly supplied by intersecting the plumb-lines by horizontal ones; but even this resource has its inconveniences; since the squares formed by transversal lines that are at a distance from the figure (though they are exactly equal), yet represent the parts of the figure as greater or smaller, according as they are more or less removed from our point of view.

Of sculpture in wood.—A sculptor in wood should first take care to choose wood of the best quality, and the most proper for the work which he intends to execute. If he undertakes a large work, requiring strength and solidity, he ought to choose the hardest wood, and that which keeps best, as oak and chesnut; but for works of moderate size, pear or apple-tree serve very well. As even these latter woods are still of considerable hardness, if the work consists only of delicate ornaments, the artist will find it preferable to take some more tender wood, provided it is at the same time firm and close; as, for instance, the Indian tree, which is excellent for this purpose, as the chisel cuts it more neatly and easily than any other wood.

The ancients made statues out of almost every different kind of wood. At Sicyon was a statue of Apollo made of box; the statue of Diana at Ephesus was of cedar. As these two sorts of wood are extremely hard and undecaying; and as cedar, in particular, is of such a nature, as, according to Pliny, to be nearly indestructible, the ancients preferred them for the images of their divinities.

In the temple built on mount Cyllene in honour of Mercury, Pausanias relates, that there was a statue of that god made of citron-wood, eight feet in height. This wood was also much esteemed.

The cypress likewise, being a wood not apt to spoil, nor to be damaged by worms, was also used for statues; as were the palm-tree, olive, and ebony, of which latter, according to Pliny's account, there was another statue of Diana at Ephesus.

Several other kinds of wood were equally employed for this purpose, even the vine, of which the same author says there were statues of Jupiter, Juno, and Diana.

Felibien speaks of a French artist at Florence, of the name of Janni, who executed several statues in wood, in a style of finishing equal to marble, and particularly one of St. Rocque, which Vasari considered as a marvellous production.

The beauty of sculpture in wood consists in the tender manner of cutting the wood, free from all appearance of hardness or dryness.

For any work of large dimensions, even though it consists of a single figure, it is better to join together several smaller pieces of wood than to make the whole of a single large piece; which is more liable to warp and crack, on account of its not being always dry at heart, although it appears perfectly dry on the outside.

No wood can be properly fit for works of this kind that has not been cut at least ten years before.

The tools used for sculpture in wood are the same as those of the joiner or cabinet-maker.

Of sculpture in stone and marble.—For sculpture in marble and other stone, the artist must make use of tools made of good steel, well tempered, and of strength proportioned to the hardness of the material.

The first thing to be done is, to saw out from a larger block of marble, a block proportioned to the size of the work which is undertaken. After this, the sculptor shapes the gross masses of the forms he designs to represent, by knocking off the superfluous parts of marble with a strong mallet or beel, and a strong steel tool called a point.

When the block is thus hewn out agreeably to the measures previously taken for the performance of the work, the sculptor brings it nearer to the intended form by means of a finer point; and sometimes of a tool called a dog's tooth, having two points, but less sharp than the single one.

After this he uses the gradine, which is a flat cutting tool, with three teeth, but is not so strong as the point.

Having advanced his work with the gradine, he usesthe chisel to take off the ridges left by the former tools; and by the dexterous and delicate use of this instrument, he gives softness and tenderness to the figure, till at length, by taking a rasp, which is a sort of a file, he brings his work into a proper state for being polished.

Rasps are of several kinds, some straight, some curved, and some harder or softer than others.

When the sculptor has thus far finished his work with the best tools he can procure, wherever certain parts or particular works require polishing, he uses pumice-stone to make all the parts smooth and even. He then goes over them with tripoli, and when he would give a still higher gloss, he rubs them with leather and straw-ashes.

Besides the tools already mentioned, sculptors use also the pick, which is a small hammer pointed at one end, and at the other formed with teeth made of good steel and squared, to render them the stronger. This serves to break the marble, and is used in all places where the two hands cannot be employed to manage the mallet and chisel.

The bouchard, which is a piece of iron, well steeled at the bottom, and formed into several strong and short points like a diamond, is used for making a hole of equal dimensions, which cannot be done with cutting tools. The bouchard is driven with the mallet or beetle, and its points bruise the marble and reduce it to powder. Water is thrown into the hole from time to time, in proportion to the depth that is made, to bring out the dust of the marble, and to prevent the tool from heating, which would destroy its temper; for the free-stone dust on which tools are edged, is only moistened with water to prevent the iron from heating and taking off the temper of the tool by being rubbed dry; and the trepans are wetted for the same reason.

The sculptor uses the bouchard to bore or pierce such parts of his work as the chisel cannot reach without danger of spoiling or breaking them. In using it, he passes it through a piece of leather, which leather covers the hole made by the bouchard, and prevents the water from spirting up in his face.

The tools necessary for sculpture on marble or stone, are the roundel, which is a sort of rounded chisel; the houguet, which is a chisel squared and pointed; and various compasses to take the requisite measures.

The process of sculpture in stone is the same as in marble, excepting that the material being less hard than marble, the tools used are not so strong, and some of them are of a different form, as the rasp, the hand-saw, the ripe, the straight chisel with three teeth, the roundel, and the grater.

If the work is executed in free-stone, tools are employed which are made on purpose, as the free-stone is apt to scale, and does not work like hard stone or marble.

Sculptors in stone have commonly a bowl in which they keep a powder composed of plaister of Paris, mixed with the same stone in which their work is executed. With this composition they fill up the small holes, and repair the defects which they meet with in the stone itself.

[*Walpole. Winckelmann. Du Fresnoy. Pantalog.*

SECTION VIII.

Pottery and Porcelain.

Porcelain may be regarded as the finest kind of pottery; the art of which consists in working and moulding plastic earths, more or less simple into hard brittle vessels of various kinds and forms, and designed for various purposes.

The essential material of pottery is clay, which alone possesses the two requisite qualities of being in its natural state so plastic that with water it becomes a soft uniformly extensible mass, capable of assuming and retainingany any form; and when thoroughly dried and undergone a red heat for a time, of losing this plasticity, becoming irretentive of water to any considerable degree, hard, close in texture, and able more or less perfectly to confine all liquids contained within its hollow.

Clay, however, is in all instances a very compound substance: it owes its plasticity to alumine, which forms a constituent part of it; but the proportion of alumine varies considerably in different species, and almost as much as the other substances with which it is combined.

It may hence be supposed that many of the impure-coloured natural clays are of themselves sufficiently mixed with other earths for the potter's use without any addition; but the white and finer clays mostly require dilution with silex in some form or other, which may be done to a considerable extent without taking away the plasticity requisite for working.

The most important circumstances requisite to be considered in selecting the materials for pottery are plasticity, contractility, solidity, and compactness after drying, colour, and fusibility.

The plasticity seems to be simply owing to the proportion of clay used, or relatively to the original plasticity of the clay itself; for all clays are not equally plastic, and the superadded substances in no instance increase this property, and in many cases considerably diminish it.

The texture, including the qualities of hardness and compactness, depends partly on the mixture of siliceous (flinty or sandy) ingredients with the clay, and partly on the heat employed in the burning of the pottery. The purer natural clays are almost infusible in any furnace heat; their hardness is nearly progressive with the intensity of the fire, but they have the essential defects of drying very slowly, of shrinking very considerably, and of becoming rifty or full of minute cracks when dried, so as on this account to be porous. It is therefore necessary to mix them intimately with any other earth of qualities opposite to those of clay; that is which absorbs but little water, and quickly parts with it, (qualities directly opposite to plasticity) and which dries compact and close.

The colour of the earths used is also of essential importance in the finer pottery, in which the great desideratum is to find a clay which after burning remains perfectly white. The appearanee before burning cannot always be depended upon, for though in general the whitest clays before burning are those that remain white afterwards, it is only in a few districts that clays are to be found that retain a perfect whiteness. Thus there exists at the foot of a range of high hills that directly overlook the Staffordshire potteries, a stratum of white clay to appearance fully equal if not superior to the best Devonshire clays, which cannot be employed for fine pottery from its acquiring in burning a yellowish cream colour which no art can correct. This colour is supposed to depend on an intermixture of iron.

The fusibility of clays and of other pottery earths is a subject of extreme importance, as it is this property that principally constitutes the difference between common pottery and porcelain.

We have defined porcelain to be a species of pottery ware composed of an earthy mixture which resists complete fusion in a very considerable heat, but has been brought by a less heat than its melting point to a state of incipient fusion, and is thereby rendered extremely hard, sonorous, and semi-transparent, and possesses a semi conchoidal splentery fracture approaching to the vitreous, which is completely conchoidal. This last is quite a distinctive character between porcelain and pottery, for the fracture of pottery is extremely granular: and hence porcelain may correctly be regarded as a substance of a middle nature between pottery and glass.

From these circumstances it appears probable that no chemical action takes place in any pottery combination till it arrives at the state of porcelain. The most perfect and beautiful porcelains of Japan in China are composed of two distinct earths; one in which silex predominates, and which melts in a strong fire; and another which is infusible *per se:* and by the union of those two earths a porcelain is produced which scarcely vitrifies at the utmost furnace heat which art can excite. This substance possesses the combined excellencies of great hardness, beautiful semi-transparency, exquisite whiteness, where not artificially coloured, strong toughness and cohesion; so that it has strength enough for the purposes for which it is designed when made very thin, and bears sudden heating and cooling without cracking.

Of the beautiful European porcelains which have been made in imitation of the oriental, it does not appear that any of them unite all its excellencies. Earthy combinations have been made equally strong, tough, and infusible, and as truly porcelaineous when burnt, but they have not quite rivalled the best Japanese in delicate whiteness and lustre. As these last qualities, however, are esteemed most essential, that of infusibility (which indeed is of no great consequence for any of the common uses of porcelain) has been sacrificed; and hence those that make a near approach to the oriental in beauty and delicate lustre, of which many manufactures in different parts of Europe have afforded splendid examples, are frequently found to soften and melt down in an intense heat of a wind-furnace, at which the true Nankin and Japan china undergo no change.

The manufacture of the ordinary pottery is on the whole very simple where a due selection of materials is made; but the ornamental branches of it, such as those of modelling, enamelling, painting, and gilding, which often display exquisite beauty, are accompanied with much delicacy, and require a combination of perseverance, skill, and practical nicety of management, that are rarely equalled in any other chemical manufacture.

An intimate mixture of the ingredients used in pottery is of great importance to the beauty, compactness, and soundness of the ware. Formerly the wet clay and ground flint, or whatever else was employed, were beaten together with long continued manual labour, no more water being added than was necessary to render the clay thoroughly plastic. This laborious and expensive method has now been laid aside in the larger potteries; and the ingenious method has been substituted of bringing each material first to an impalpable powder, and diffusing them separately in as much water as will bring them to the consistence of thick cream, mixing them in due proportion by measure, and when thoroughly stirred together, evaporating the superfluous water till the mass is brought to a proper consistence for working.

In the Staffordshire process the materials are a fine clay, brought chiefly from Devonshire, and a siliceous stone called chert, or else common flint reduced to powder by heating it red-hot, quenching it in water, and then grinding it by windmills. Each material is passed through fine brass sieves, then diffused in water, mixed by measure, and brought to a plastic state as above.

The wheel and lathe are the chief, and almost the only, instruments made use of: the first for large works, and the last for small. The potter's wheel consists principally in the nut, which is a beam or axis, whose foot or pivot plays perpendicularly on a free-ston esole or bottom. From the four corners of this beam, which does not exceed two feet in height, arise four iron bars, called the spokes of the wheel ; which, forming diagonal lines with the beam, descend, and are fastened at bottom to the edges of a strong wooden circle, four feet in diameter, perfectly like the fel-loes of a coach-wheel, except that it has neither axis nor radii, and is only joined to the beam, which serves it as an axis, by the iron bars. The top of the nut is flat, of a circular figure, and a foot in diameter : and on this is laid the clay which is to be turned and fashioned. The wheel, thus disposed, is encompassed with four sides of four different pieces of wood fastened on a wooden frame ; the hind-piece, which is that on which the workman sits, is made a little inclining towards the wheel ; on the fore-piece are placed the prepared earth ; on the side-pieces he rests his feet, and these are made inclining, to give him more or less room. Having pre-pared the earth, the potter lays a round piece of it on the circular head of the nut, and sitting down, turns the wheel with his feet till it has got the proper velocity ; then, wetting his hands with wa-ter, he presses his fist or his finger-ends into the middle of the lump, and thus forms the cavity of the vessel, continuing to widen it from the middle ; and thus turning the inside into form with one hand, while he proportions the outside with the other, the wheel constantly turning all the while, and he wetting his hands from time to time. When the vessel is too thick, he uses a flat piece of iron, somewhat sharp on the edge, to pare off what is redundant ; and when it is finished, it is taken off from the circular head, by a wire passed underneath the vessel.

The potter's lathe is also a kind of wheel, but more simple and slight than the former, its three chief members are an iron beam or axis three feet and a half high, and two feet and a half diameter, placed horizontally at the top of the beam, and serving to form the vessel upon : and another large wooden wheel, all of a piece, three inches thick, and two or three feet broad, fastened to the same beam at the bottom, and parallel to the horizon. The beam or axis turns by a pivot at the bottom in an iron stand. The work-man gives the motion to the lathe with his feet, by pushing the great wheel alternately with each foot, still giving it a greater or lesser degree of motion, as his work requires. They work with the lathe, with the same instruments, and after the same manner, as with the wheel. The mouldings are formed by holding a piece of wood or iron, cut in the form of the moulding, to the vessel, while the wheel is turning round, but the feet and handles are made by themselves, and set on with the hand; and if there be any sculpture in the work, it is usually done in wooden moulds, and stuck on piece by piece on the outside of the vessel.

Handles, spouts, &c. are afterwards fixed on to the moulded piece if required; and it is then set to dry for some days in a warm room, where it becomes so hard as to bear handling without altering its shape. When dry enough it is inclosed along with many others in baked clay cases of the shape of bandboxes, called seggars, which are made of the coarse clays of the country. These are next ranged in the kiln or furnace so as to fill it except a space in the middle for the fuel. Here the ware is baked till it has remained fully red hot for a considerable time, which in the larger kilns consumes ten or fifteen tons of coals: after which the fire is allowed to go out, and when all is cooled, the seggars are taken out, and their contents unpacked.

The ware is now in a state of biscuit, perfectly void of gloss, and resembling a clean egg-shell. In order to glaze it, which is the next process, the biscuit ware is dipped in a tub containing a mixture of about sixty parts of litharge, ten of clay, and twenty of ground flint, diffused in water to a creamy consistence, and when taken out, enough adheres to the piece to give an uniform glazing, when again heated: for which pnrpose the pieces are re-packed up in the seggars, with small bits of pottery interposed between each, and fixed in the kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process for common white ware; though the painting and gilding require subsequent attention.

[*Pantologia. D'Entrecolles. Lettres Edifiantes et Curieuses.*

CHAP. IV.

BURNING MIRRORS.

THE fertile genius of Archimedes illustriously appears, not only in those works of his which have been handed down to us, but also in the admirable descriptions which the authors of his time have given us of his discoveries in mathematics and mechanics. Some of the inventions of this great man have appeared so far to surpass human ability and imagination, that some celebrated philosophers have called them in question *, and even gone so far as to pretend to prove their impossibility, The following pages will produce many proofs of what is here advanced : meanwhile, our present object is to examine into the subject of the burning glasses, employed by Archimedes to set fire to the Roman fleet at the siege of Syracuse. Kepler, Naudéus, and Descartes, have treated it as a mere fable, though the reality of it hath been attested by Diodorus Siculus, Lucian, Dion, Zonaras, Galen, Anthemius, Eustathius, Tzetzes, and others. Nay, some have even pretended to demonstrate by the rules of catoptrics the impossibility of it, notwithstanding the asseveration of such respectable authors, whose testimony ought to have prevented them from rejecting so lightly a fact so well supported.

Yet all modern enquiries have not been involved in this mistake. Father Kircher, attentively observing the description which Tzetzes gives of the burning glasses of Archimedes, resolved to prove the possibility of this; and having, by means of a number of plain mirrors, collected the sun's rays into one focus, he so augmented †

* Descartes in his Dioptrics, Discourse 8th, p. 128. Fontenelle, and many other.

† Kircher, de Arte Magna Lucis, et Umbræ, lib. 10, p. 3. p. 874 ad finem, et Problem. 4, 3a part. de Magiâ Catoptricâ—And p. 884, 887, he delivers the catoptric rules for making burning glasses by a proper disposition of many plain mirrors. And in p. 88, relates an experiment of his own, whereby he produced a heat intense enough to burn, by means of five mirrors directing the rays of the sun into one focus; he supposes that Proclus by such means might set fire to Vitellius's fleet, and invites the skilful to bring this assay to perfection.

the solar heat, that at last by encreasing the number of mirrors, he could produce the most intense degree of it.

Tzetzes's description of the glass Archimedes made use of, is indeed very proper to raise such an idea as Kircher entertained. That author says, that Archimedes set fire to Marcellus's navy, by means of a burningglass composed of small square mirrors, moving every way upon hinges; which, when placed in the sun's rays, directed them upon the Roman fleet, so as to reduce it to ashes at the distance of a bow-shot. It is probable Mr. De Buffon availed himself of this description, in constructing his burning glass, composed of 168 little plain mirrors, which produced so considerable a heat, as to set wood in flames at the distance of two hundred and nine feet; melt lead, at that of one hundred and twenty; and silver, at that of fifty.

Another testimony occurs, which leaves not the least doubt in this case, but resolves all in favour of Archimedes. Anthemius of Tralles, in Lydia, a celebrated architect, able sculptor, and learned mathematician, who in the emperor Justinian's time built the church of St. Sophia, at Constantinople, wrote a small treatise in Greek, which is extant only in manuscript, intitled Mechanical Paradoxes. That work, among other things, has a chapter respecting burning glasses, where we meet with the most complete descrpition of the requisites that Archimedes, according to this author, must needs have been possessed of, to enable him to set fire to the Roman fleet. He begins with this enquiry, "How in any given place, at a bow-shot's distance, a conflagration may be raised by means of the sun's rays?" And immediately lays it down as a first principle "That the situation of the place must be such, that the rays of the sun may be reflected upon it in an oblique, or even opposite direction to that in which they came from the sun itself." And he adds, "that the assigned distance being so very considerable, it might appear at first impossible to effect this by means of the reflection of the sun's rays; but as the glory Archimedes had gained by thus setting fire to the Roman vessels, was a fact universally agreed in, he thought it reasonable to admit the possibility of it, upon the principles he had laid down." He afterwards advances farther, in this enquiry, establishing certain necessary propositions in order to come at a solution of it. "To find out therefore in what position a plain mirror should be placed to carry the sun's rays by reflection to a given point, he demonstrates that the angle of incidence is equal to the angle of reflection; and having shewn that, in so just a position of the glass, the sun's rays might be reflected to the given place, he observes that by means of a number or glasses reflecting the rays into the same focus, there must arise at the given place the conflagration required, for inflaming heat is the result of thus concentrating the sun's rays: and that when a body is thus set on fire, it kindles the air around it, so that it comes to be acted upon by the two forces at once, that of the sun, and that of the circumambient air, reciprocally augmenting and increasing the heat; whence", continues he, "it necessarily results, that by a proper number of plain mirrors duly disposed, the sun's rays might be reflected in such quantity into a common focus, at a bow-shot distance, as to set all in flames around it. As to the manner of putting this in practice," he says, "it might be done by employing many hands to hold the mirrors in the described position: but to avoid the confusion that might thence arise, twenty-four mirrors at least being requisite to communicate flame at such distance, he fixes upon another method, that of a plain hexagon mirror, accommodated on every side by lesser ones, adhering to it by means of plates, bands, or hinges connecting them mutually together, so as to be moved or fixed at pleasure in any direction. Thus having adapted the large or middle mirror to the rays of the sun, so as to point them to the given place, it will be easy in the same manner to dispose the rest, so that all the rays together may meet in the same focus; and by multiplying compound mirrors of this kind, and giving them all the same direction there must thence infallibly result, to whatever degree of intenseness, the conflagration required at the place given. The better to succeed in this enterprize, there should be in readiness," he adds, "a considerable number of those compound mirrors to act all at once, from four at least, to seven." He concludes his dissertation with observing, "that all the authors who mention the burning machine of the divine Archimedes, never speak of it as of one compound mirror, but as a combination of many." So large and accurate a description is more than sufficient to demonstrate the possibility of a fact, so well attested in history, and by such a number of authors, that it would be the highest degree of arrogance and conceit, to refuse our suffrage to such invincible testimony. Vitellion, who lived about the thirteenth century, speaks of a work of Anthemius of Tralles, who had composed a burning glass consisting of twenty-four mirrors, which conveying the rays of the sun into a common focus, produced an extraordinary degree of heat. And Lucian speaking of Archimedes, says, that at the siege of Syracuse he reduced, by a singular contrivance, the Roman ships to ashes. And Galen; that with burning glasses he fired the ships of the enemies of Syracuse. Zonaras also speaks of Archimedes' glasses, in mentioning those of Proclus, who, he says, burnt the fleet of Vitellius at the siege of Constantinople, in imitation of Archimedes, who set fire to the Roman fleet at the siege of Syracuse. He intimates, that the manner wherein Proclus effected this, was by launching upon the enemies vessels, from the surface of reflecting mirrors, such a quantity of flame as reduced them to ashes.

Eustathius, in his Commentary upon the Iliad, says that Archimedes, by a catoptric machine, burnt the Roman fleet at a bow-shot's distance. Insomuch that there is scarcely any fact in history, warranted by more authentic testimony; so that it would be difficult not to surrender to such evidence, even although we could not comprehend how it were possible for Archimedes to have constructed such glasses: but now that the experiments of father Kircher and Mr. de Buffon have made it apparent, that nothing is more easy in the execution, than what some gentlemen have denied the possibility of; what ought they to think of the genius of that man, whose inventions, even by their own accounts, surpass the conception of the most celebrated mathematicians of our days, who think they have done something very extraordinary, when they have shewed themselves capable of imitating in some degree, the sketches of those great masters, of whom, however, they are very unwilling to be thought the disciples?

Again, it appears that the ancients were acquainted with refracting burning glasses; for we find in Aristophanes's Comedy of the Clouds, a passage which clearly treats of the effects of those glasses. The author introduces Socrates as examining Strepsiades about the method he had discovered for getting clear for ever of his debts. He replies, that he thought of making use of a burning-glass, which he had hitherto used in kindling his fire; for, says he, should they bring a writ against me, I'll immediately place my glass in the sun, at some little distance from the writ, and set it a fire. Where we see he speaks of a glass which burned at a distance, and which could be no other than a convex glass. Pliny and Lactantius have also spoken of glasses that burnt by refraction. The former calls them balls or globes of glass, or chrystal, which exposed to the sun, transmit a heat sufficient to set fire to cloth, or corrode away the dead flesh of those patients who stand in need of caustics; and the latter, after Clemens Alexandrinus, takes notice that fire may be kindled, by interposing glasses filled with water, between the sun and the object, so as to transmit the rays to it. [*Dutens.*

Among the moderns one of the earliest who devised a burning mirror, was the celebrated Lord Napier, the inventor of logarithms, who, in a paper containing hints of secret inventions, dated June 2, 1596, (the original of which is now among the MSS. in the Lambeth library, marked 658, anno 1596), says,

"*First*, The invention, proof, and perfect demonstration, geometrical and algebraical, of a burning mirror, which receiving of dispersed beams of the sun, doth reflex the same beams altogether united, and concurring precisely in one mathematical point, in the which point, most necessarily it engendereth fire; with an evident demonstration of their error who affirm this to be made a parabolic section. The use of this invention serveth for the burning of the enemy's ships at whatsoever appointed distance.

"*Secondly*, The invention and sure demonstration of another mirror, which receiving the dispersed beams of any material fire, or flame, yieldeth also the former effect, and serveth for the like use."

Of the moderns, the most remarkable burning-glasses, are those of Magine of 20 inches diameter; of Sepatala of Milan, near 42 inches diameter, and which burnt at the distance of 15 feet; of Settala, of Vilette, of Tchirnhausen, of Buffon, of Trudaine, and of Parker.

That of M. de Villette was three feet eleven inches in diameter, and its focal distance was three feet two inches. Its substance is a composition of tin, copper, and tin-glass. Some of its effects, as found by Dr. Harris and Dr. Desaguliers, are, that a silver sixpence melted in $7\frac{1}{2}''$; a King George's halfpenny melted in $16''$, and ran in $34''$; tin melted in $3''$, and a diamond weighing 4 grains, lost $\frac{7}{8}$ths of its weight.

That of M. de Buffon is a polyhedron, six feet broad, and as many high, consisting of 168 small mirrours, or flat pieces of looking-glass, each six inches square; by means of which, with the faint rays of the sun in the month of March, he set on fire boards of beech wood at 150 feet distance. Besides, his machine has the conveniency of burning downwards, or horizontally, as one pleases; each speculum being moveable, so as, by the means of three screws, to be set to a proper inclination for directing the rays towards any given point; and it turns either in its greater focus, or in any nearer interval, which our common burning-glasses cannot do, their focus being fixed and determined. M. de Buffon, at another time, burnt wood at the distance of 200 feet. He also melted tin and lead at the distance of above 120 feet, and silver at 50.

Mr. Parker, of Fleet-street, London, was induced, at an expence of upwards of 700*l.* to contrive, and at length to complete a large transparent lens, that would serve the purpose of fusing and vitrifying such substances as resist the fires of ordinary furnaces, and more especially of applying heat in vacuo, and in other circumstances in which it cannot be applied by any other means. After directing his attention for several years to this object, and performing a great variety of experiments in the prosecution of it, he at last succeeded in the construction of a lens, of flint-glass, three feet in diameter, which, when fixed in its frame, exposes a surface of 32 inches in the clear; the distance of the focus is 6 feet 8 inches, and its diameter 1 inch. The rays from this large lens are received and transmitted through a smaller, of 13 inches diameter, in the clear within the frame, its focal length 29 inches, and diameter of its focus $\frac{3}{8}$ths of an inch: so that this second lens increases the power of the former more than 7 times, or as the square of 8 to the square of 3.

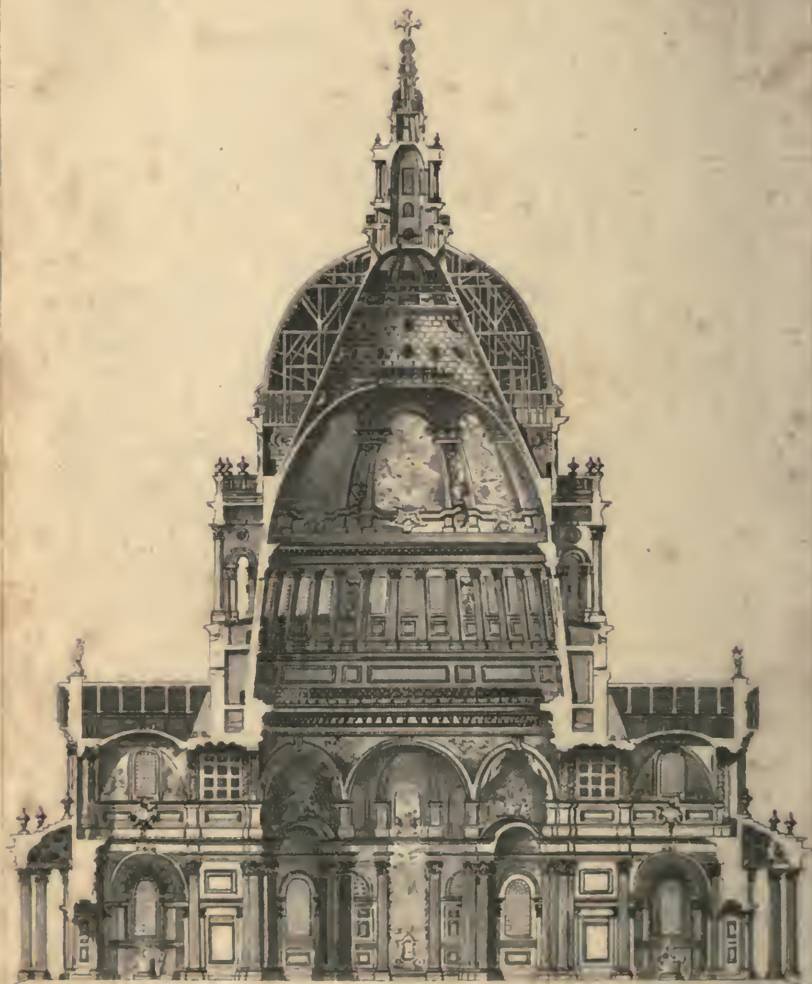
From a great number of experiments made with this lens, the following are selected to serve as specimens of its powers:

Substances fused; with their weight, and time of fusion.	Time in sec.	Wgt. in grs.
Scoria of wrought iron . . .	2	12
Common slate	2	10
Silver, pure	3	20
Platina, pure	3	10
Nickel	3	16
Cast iron, a cube	3	10

Substances fused; with their weight, and time of fusion.	Time in sec.	Wgt. in grs.
Kearsh	3	10
Gold, pure	4	20
Crystal pebble	6	7
Cauk, or terra ponderosa . . .	7	10
Lava	7	10
Asbestos	10	10
Bar iron, a cube . . .	12	10
Steel, a cube	12	10
Garnet	17	10
Copper, pure	20	33
Onyx	23	10
Zeolites	23	10
Pumice stone	24	10
Oriental emerald . . .	25	2
Jasper	25	10
White agate	30	10
Flint, oriental	30	10
Topaz, or chrysolite . . .	45	3
Common limestone . . .	55	10
White rhomboidal spar . . .	60	10
Volcanic clay	60	10
Cornish moorstone . . .	60	10
Rough cornelian . . .	75	10
Rotten stone	80	10

What is remarkable with regard to experiments on iron, is, that the lower part, *i. e.* that part in contact with the charcoal, was first melted, when that part which was exposed to the focus remained unfused: an evidence of the effect of flux on this metal.

Several of the semi-crystalline substances, exposed to the focal heat, exhibited symptoms of fusion: such as the agate, oriental flint, cornelian, and jasper; but as the probability is, that these substances were not capable of complete vitrification, it is enough that they were rendered externally of a glassy form. Garnet completely fused on black-lead in 120″, lost $\frac{1}{4}$th of a grain, became darker in colour, and was attracted by the magnet. Ten cut garnets taken from a bracelet, began to run the one into the other in a few seconds, and at last formed into one globular garnet. The clay used by Mr. Wedgwood, to make his pyrometric test, run in a few seconds into a white enamel. Seven other kinds of clay sent by Mr. Wedgwood, were all vitrified. Several experiments



SECTION OF ST PAUL'S CATHEDRAL.

were made on limestone, some of which were vitrified, but all of which were agglutinated; it is, however, suspected that some extraneous substance must have been intermixed. A globule produced from one of the specimens, on being put into the mouth, flew into a thousand pieces, occasioned, it is presumed, by the moisture.

[*Pantologia.*

CHAP. V.

GENERAL ARCHITECTURE AND MECHANICAL SCIENCES.

SECTION I.

Architecture and Mechanical Sciences of the Ancients.

ARCHIMEDES alone would afford sufficient matter for a volume, in giving a detail of the marvellous discoveries of a genius so profound, and fertile in invention. We have seen in the preceding chapters, that some of his discoveries appeared so much above the reach of men, that many of the learned of our days found it more easy to call them in doubt, than even to imagine the means whereby he had acquired them. We are again going to produce proofs of the fecundity of genius belonging to this celebrated man; and in how high a degree of excellence he possessed this inventive faculty, may easily be judged of by the greatness of those events which were effected by it. Leibnitz, who was one of the greatest mathematicians of his age, did justice to the genius of Archimedes when he said, that if we were better acquainted with the admirable productions of that great man, we would throw away much less of our applause on the discoveries of eminent moderns.

Wallis also, in speaking of Archimedes, calls him a man of admirable sagacity, who laid the foundation of almost all those inventions, which our age glories in having brought to perfection. In reality, what a glorious light hath he diffused over the mathematics, in his attempt to square the circle; and in discovering the square of the parabola, the properties of spiral lines, the proportion of the sphere to the cylinder, and the true principles of statics and hydrostatics? What a proof of his sagacity did he give in discovering the quantity of silver, that was mixed along with the gold, in the crown of King Hierem; whilst he reasoned upon that principle, that all bodies immersed in water, lose just so much of their weight, as a quantity of water equal to them in bulk weighs? Hence he drew this consequence, that gold being more compact, must lose less of its weight, and silver more; and that a mingled mass of both, must lose in proportion to the quantities mingled. Weighing therefore the crown in water and in air, and two masses, the one of gold, the other of silver, equal in weight to the crown; he thence determined what each lost of their weight, and so resolved the problem. He likewise invented a perpetual screw, valuable on account of its being capable to overcome any resistance; and the screw, that still goes by his own name, used in elevating of water. He, of himself alone, defended the city of Syracuse, by opposing to the efforts of a Roman general, the resources he found in his own genius. By means of many various warlike machines, all of his own construction, he rendered Syracuse inaccessible to the enemy. Sometimes he hurled upon their land-forces stones of such an enormous size, as crushed whole bodies of them at once, and put the whole army into confusion. And when they retired from the walls, he still found means to annoy them; for with catapults and balistæ, he overwhelmed them with arrows innumerable, and beams of a prodigious weight. If their vessels approached the fort, he seized them by the prows with grapples of iron, which he let down upon them from the wall, and rearing them up in the air, to the great astonishment of every body, shook them with such violence, as either to break them in pieces, or sink them to the bottom. And when the Romans thought of sheltering themselves from his pursuit, by keeping at a distance from the haven, he borrowed fire from heaven, and aided by his own ingenuity, wrapped them in sudden and inevitable conflagration, as we have seen in a preceding chapter.

The superior knowledge he had in sciences, and his confidence in the powers of mechanism, prompted him once to say to King Hieron, who was his patron, admirer and friend; give me but some other place to stand upon, and I'll set the earth itself in motion: and when the king, amazed at what he had said, seemed to be in hesitation: he gave him a striking proof of the possibility of what he had advanced, by launching singly by himself a ship of a prodigious size. He built likewise for the king an immense galley, of twenty banks of oars, containing spacious apartments, gardens, walks, ponds, and all other conveniences suitable to the dignity of a great King. He constructed also a sphere, representing the motions of the stars, which Cicero esteemed one of the inventions which did the highest honour to human genius. He perfected the manner of augmenting the mechanic powers by the multiplication of wheels and pullies; and, in short, carried mechanics so far, that the works he produced of this kind, even surpass imagination.

Nor was Archimedes the only one who succeeded in mechanics. The immense machines, and of such astonishing force, as were those which the art of the ancients adapted to the purposes of war, are a proof they came nothing behind us in this respect. It is with difficulty we can conceive how they reared those bulky moving towers, an hundred and fifty-two feet in heighth, and sixty in compass, ascending by many stories, having at bottom a battering ram, a machine of strength sufficient to beat down walls; in the middle a draw-bridge, to be let down upon the wall of the city attacked, in order to open a passage into the town for the assailants; and at top a body of men, who, being placed above the besieged, harrassed them without running any risk. An ancient historian hath transmitted to us an action of an engineer at Alexandria, which deserves a place here. In defending that city against the army of Julius Cæsar, who attacked it, he by means of wheels, pumps, and other machines, drew from the sea a prodigious quantity of water, which he afterwards turned upon the adverse army to their extreme annoyance. In short, the art of war gave occasion for a great number of proofs of this kind, which cannot but excite in us the highest idea of the enterprizing genius of the ancients, and the vigour with which they put their designs in execution. The invention of pumps by Ctesibius; and that of water-clocks, automatical figures, wind-machines, cranes, &c. by Heron, who lived in the second century; and the other discoveries of the Grecian geometricians, are so very numerous, that it would exceed the limits of a chapter, even to mention them.

Should we pass to other considerations, we shall find equally incontestable evidences of greatness of genius among the ancients, in the difficult, and indeed astonishing enterprizes, in which they so successfully engaged. Egypt and Palestine still present us with proofs of this, the one in its pyramids, the other in the ruins of Palmyra and Balbec*. Italy is filled with monuments, and the ruins of monuments, which aid us in comprehending the former magnificence of that people; and ancient Rome even now attracts much more of our admiration than the modern.

The greatest cities of Europe give but a faint idea of that grandeur, which all historians unanimously ascribe to the famous city of Babylon, which being fifteen leagues in circumference, was encompassed with walls two hundred feet in height, and fifty in breadth, whose sides were adorned with gardens of a prodigious extent, which arose in terasses one above another, to the very summit of the walls; and for the watering of those gardens they had contrived machines, which raised the water of the Euphrates to the very highest of those terrasses; a height equalling that to which the water is carried by the machine of Marly. The tower of Belus, arising out of the middle of a temple, was of so vast a height, that some ancient authors have not ventured to assign the measure of it; others put it at a thousand paces.

Ecbatane, the capital of Media, was of immense magnificence, being eight leagues in circumference, and surrounded with seven walls, in form of an amphitheatre, the battlements of which were of various colours, white, black, scarlet, blue, and orange; but all of them covered with silver or with gold. Persepolis was also a city, which all historians speak of as one of the most ancient and noble of Asia. There remain the ruins of one of its palaces, which measured six hundred paces in front, and still displays the relics of its ancient grandeur.

The lake of Mœris is likewise a striking proof of the vast undertakings of the ancients. All historians agree in giving it above an hundred and fifty leagues in circuit; yet was it entirely the work of one Egyptian king, who caused that immense compass of ground to be hollowed, to receive the waters of the Nile, when it overflowed more than ordinary, and to serve as a reservoir for watering Egypt by means of its canals, when the overflowing of the river was not of height sufficient to enrich the country. Out of the midst of this Lake, arose two pyramids, of about six hundred feet in height.

* It is proper to remark that the temples and immense palaces of Palmyra, whose magnificence surpasses all other buildings in the world, appear to have been built at the time when architecture was in its decline.

The other pyramids of Egypt, in their largeness and solidity, so far surpass whatever we know of edifices, that we should be ready to doubt of the reality of their having ever existed, did they not still subsist to this day. Mr. de Chezele, of the Academy of Sciences, who travelled into Egypt to measure them, assigns to one of the sides of the base of the highest pyramid, a length of six hundred and sixty feet, which reduced to its perpendicular altitude, makes four hundred sixty and six feet. The free-stones, of which it is composed, are each of them thirty feet long; so that we cannot imagine how the Egyptians found means to rear such heavy masses to so prodigious a height.

The Colossus of Rhodes was another of the marvellous productions of the ancients. To give an idea of its excessive bigness, it need only be observed, that the fingers of it were as large as statues, and very few were able, with outstretched arms, to encompass the thumb *.

In short, what shall we say of the other structures of the ancients, which still remain to be spoken of? Of their cement, which in hardness equalled even marble itself; of the firmness of their highways, some of which were paved with large blocks of black marble; and of their bridges, some of which still subsist irrefragable monuments of the greatness of their conceptions? The bridge at Gard, three leagues from Nimes, is one of them. It serves at once as a bridge and an aqueduct. It goes across the river Gardon, and joins together the two mountains, between which it is inclosed. It comprehends three stories; the third is the aqueduct, which conveys the waters of the Eure into a great reservoir, which

* Plin. book 34, chap. 7, and Diodorus Siculus, book 2, relate that Semiramis made the mountain Bagistan, between Babylon and Media, be cut out into a statue of herself, which was seventeen stades high; that is, above half a French league; and around it were an hundred other statues, of proportionable size, though less large. And Plutarch, vol. 2, p. 335, speaks of a very great undertaking which one Stesicrates proposed to Alexander; viz. to make a statue of him out of Mount Athos, which would have been an hundred and fifty miles in circumference, and about ten in height. His design was to make him hold in his left hand a city, large enough to contain ten thousand inhabitants; and in the other an urn, out of which should flow a river, poured by him into the sea. See also the same, Plutarch, vol. 1, p. 705, in the Life of Alexander. Vitruvius, in the preface to his 2d Book, gives to this statuary the name of Dinocrates. Strabo, lib. 14, p. 641, calls him Chiromocrates. Tzetzes, Chiliad. 8, 199.

supplies the amphitheatre and city of Nimens. The bridge of Alcantara, upon the Tagus, is still a work fit to raise in us a great idea of the Roman magnificence: it is six hundred and seventy feet long, and contains six arches, each of which measure above a hundred feet from one pier to the other; and its height from the surface of the water is two hundred feet. The broken remains of Trajan's bridge over the Danube, are still to be seen; which had twenty piers of free stone, some of which are still standing, a hundred and fifty feet high, sixty in circumference, and distant one from another an hundred and seventy. I should never end, were I to enumerate all the admirable monuments left us by the ancients; the slight sketch here given of them, will more than suffice to answer my purpose. As to the ornaments and conveniencies of their buildings, among many I shall mention but one, that of their using glass in their windows, and in the inside of their apartments, just in the same manner as we do. Seneca and Pliny inform us, that they decorated their rooms with glasses; and do not we the same in the use of mirrors and pier glasses? But what will more shock the general prejudices is, that they should know how to glaze their windows, so as to enjoy the benefit of light, without being injured by the air; yet this they did very early. Before they discovered this manner of applying glass, which is so delightful and so commodious, the rich made use of transparent stones in their windows such as the agat, the alabaster, the phengites, the talcum, &c. whilst the poor were under a necessity of being exposed to all the severities of wind and weather.

If we admire the ancients in those monuments which remain to us of the greatness of their undertakings, we shall have no less reason for wonder in contemplating the dexterity and skill of their artists, in works of a quite different kind. Their works in miniature are well deserving of notice. Archytas, who was contemporary with Plato, is famous in antiquity, for the artful structure of his wooden pidgeon, which imitated the flight and motions of a living one. Cicero, according to Pliny's report, saw the whole Iliad of Homer, written in so fine a character that it could be contained in a nut-shell: and Ælian speaks of one Myrmecides a Milesian, and of Callicrates a Lacedemonian, the first of whom made an ivory chariot, so small and so delicately framed, that a fly with its wiing could at the same time cover it, and a little ivory ship of the same dimensions; the second formed ants and other little animals out of ivory, which were so extremely small, that their component parts were scarcely to be distinguished. He says also in the same place, that one of those artists wrote a distitch in golden letters, which he enclosed in the rind of a grain of corn.

It is natural here to enquire, whether in such undertakings as our best artists cannot accomplish without the assistance of microscopes, the ancients had no such aid; and the result of this research will be that they had several ways of helping the sight, of strengthening it, and of magnifying small objects. Jamblichus says of Pythagoras, that he applied himself to find out instruments as efficacious to aid the hearing, as a ruler, or a square, or even optic glasses, *διόπτρα*, were to the sight. Plutarch speaks of mathematical instruments which Archimedes made use of, to manifest to the eye the largeness of the sun; which may be meant of Telescopes. Aulus Gellius having spoken of mirrors that multiplied objects, makes mention of those which inverted them; and these of course, must be concave or convex glasses. Pliny says, that in his time, artificers made use of emeralds to assist their sight, in works that require a nice eye; and to prevent us from thinking that it was on account of its green colour only that he had recourse to it, he adds, that they were made concave, the better to collect the visual rays; and that Nero made use of them in viewing the combats of the Gladiators. In short, Seneca is very full and clear upon this head, when he says, that the smallest characters in writing, even such as almost intirely escape the naked eye, may easily be brought to view by means of a little glass ball, filled with water, which had all the effect of a microscope, in rendering them large and clear; and indeed this was the very sort of microscope that Mr. Gray made use of in his observations. To all this add the burning glasses made mention of before, which were in reality magnifying glasses; nor could this property of them remain unobserved.

[*Dutens.*

SECTION II.

Comparative View of the Architecture of different Ages.

THAT architecture is of great antiquity is undeniable. But the primitive buildings were very different from the specimens of architecture we now meet with in civilized countries. In those mild climates which seem to have been the first inhabited parts of this globe, mankind stood more in need of shade from the sun than of shelter from the inclemency of the weather. A very small addition to the shade of the woods, served them for a dwelling. Sticks laid across from tree to tree, and covered with brushwood and leaves, formed the first houses in those delightful regions. As population and the arts improved, these huts were gradually refined into commodious dwellings. The materials were the same, but more artfully put together. At last agriculture led the inhabitants out of the woods into the open country. The connection between the inhabitant and the soil became more constant and more interesting. The wish to preserve this connection was natural, and fixed establishments followed of course. Durable buildings were more desirable than those temporary and perishable cottages, stone was substituted for timber. But as these improved habitations were gradual refinements on the primitive hut, traces of its construction remained, even when the choice of more durable materials made it in some measure inconvenient. Thus it happens that the trunks of trees, upright, represent columns; the girts or bands, which serve to keep the trunks from bursting, express bases and capitals; and the summers, laid across, gave a hint of entablatures; as the coverings, ending in points, did of pediments.

We shall not enter minutely into a history of the progress of architecture; but shall shew that the above view of ornamental architecture will go far in accounting for some of the more general differences of national style which may be observed in different parts of the world. The Greeks borrowed many of their arts from their Asiatic neighbours, who had cultivated them long before. It is highly probable that architecture travelled from Persia into Greece. In the ruins of Shushan, Persepolis, or Tchiminar, are to be seen the first models of every thing that distinguishes the Grecian architecture. There is no doubt, we suppose, among the learned, as to the great priority of these great monuments to any thing that remains in Greece; especially if we take into account the tombs of the mountains, which have every appearance of greater antiquity than the remains of Persepolis. In those tombs we see the whole ordonnance of column and entablature, just as they began to deviate from their first and necessary forms in the wooden buildings. We have the architrave, frize, and corniche; the far-projecting mutules of the Tuscan and Doric orders; the modillions no less distinct; 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 custom which we know was common in their temples and banqueting rooms. Where the distance between the columns is great, so that each had to support a weight too great for one tree, we see the columns clustered or fluted, &c. In short, we see every thing of the Grecian architecture, but the sloped roof or pediment; a thing not wanted in a country where it hardly ever rains. 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 ancient Egyptian architecture seems to be a refinement on the hut built of clay, or unburnt bricks mixed with straw: every thing is massive, clumsy, and timid; small intercolumniations, and hardly any projections.

The Arabian architecture seem 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 caravansary 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 of 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.

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

The great incorporation of architects who built most of 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 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 afforded opportunities of giving all possible varieties of these intersections, and taught the art of balancing arch against arch in every variety of situation. In a little time arches became their principal ornament, and a wall or ceiling was not thought properly decorated till it was filled full of mock arches, crossing and butting on each other in every direction. In this process in their ceilings these architects found that the projecting mouldings, which we now call the Gothic tracery, formed the chief support 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 shall we find any false positions. This is far from being the case in most of the modern imitations of this species of architecture.

We call the middle ages rude and barbarous, and give to their architecture the appellation Gothic; but there was surely much knowledge in those who could execute such magnificent and difficult works. The more appropriate terms, we conceive, would be those of Saxon and Norman architecture, at least, so far as relates to such works in Britain; giving the first term to that kind distinguished by the circular arch, and the latter to that distinguished by the pointed arch: for under the guidance of these respective nations did each kind principally display its grandeur and peculiarities.

The architects of whom we now speak do not appear to have studied the theory of equlibrated arches: but, for a long period, they 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. They had, however, with great care, studied the mutual dependence of arches on each other; 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 on the sides. These are necessary in a large vaulted building, for withstanding the outward thrust of the vaulting; but they are useless when there is a flat ceiling within. Pinnacles on the heads of 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 continues its chief ornament, is a load almost indispensably necessary, for enabling the four principal columns to withstand the combined dependences of the aisles, of the naves, 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 extremes, and pushed to the limit of possibility of execution.

From the end of the 15th century, this architecture began to decline; and was soon after supplanted by a mixed style, if we may venture to call it so; wherein the Grecian and Gothic, however discordant and irreconcilable, are jumbled together. Concerning this mode of building, Mr. Warton, in his observations on Spencer's Fairy Queen, has the following anecdotes and remarks:

" Although the Roman or Grecian architecture did not begin to prevail in England till the time of Inigo Jones, yet our communication with the Italians, and our imitation of their manners, produced some specimens of that style much earlier. Perhaps the earliest was Somerset-house in the Strand, built about the year 1549, by the duke of Somerset, uncle to Edward VI.

In the year 1613, the magnificent portico of the schools at Oxford was erected, in which, along with the old Gothic style, the architect has affectedly displayed his extraordinary skill in the Grecian and Roman architecture, and has introduced all the five orders together.

" In the 15th and 16th centuries, when learning of all kinds began to revive, the chaste architecture of the Greeks and Romans seemed, as it were, to be recalled into life. The first improvements of it began in Italy, and even owed their existence to the many ruins of the ancient Roman structures that were to be found in that country, from whence an improved method of building was gradually brought into the other countries of Europe: and though the Italians for a long time retained the superiority as architects, over the other European nations, yet as men of genius from all quarters constantly visited Italy for the purpose of improvement in architecture, as well as the other arts, since that period they have been equalled, if not surpassed, by architects of other nations, and even of our own country."

The orders, as now executed by architects, are five, viz. the Tuscan, the Doric, the Ionic, the Corinthian, and the Composite; which are distinguished from each other by the column with its base and capital, and by the entablature. The Tuscan order is characterised by its plain and robust appearance, and is therefore used only in works where strength and plainness are wanted; it has been used with great effect and elegance in that durable monument of ancient grandeur, the Trajan column at Rome; indeed general consent has established its proportions for such purposes beyond all others. The Doric possesses nearly the same character for strength as the Tuscan, but is enlivened by its peculiar ornaments; the triglyph, mutule, and guttæ or drops under the triglyph; these decorations characterise the Doric order, and in part are inseparable from it. Its proportions recommended it where united strength and grandeur are wanted. The Ionic partakes of more delicacy than either of the former, and therefore as well as on account of its origin, is called Feminine, and not improperly supposed to have a matronic appearance. It is a medium between the masculine Tuscan and Doric, and the virginal slenderness of the Corinthian: the boldness of the capital, with the beauty of the shaft, makes it eligible for porticoes, frontispieces, entrances to houses, &c. Denteles were first added to the cornice of this order. The Corinthian possesses more delicacy and ornament than any other order; the beauty and richness of the capital, and the delicacy of the pillar, render it the most suitable in those edifices where magnificence and elegance are required. On this account it is frequently used for the internal decoration of large state rooms; in which it has a chaste appearance, though at the same time superb. The Composite order is the same as the Corinthian in its proportions, and nearly alike in ornamental properties. The addition of the modern Ionic voluté to the capital, gives a bolder projection. It is aplicable in the same manner and in the same cases as the Corinthian.

The first complete system of architecture we meet with is that of Vitruvius, who lived in the reign of Julius Cæsar and Augustus. Since Vitruvius, the principal authors are Alberti, Baldus, Barbarus, Blondel, Catanei, Demoniosius, Freard, Goldman, Gulielmus, Langley, Mayer, Nicholson, Pain, Palladio, Perrault, Rivius, Serlio, Scamozzi, Vignoli, and Ware. On the subject of Gothic architecture, we refer to Essays on Gothic Architecture, published by Taylor, and to a paper in vol. iv. Trans. Royal Society Edin. by sir James Hall.

[*Pantologia.*

SECTION III.

Labyrinths.

Among the architectural curiosities of antiquity, there are few entitled to more attention than the complicated and extraordinary edifices known by the name of *labyrinths.* The most celebrated were those of Crete, Lemnos, and Egypt. The first stood near mount Ida, and was the production of the celebrated Dædalus. All we know of it, however, is from loose rumour, or casual reference. Even in Pliny's time not a vestige of it was to be traced; and Bellonius has been so much of an infidel as to conjecture that it was nothing but an ancient quarry excavated by digging the stones that served to build the neighbouring towns of Gortynæ and Grossas.

The labyrinth of Lemnos is aupposed by Pliny to have been more magnificent than that of Crete, when both were in their full perfection. It was a vast and splendid pile supported by forty columns of extraordinary height and circumference. The architects employed in raising it were, Zinilus, Rhodus and Theodorus, the last a native of the island. In Pliny's time its vestiges were still to be traced; but Bellonius could not discover a relic of it during his visit to Lemnos.

Of all the labyrinths, however, of antiquity, that of Egypt was the largest and most costly: and it is said to have furnished to Dædalus the model of that of Crete, though he imitated not more than the hundredth part of it. It was so extraordinary, that Herodotus who saw it says, that it far surpassed the report of fame, being, in his judgment, even more admirable than the pyramids. As there were at least three buildings of this kind, ancient writers, not distinguishing them, generally speak but of one, and consequently with great confusion and disagreement.

They tell us the labyrinth of Egypt stood in the Heracleotic nome, near the city of Crocodiles, or Arsinoe, a little above the lake Mœris. Pliny places it in the lake, and says, it was built by Petesuccus, or Tithoes, one of the demi-gods, four thousand six hundred years before his time ; but that Demoteles would have it to be the palace of Motherudes ; Lyceas, the sepulchre of Mœris ; and others the temple of the Sun. It is recorded by Manetho, that Lachares or Labares the successor of Sesostris, built a labyrinth for his monument. And Diodorus writes, that Mendes, or Marus made another for the samepurpose, which was not so considerable on account of its magnitude, as for the artificial contrivance of it ; but this seems to be adifferent building from that described by him a little after ; which is, in all probability, the same with the labyrinth of Herodotus ; for they both agree in the situation. They say it was the work of tweive kings, among whom Egypt was at one time divided ; and that they built it at their common charge.

This structure seems to have been designed as a pantheon, or universal temple of all the Egyptian deities, which were separately worshipped in the provinces. It was also the place of the general assembly of the magistracy of the whole nation, for those of all the provinces or nomes met here to feast and sacrifice, and to judge causes of great consequence. For this reason, every nome had a hall or palace appropriated to it ; the whole edifice containing, according to Herodotus, twelve ; Egypt being then divided into so many kingdoms. But Pliny makes the number of these palaces sixteen, and Strabo, as it seems, twenty-seven. Herodotus tells us, that the halls were vaulted, and had an equal number or doors opposite to one another, six opening to the north, and six to the south, all encompassed with the same wall ; that there were three thousand chambers in this edifice, fifteen hundred in the upper part, and as many under-ground ; and that he viewed every room in the upper part, but was not permitted, by those who kept the palace, to go into the subterraneous part, because the sepulchres of the holy crocodiles, and of the kings who built the labyrinth were there. He reports, that what he saw seemed to surpass the art of man ; so many exits by various passages, and infinite returns, afforded a thousand occasions of wonder. He passed from a spacious hall to a chamber, from thence to a private cabinet ; then again into other passages out of the cabinets, and out of the chamber into the more spacious rooms. All the roofs and walls within were incrusted with marble, and adorned with figures in sculpture. The halls were surrounded with pillars of white stone finely polished; and at the angle, where the labyrinth ended, stood the pyramid formerly mentioned, which Strabo asserts to be the sepulchre of the prince who built the labyrinth.

To this description of Herodotus, others add, that it stood in the midst of an immense square, surrounded with buildings at a great distance; that the porch was of Parian marble, and all the other pillars of marble of Syene; that within were the temples of their several deities, and galleries, to which was an ascent of ninety steps, adorned with many columns of porphyry, images of their gods, and statues of their kings, of a colossal size; that the whole edifice consisted of stone, the floors being laid with vast flags, and the roof appearing like a canopy of stone; that the passages met, and crossed each other with such intricacy, that it was impossible for a stranger to find his way, either in or out, without a guide; and that several of the apartments were so contrived, that on opening of the doors, there was heard within a terrible noise of thunder.

We shall subjoin part of the description given by Diodorus of a fabric, which though he does not call it a labyrinth, but a sepulchre, yet appears to be the same we are now speaking of. He says it was of a square form, each side a furlong in length, built of most beautiful stone, the sculpture and other ornaments of which posterity could not exceed; that on passing the outward inclosure, a building presented itself to view, surrounded by an arcade, every side consisting of four hundred pillars; and that it contained the ensigns or memorials of the country of each king; and was, in all respects, a work so sumptuous, and of such vast dimensions, that if the twelve princes who began it, had not been dethroned before it was finished, the magnificence of it could never have been surpassed. Whence it seems, that Psammetichus, one of the twelve, who, expelling his associates, made himself master of all Egypt, finished the design, but not with a grandeur answerable to the rest of the structure; though Mela attributes the glory of the whole to that king.

The solidity of this wonderful building was such, that it withstood, for many ages, not only the rage of time, but that of the inhabitants of Heracleopolis, who, worshipping the ichneumon, the mortal enemy of the crocodile, which was the peculiar deity of Arsinoe, bore an irreconcileable hatred to the labyrinth, which served also for a sepulchre to the sacred crocodiles, and therefore they strove to demolish it. Pliny says, it was remaining in his days; and that about five hundred years before Alexander, Circummon eunuch to king Nectabis, was reported to have bestowed some small reparations on it, supporting the building with beams of acacia, or the Egyptian thorn, boiled in oil, while the arches of square stone were erecting.

[*Ancient Univ. Hist.*

SECTION IV.

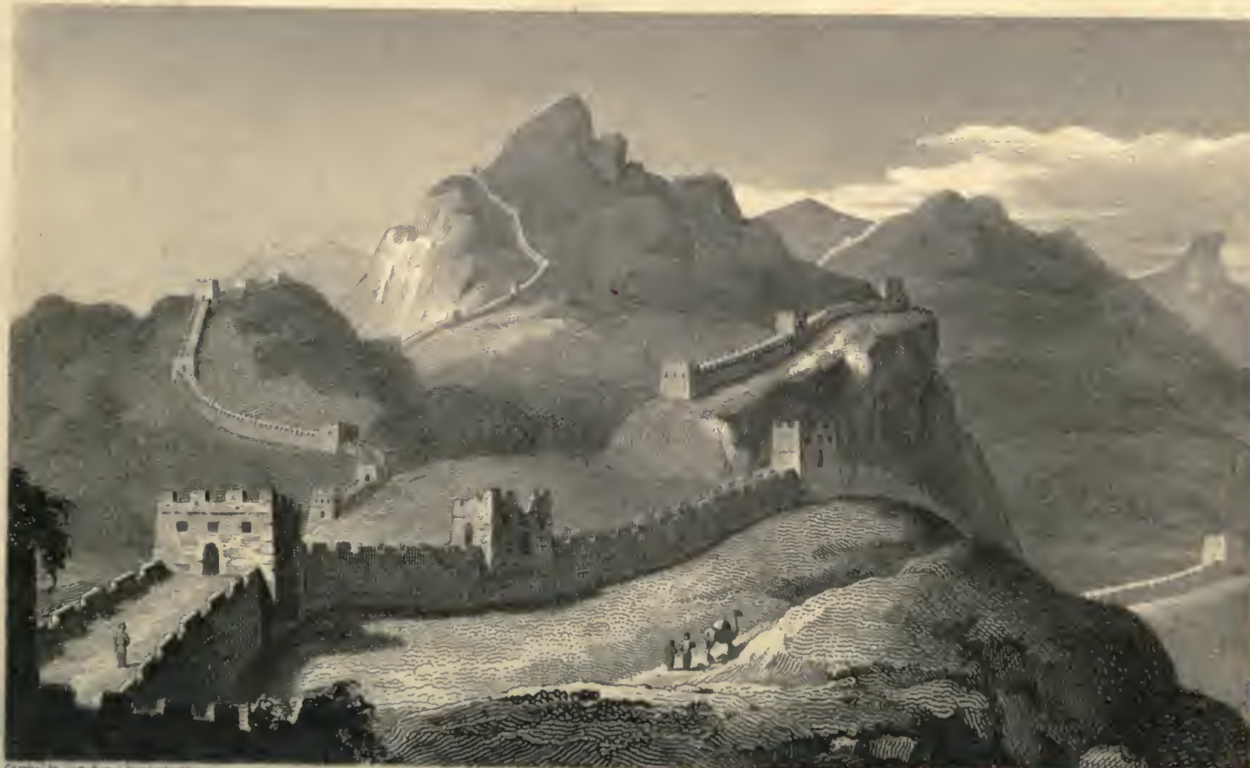
Great Wall of China.

The chief remain of ancient art in China is that stupendous wall, extending across the northern boundary *. This work, which is deservedly esteemed among the grandest labours of art, is conducted over the summits of high mountains, some of which rise to the height of 5225 feet, across the deepest vales, over wide rivers by means of arches; and in many parts is doubled or trebled to command important passes: at the distance of almost every hundred yards is a tower or massy bastion. The extent is computed at 1500 miles; but in some parts of smaller danger it is not equally strong or complete, and towards the N. W. only a rampart of earth. For the precise height and dimensions of this amazing fortification the reader is referred to Sir George Staunton already quoted, whence it appears that near Koopekoo the wall is twenty-five feet in height, and at the top about fifteen feet thick: some of the towers, which are square, are forty-eight feet high, and about forty feet wide. The stone employed in the foundations, angles, &c. is a strong grey granite; but the greatest part consists of bluish bricks, and the mortar is remarkably pure and white.

Sir George Staunton considers the era of this great barrier as absolutely ascertained, and he asserts that it has existed for two thousand years. In this asseveration he seems to have followed Du Halde, who informs us that "this prodigious work was constructed two hundred and fifteen years before the birth of Christ, by the orders of the first emperor of the family of Tsin, to protect

* Sir G. Staunton's Embassy, vol. ii. 360. 8vo.

480'



Engraved by [illegible] from a drawing by [illegible]

VIEW OF THE GREAT WALL OF CHINA CALLED VAN LEE TCHING OR WALL OF [illegible]

three large provinces from the irruptions of the Tartars*." But in the History of China, contained in his first volume, he ascribes this erection to the second emperor of the dynasty of Tsin, namely Chi Hoang Ti; and the date immediately preceding the narrative of this construction is the year 137 before the birth of Christ †. Hence suspicions may well arise, not only concerning the epoch of this work, but even with regard to the purity and precision of the Chinese annals in general. Mr. Bell, who resided for some time in China, and whose travels are deservedly esteemed for the accuracy of their intelligence, assures us ‡, that this wall was built about six hundred years ago (that is about the year 1160), by one of the emperors, to prevent the frequent incursions of the Monguls, whose numerous cavalry used to ravage the provinces, and escape before an army could be assembled to oppose them. Renaudot observes that no oriental geographer, above three hundred years in antiquity, mentions this wall §: and it is surprising that it should have escaped Marco Polo; who, supposing that he had entered China by a different rout, can hardly be conceived, during his long residence in the north of China, and in the country of the Monguls, to have remained ignorant of so stupendous a work ‖. Amidst these difficulties, perhaps it may be conjectured that similar modes of defence had been adopted in different ages; and that the ancient rude barrier having fallen into decay, was replaced, perhaps after the invasion of Zingis, by the present erection, which even from the state of its preservation can scarcely aspire to much antiquity.

[*Du Halde. Staunton. Pinkerton.*

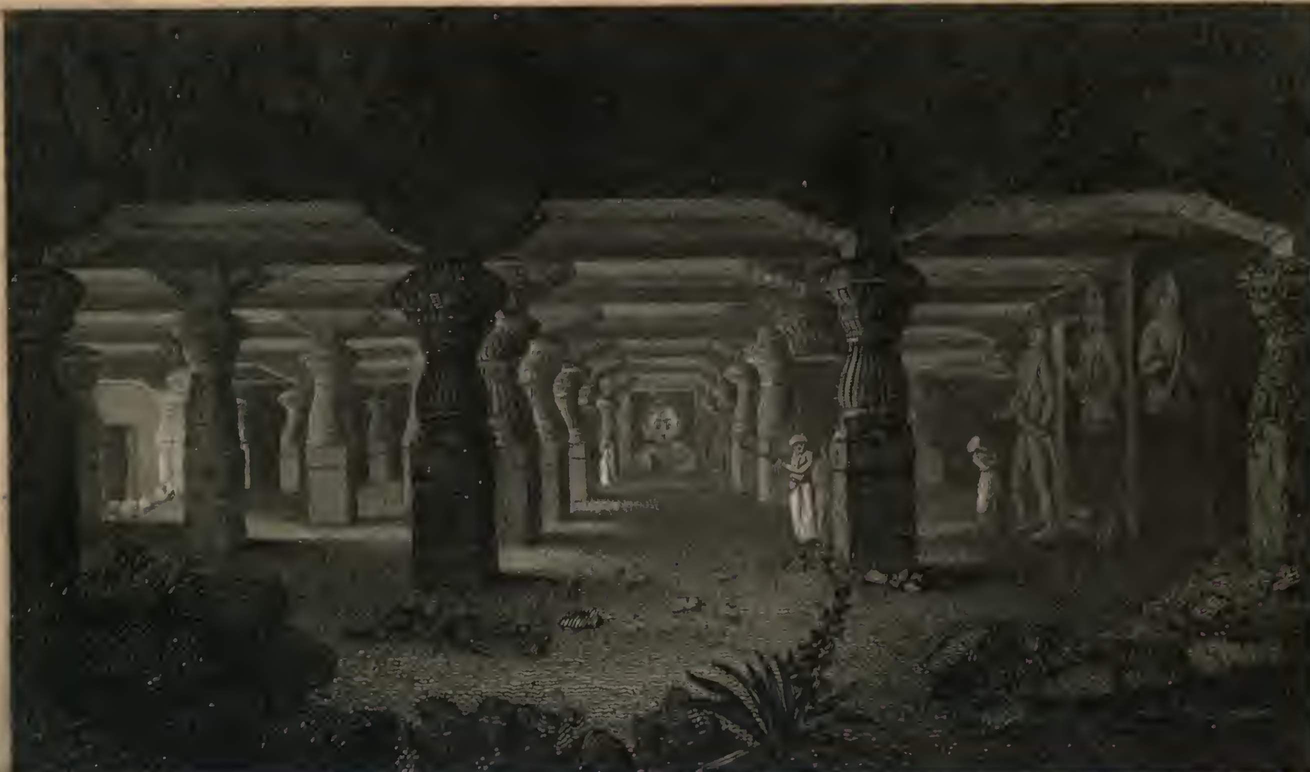
SECTION V.

Temple of Elephanta.

WE got into our boat at Mazagong a little before sunrise, and had the pleasure of marking the gradual increase of day as it broke over the Mahratta mountains. First the woody tops of Caranja and Elephanta became illuminated, then Bombay, with its forts and villages stretching along the north of the bay, while the bases of the rocky islands to the south, slowly became distinguishable from the reflecting waves. After an hour's row, during which we

* Tome ii.. p. 54. † Tome i. 340.
‡ Travels, ii. 112. 8vo. § Ut supra, 137.
‖ Some, however, deny that he entered China.

passed Butcher's Island, called by the natives Deva Devi, or holy island, we arrived at Elephanta, a mountain isle with a double top wooded to the summit: Opposite to the landing-place is the colossal stone elephant, from which the Portuguese named the place. It is now cracked and mutilated, as tradition says, by the Portuguese. It must have been carved out of the rock on which it stands, for it appears too large to have been carried to its present situation. After passing a village which, as well as whole island, the natives call Gharipoori, we ascended the hill through romantic passes, sometimes overshadowed with wood, sometimes walled by rocks, till we arrived at the cave. We came upon it unexpectedly, and I confess that I never felt such a sensation of astonishment as when the cavern opened upon me. At first it appeared all darkness, while on the hill above, below, and around, shrubs and flowers of the most brilliant hues were waving in the full sunshine. As I entered, my sight became gradually more distinct, and I was able to consider the wonderful chamber in which I stood. The entrance is fifty-five feet wide, its height is eighteen, and its length about equal to its width. It is supported by massy pillars, carved in the solid rock; the capital of these resembles a compressed cushion bound with a fillet; the abacus is like a bunch of reeds supporting a beam, six of which run across the whole cave; below the capital the column may be compared to a fluted bell resting on a plain octagonal member placed on a die, on each corner of which sits Hanuman, Ganesa, or some of the other inferior gods. The sides of the cavern are sculptured in compartments, representing persons of the mythology; but the end of the cavern opposite to the entrance is the most remarkable. In the centre is a gigantic trimurti, or three-formed god. Brahma the creator is in the middle, with a placid countenance; his cap is adorned with jewels. Vishnu, the preserving deity, is represented as very beautiful; his face is full of benevolence, his hand holds a lotus, the same sacred flower is placed in his cap, with the triveni or triple-plaited lock, signifying the rivers Gunga (Ganges), Yamuna (Jumna), and Seraswati, and other ornaments referring to his attributes Siva frowns; his nose is aqualine, and his mouth half open; in his hand is his destructive emblem, the cobra-capella, and on his cap, among other symbols, a human skull and a new-born infant marks his double character of destroyer and reproducer. These faces are all beautiful but for the under lips, which are remarkably thick.



SUBTERRANEAN TEMPLE OF ELEPHANTA.

The length from the chin to the crown of the head is six feet; the caps are about three feet more. No part of the bust is mutilated but the two hands in front, which are quite destroyed. Concealed steps behind Siva's hand lead to a convenient ledge or bench behind the cap of the bust, where a Bramin might have hidden himself for any purpose of priestly imposition. On each side of the trimurti is a pilaster, the front of which is filled up by a figure fourteen feet high, leaning on a dwarf; these are much defaced. To the right is a large square compartment, hollowed a little, carved into a great variety of figures, the largest of which is sixteen feet high, representing the double figure of Siva and Parvati, called Viraj or Ardha Nari, half male half female, the right side of which is Siva and the left his wife; it is four-handed; the two lower hands, one of which appears to have rested on the Nundi, are broken; the upper right hand has a cobra-capella, and the left a shield. On the right of the Viraj is Brama, four-faced, sitting on a lotus; and on the left is Vishnu on the shoulders of Garuda. Near Brahma are Indra and Indranee on their elephant, and below is a female figure holding a chamara or chowree *. The upper part of the compartment is filled with small figures in the attitudes of adoration.

On the other side of the trimurti is a compartment answering to that I have just described. The principal figure I take to be Siva; at his left hand stands Parvati, on whose shoulder he leans; between them is a dwarf, on whose head is one of Siva's hands, and near Parvati is another. Over Siva's shoulder hangs the zenaar, and he holds the cobra-capella in one of his four hands. He is surrounded by the same figures which fill up the compartment of the Veraji; his own height (which we measured by a plumb-line dropped from his head,) is fourteen feet, and that of Parvati is ten. All these figures are in alto-relievo, as are those of the other sides of the cavern, the most remarkable of which is one of Siva in his vindictive character; he is eight-handed, with a ch plet of skulls round his neck, and appears in the act of performing the human sacrifice.

On the right hand, as you enter the cave, is a square apartment

* The chamara is a whisk to keep off flies, made either of a cow's tail or peacock's feathers, or ivory shavings, set in a handle two feet long. They are always carried behind persons of rank.

with four doors, supported by eight colossal figures; it contains a gigantic symbol of Maha Deo, and is cut out of the rock like the rest of the cave. There is a similar chamber in a smaller and more secret cavern, to which there is access from the corner next to the Viraji; the covering of the passage has fallen in, but, on climbing over the rubbish, we found ourselves in a little area which has no outlet, and is lighted from above, the whole thickness of the hill being cut through. The cavern to which it belongs contains nothing but the square chamber of Maha Deo, and a bath at each end, one of which is decorated with rich sculpture.

When we had tired ourselves with examining the various wonders of the cavern of Elephanta, I sat down to take a sketch of the great compartments opposite to the entrance, and on our return to Bombay, comparing the drawing with those in Niebuhr, we were satisfied that its resemblance to the original is the most correct. I am sorry to observe, that the pillars and sculptures of the cave are defaced in every part, by having the names of most who visit them either carved or daubed with black chalk upon them; and the intemperate zeal of the Portuguese, who made war upon the gods and temples, as well as upon the armies of India, added to the havoc of time, has reduced this stupendous monument of idolatry to a state of ruin. Fragments of statues strew the floor; columns, deprived of their bases, are suspended from the parent roof, and others without capitals, and sometimes split in two, threaten to leave the massy hill that covers them without support.

The temple of Elephanta, and other equally wonderful caverns in the neighbourhood, must have been the works of a people far advanced in the works of civilized life, and possessed of wealth and power; but these were lodged in the hands of a crafty priesthood, who kept science, affluence, and honour, for their own fraternity, and, possessed of better ideas, preached a miserable and degrading superstition to the multitude. It would be curious to follow out the advancement and fall of the arts which produced such monuments; but not a trace of their history remains, and we are left to seek it in the natural progress of a people subtle and ingenious, but depressed by superstition, and the utter impossibility of rising individually, by any virtues or any talents, to a higher rank in society than that occupied by their forefathers.

[*Mrs. Grahame.*

SECTION VI.

Temple of Juggernaut.

"*Buddruck in Orissa, May 30th*, 1806.

"We know that we are approaching Juggernaut (and yet we are more than fifty miles from it) by the human bones which we have seen for some days strewed by the way. At this place we have been joined by several large bodies of pilgrims, perhaps 2000 in number, who have come from various parts of Northern India. Some of them with whom I have conversed, say that they have been two months on their march travelling slowly in the hottest season of the year, with their wives and children. Some old persons are among them who wish to die at Juggernaut. Numbers of pilgrims die on the road; and their bodies generally remain unburied. On a plain by the river, near the Pilgrim's Caravensera at this place, there are more than a hundred skulls. The dogs, jackals, and vultures, seem to live here on human prey. The vultures exhibit a shocking tameness. The obscene animals will not leave the body sometimes till we come close to them. This Buddruck is a horrid place. Wherever I turn my eyes, I meet death in some shape or other. Surely Juggernaut cannot be worse than Buddruck."

"*In sight of Juggernaut, 12th June*, 1806.

"—— Many thousands of pilgrims have accompanied us for some days past. They cover the road before and behind as far as the eye can reach. At nine o'clock this morning, the temple of Juggernaut appeared in view at a great distance. When the multitude first saw it, they gave a shout, and fell to the ground and worshipped. I have heard nothing to-day but shouts and acclamations by the successive bodies of pilgrims. From the place where I now stand I have a view of a host of people like an army, encamped at the outer gate of the town of Juggernaut: where a guard of soldiers is posted to prevent their entering the town, until they have paid the pilgrim's tax.—I passed a devotee to-day who laid himself down at every step, measuring the road to Juggernaut by the length of his body, as a penance of merit to please the God."

"*Outter Gate of Juggernaut*, 12*th June*, 1806.

" —— A disaster has just occurred.—As I approached the gate, the pilgrims crowded from all quarters around me, and shouted, as they usually did when I passed them on the road, an expression of welcome and respect. I was a little alarmed at their number, and looked round for my guard. A guard of soldiers accompanied me from Cutack, the last military station; but they were now about a quarter of a mile behind with my servants and the baggage. The pilgrims cried out that they were entitled to some indulgence, that they were poor, that they could not pay the tax; but I was not aware of their design. At this moment, when I was within a few yards of the gate, an old Sanyassee (or holy man) who had travelled some days by the side of my horse, came up and said, 'Sir you are in danger; the people are going to rush through the gate when it is opened for you.' I immediately dismounted, and endeavoured to escape to one side; but it was too late. The mob was now in motion, and with a tumultuous shout pressed violently towards the gate. The guard within seeing my danger opened it, and the multitude rushing through, carried me forward in the torrent a considerable space; so that I was literally borne into Juggernaut by the Hindoos themselves. A distressing scene followed. As the number and strength of the mob increased, the narrow way was choaked up by the mass of people; and I apprehended that many of them would have been suffocated, or bruised to death. My horse was yet among them. But suddenly one of the side posts of the gate, which was of wood, gave way and fell to the ground. And perhaps this circumstance alone prevented the loss of lives. Notice of the event was immediately communicated to Mr. Hunter, the superintendant of the temple, who repaired to the spot, and sent an additional guard to the inner gate, lest the people should force that also; for there is an outer and an inner gate to the town of Juggenaut; but both of them are slightly constructed. Mr. Hunter told me that similar accidents sometimes occur, and that many have been crushed to death by the pressure of the mob. He added, that sometimes a body of pilgrims, (consisting chiefly of women and children, and old men) trusting to the physical weight of their mass, will make, what he called a charge on the armed guards, and overwhelm them; the guards not being willing, in such circumstances, to oppose their bayonets."

"*Juggernaut*, 14*th June*, 1806.

"—— I have seen Juggernaut. The scene at Buddruck is but the vestibule to Juggernaut. No record of ancient or modern history can give, I think, an adequate idea of this valley of death; it may be truly compared with the 'valley of Hinnom." The idol called Juggernaut, has been considered as the Moloch of the present age; and he is justly so named, for the sacrifices offered up to him by self-devotement, are not less criminal, perhaps not less numerous, than those recorded of the Moloch of Canaan. Two other idols accompany Juggernaut, namely, Boloram and Shubudra, his brother and sister: for there are three deities worshipped here. They receive equal adoration, and sit on thrones of nearly equal height."

"—— This morning I viewed the temple; a stupendous fabric, and truly commensurate with the extensive sway of 'the horrid king.' As other temples are usually adorned with figures emblematical of their religion, so Juggernaut has representations (numerous and varied) of that vice which constitutes the essence of his worship. The walls and gates are covered with indecent emblems, in massive and durable sculpture.—I have also visited the sand plains by the sea, in some places whitened with the bones of the pilgrims; and another place a little way out of the town, called by the English, the Golgotha, where the dead bodies are usually cast forth; and where dogs and vultures are ever seen*."

"The grand Hindoo festival of the Rutt Jattra, takes place on the 18th instant, when the idol is to be brought forth to the people. I reside during my stay here at the house of James Hunter, Esq. the Company's collector of the tax on pilgrims, and superintendant of the temple, formerly a student in the College of Fort William; by whom I am hospitably entertained, and also by Cap-

* The vultures generally find out the prey first; and begin with the intestines; for the flesh of the body is too firm for their beaks immediately after death. But the dogs soon receive notice of the circumstance, generally from seeing the hurries, or corpse-carriers, returning from the place. On the approach of the dogs, the vultures retire a few yards, and wait till the body be sufficiently torn for easy deglutition. The vultures and dogs often feed together; and sometimes begin their attack before the pilgrim be quite dead. There are four animals which may be seen about a carcase at the same time, viz. the dog, the jackal, the vulture, and the hurgeela, or adjutant, called by Pennant, the gigantic crane.

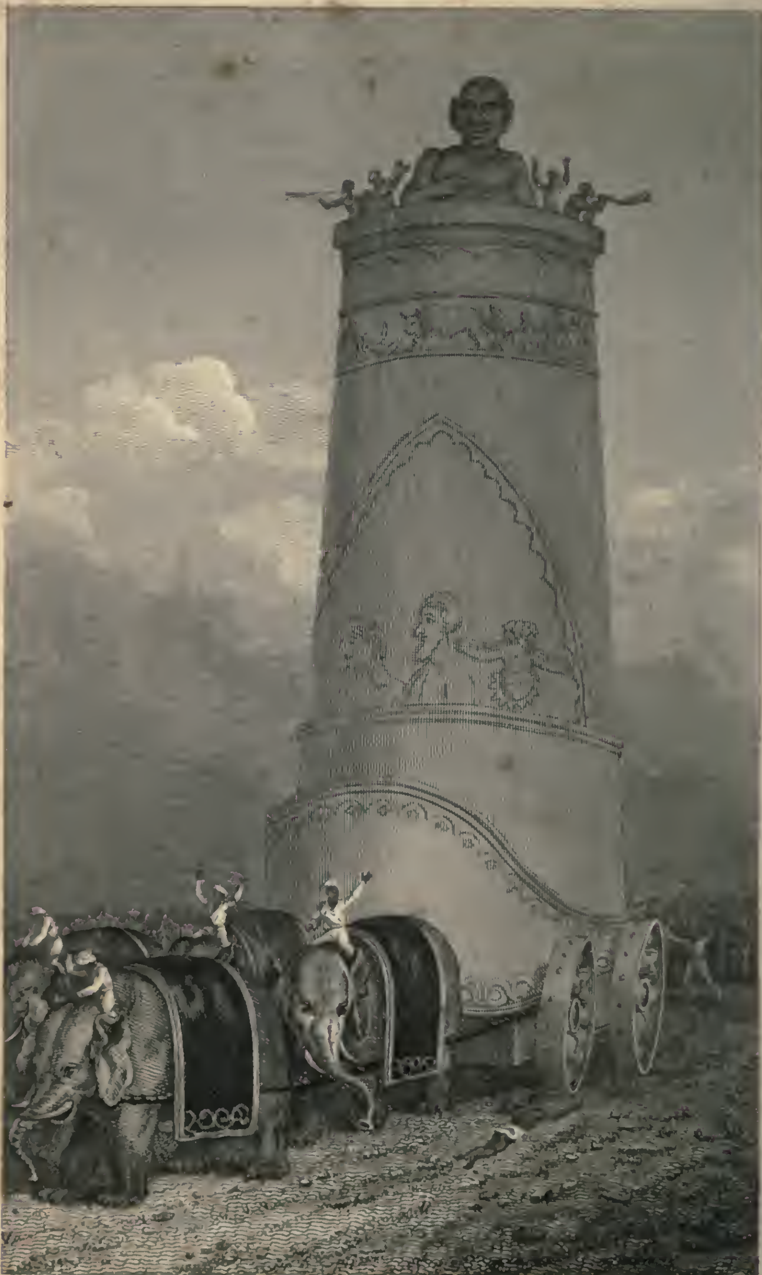
tain Patton, and lieutenant Woodcock, commanding the military force. Mr. Hunter distinguished himself at the college by his proficiency in the Oriental Languages. He is a gentleman of polished manners and of classical taste. The agreeable society of these gentlemen is very refreshing to my spirits in the midst of the present scenes. I was surprised to see how little they seemed to be moved by the scenes at Juggernaut. They said they were now so accustomed to them, they thought little of them. They had almost forgot their first impressions. Their houses are on the sea-shore, about a mile or more from the temple. They cannot live nearer, on account of the offensive effluvia of the town. For, independently of the enormity of the superstition, there are other circumstances which renders Juggernaut noisome in an extreme degree. The senses are assailed by the squalid and ghastly appearance of the famished pilgrims; many of whom die in the streets of want or of disease; while the devotees, with clotted hair and painted flesh, are seen practising their various austerities, and modes of self torture. Persons of both sexes, with little regard to concealment, sit down on the sands close to the town in public view; and the Sacred Bulls walk about among them and eat the ordure*."

"The vicinity of Juggernaut to the sea probably prevents the contagion which otherwise would be produced by the putrefaction of the place. There is scarcely any verdure to refresh the sight near Juggernaut; the temple and town being nearly encompassed by hills of sand, which has been cast up in the lapse of ages by the surge of the ocean. All is barren and desolate to the eye; and in the ear there is the never-intermitting sound of the roaring sea."

"*Juggernaut*, 18*th of June*, 1806.

"I have returned home from witnessing a scene which I shall never forget. At twelve o'clock of this day, being the great day of the feast, the Moloch of Hindostan was brought out of his temple amidst the acclamations of hundreds of thousands of his worshippers. When the idol was placed on his throne, a shout was raised by the multitude, such as I had never heard before. It

* This singular fact was pointed out to me by the gentlemen here. There is no vegetation for the sacred Bulls on the sand-plains. They are fed generally with vegetables from the hands of the pilgrims.



Engraved by Angus from a Drawing by Craig

For the Gallery of Nature & Art

THE IDOL OF JUGGERNAUT, IN ORISSA.

London, Published by R. Wilks, 89, Chancery Lane, [illegible]

continued equable for a few minutes, and then gradually died away. After a short interval of silence, a murmer was heard at a distance; all eyes were turned towards the place, and, behold, a grove advancing. A body of men, having green branches, or palms, in their hands, approached with great celerity. The people opened a way for them; and when they had come up to the throne, they fell down before him that sat thereon, and worshipped. And the multitude again sent forth a voice 'like the sound of a great thunder.'—But the voices I now heard, were not those of melody or of joyful acclamation; for there is no harmony in the praise of Moloch's worshippers. Their number indeed brought to my mind the countless multitude of the Revelations; but their voices gave no tuneful Hosanna or Hallelujah; but rather a yell of approbation, united with a kind of hissing applause.*—I was at a loss how to account for this latter noise, until I was directed to notice the women; who emitted a sound like that of whistling, with the lips circular and the tongue vibrating: as if a serpent would speak by their organs, uttering human sounds."

"The throne of the idol was placed on a stupendous car or tower about sixty feet in height, resting on wheels which indented the ground deeply, as they turned slowly under the ponderous machine. Attached to it were six cables, of the size and length of a ship's cable, by which the people drew it along. Thousands of men, women, and children pulled by each cable, crowding so closely, that some could only use one hand. Infants are made to exert their strength in this office, for it is accounted a merit of righteousness to move the god. Upon the tower were the priests and satalites of the idol, surrounding his throne. I was told that there were about a hundred and twenty persons upon the car altogether. The idol is a block of wood, having a frightful visage painted black, with a distended mouth of a bloody colour. His arms are of gold, and he is dressed in gorgeous apparel. The other two idols are of a white and yellow colour.—Five elephants preceded the three towers, bearing towering flags, dressed in crimson caparisons, and having bells hanging to their caparisons, which sounded musically as they moved."

"I went on in the procession, close by the tower of Moloch; which, as it was drawn with difficulty, 'grated on its many

* See Milton's Pandemonium, Book X.

wheels harsh thunder*.' After a few minutes it stopped; and now the worship of the god began. A high priest mounted the car in front of the idol, and pronounced his obscene stanzas in the ears of the people; who responded at intervals in the same strain. 'These songs,' said he, 'are the delight of the god. His car can 'only move when he is pleased with the song.' The car moved on a little way and then stopped. A boy of about twelve years was then brought forth to attempt something yet more lascivious, if peradventure the god would move. The 'child perfected the praise' of his idol with such ardent expression and gesture, that the god was pleased, and the multitude, emitting a sensual yell of delight, urged the car along. After a few minutes it stopped again. An aged minister of the idol then stood up, and with a long rod in his hand, which he moved with indecent action, completed the variety of this disgusting exhibition. I felt a consciousness of doing wrong in witnessing it. I was also somewhat appalled at the magnitude and horror of the spectacle; I felt like a guilty person on whom all eyes were fixed, and I was about to withdraw. But a scene of a different kind was now to be presented. The characteristic of Moloch's worship are obscenity and blood. We have seen the former. Now comes the blood.

"After the tower had proceeded some way, a pilgrim announced that he was ready to offer himself a sacrifice to the idol. He laid himself down in the road before the tower as it was moving along, lying on his face, with his arms stretched forwards.—The multitude passed round him, leaving the space clear, and he was crushed to death by the wheels of the tower. A shout of joy was raised to the god. He is said to smile when the libation of

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* Two of the military gentlemen had mounted my elephant that they might witness the spectacle while I walked, and had brought him close to the tower; but the moment it began to move, the animal, alarmed at the unusual noise, took fright and ran off through the crowd till he was stopt by a wall. The natural fear of the elephant, lest he should injure human life, was remarkably exemplified on this occasion. Though the crowd was very closely set, he endeavoured, in the midst of his own terror, to throw the people off, on both sides, with his feet, and it was found that he had only trod upon one person. It was with great concern I afterwards learnt, that this was a poor woman, and that the fleshy part of her leg had been torn off. There being no medical person here, lieutenant Woodcock, with great humanity, endeavoured to dress the wound, and attended her daily; and Mr. Hunter ordered her to be supplied with every thing that might conduce to her recovery.

the blood is made. The people threw cowries, or small money, on the body of the victim, in approbation of the deed. He was left to view a considerable time, and was then carried by the Hurries to the Golgotha, where I have just been viewing his remains. How much I wished that the proprietors of India stock could have attended the wheels of Juggernaut, and seen this peculiar source of their revenue."

"*Juggernaut*, 20*th June*, 1806.

" Molloch, horrid king, besmeared with blood
" Of human srcrifice, and parents' tears.—MILTON.

" —— The horrid solemnities still continue. Yesterday a woman devoted herself to the idol. She laid herself down on the road in an oblique direction, so that the wheel did not kill her instantaneously, as is generally the case; but she died in a few hours. This morning as I passed the Place of Skulls, nothing remained of her but her bones.

" And this, thought I, is the worship of the Brahmins of Hindostan, and their worship in its sublimest degree! What then shall we think of their private manners, and their moral principles! For it is equally true of India as of Europe. If you would know the state of the people, look at the state of the Temple.

" I was surprised to see the Brahmins with their heads uncovered in the open plain falling down in the midst of the Sooders before 'the horrid shape,' and mingling so complacently with 'that polluted cast.' But this proved what I have before heard, that so great a god is this, that the dignity of high cast disappears before him. This great king recognises no distinction of rank among his subjects, all men are equal in his presence."

"*Juggernaut*, 21*st June*, 1806.

" The idolatrous processions continue for some days longer, but my spirits are so exhausted by the constant view of these enormities, that I mean to hasten away from this place sooner than I at first intended. I beheld another distressing scene this morning at the Place of Skulls;—a poor woman lying dead, or nearly dead, and her two children by her, looking at the dogs and vultures which were near. The people passed by without noticing the children. I asked them where was their home. They said, 'they had no home but where their mother was.'—O, there is no pity in Juggernaut! no mercy, no tenderness of heart in Moloch's kingdom! Those who support his kingdom, err, I trust, from ignorance. 'They know not what they do.''

"As to the number of worshippers assembled here at this time, no accurate calculation can be made. The natives themselves when speaking of the numbers at particular festivals, usually say that a lack of people (100,000) would not be missed. I asked a Brahmin how many he supposed were present at the most numerous festival he had ever witnessed. 'How can I tell,' said he, 'how many grains there are in a handful of sand?"

"The languages spoken here are various, as there are Hindoos from every country in Indi: but the two chief languages in use by those who are resident, are the Orissa and the Telinga. The border of the Telinga country is only a few miles distant from the tower of Juggernaut*.''

"*Chilka Lake, 24th June.*

"—— I felt my mind relieved and happy when I had passed beyond the confines of Juggernaut. I certainly was not prepared for this scene. But no one can know what it is who has not seen it. From an eminence † on the pleasant banks of the Chilka Lake (where no human bones are seen) I had a view of the lofty tower of Juggernaut far remote; and while I viewed it, its abominations came to mind. It was on the morning of the Sabbath. Ruminating long on the wide and extended empire of Moloch in the heathen world, I cherished in my thoughts the design of some 'Christian Institution,' which, being fostered in Britain, my Christian country, might gradually undermine this baleful idolatry, and put out the memory of it for ever."

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* It will give pleasure to the reader to hear, that a translation of the Holy Scriptures is preparing in Orissa and Telinga, the languages of Juggernaut.

† Manickpatam.

Annual Expenses of the Idol Juggernaut, presented to the English Government.

[Extracted from the Official Account.]

	Rupees.	£. Sterling.
1. Expenses attending the table of the idol	36,115 or	4,514
2. Ditto of his dress or wearing apparel .	2,712	339
3. Ditto of the wages of his servents . .	10,057	1,259
4. Ditto of contingent expenses at the different seasons of pilgrimage . . .	10,989	1,373
5. Ditto of his elephants and horses . .	3,030	378
6. Ditto of his rutt or annual state carriage	6,713	839
Rupees	69,616	£8702

" In item third, ' wages of his servants,' are included the wages of the courtesans, who are kept for the service of the temple.

" Item sixth.—What is here called in the official account ' the state carriage,' is the same as the car or tower. Mr. Hunter informed me that the three ' state carriages' were decorated this year (in June 1806) with upwards of 200*l.* sterling worth of English broad cloth.

" Of the rites celebrated in the interior of Juggernaut, called the Daily Service, I can say nothing of my own knowledge, not having been within the temple*."

Dr. Buchanan's Christian Researches in India.

* "At the Temple of Juggernaut, the English government levy a tax on pilgrims as a source of revenue. The first law, enacted by the Bengal government for this purpose, was entitled " A regulation for levying a tax from pilgrims resorting to the Temple of Juggernaut, and for the superintendance of and management of the Temple.—Passed 3d of April, 1806." Another regulation was passed in Bengal, in April, 1809, rescinding so much of the former as related to the " interior management and controul" of the Temple; but sanctioning the levying the tax from pilgrims for admission to the temple; allotting a sum toward the expenses of the idol; and appointing an officer of government to collect the tax. Of this second regulation, the author received no intimation until the third edition of his work was put to press. In the former editions, it was stated that the Temple was under the immediate management and controul of the English government; which he is now happy to find was not the fact at the time. Whether the account of the new regulation had

SECTION VII.

Morai, or Cemetery and Temple of the Australasian Islands.

One of the most singular discoveries which occurred to Captain Cook at Otaheite, was the sacred edifices which the inhabitants denominated *Morais*, and which were appropriated to the double purpose of places of worship, and sepulchres: and the name has since appeared to the learned world as extraordinary as the fact; for the word *Mor-ai* is literally a Greek compound Μορ αια, "the region of death; though it is probable that the Australasians, as well as the Greeks, derived the term from the Sanscrit, in which it is equally to be found.

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reached England before the 1st of July, 1810, when he had occasion first to notice the subject, he does not know. But he has it now in his power to communicate to the public the following authentic information, which, in justice to the honorable Court of Directors, as to the part they have taken in this matter, ought to be known.

When the Bengal government first announced their regulation of the 3d of April, 1806, to the Court of Directors, (which they did by letter, dated 16th May, 1806,) they communicated their intention of making the following alterations therein;—namely to permit "certain officers of the temple to collect their fees directly from the pilgrims agreeably to former usage, instead of receiving the amount of those fees from the public treasury: to allow the Pundits, who are to superintend the affairs of the temple, to be elected by particular classes of persons attached to it, instead of being appointed by the government; and to vest in the Pundits so elected, the entire controul over the temple and its ministers and officers, as well as over the funds allotted for its expenses; restricting the interference of the officers of Government to the preservation of the peace of the town, to the protection of pilgrims from oppression and extortion, and to the collection of the tax to be appropriated to the use of government."

When this subject came under the notice of the Court of Directors in the year 1808, they thought it proper to propose a distinct statement of their opinions upon it to the Bengal government; and they prepared a letter, wherein they enjoined, that the government should not elect the priests who were to superintend the affairs of the Temple, or exercise a controul over its ministers and officers, or take the management of it funds; and that the exercise of the authority of the government should extend only to objects falling directly within the province of the magistrates, as the care of the police, the administration of justice, and the collection of such a tax, professedly for these ends, as should be required for their due attainment of them; not subjecting the Hindoos to any tax for access to the place of devotion, or under the notion of granting them a religious privilege, or of tolerating idolatry, in consideration of money. The Court of Directors, how-

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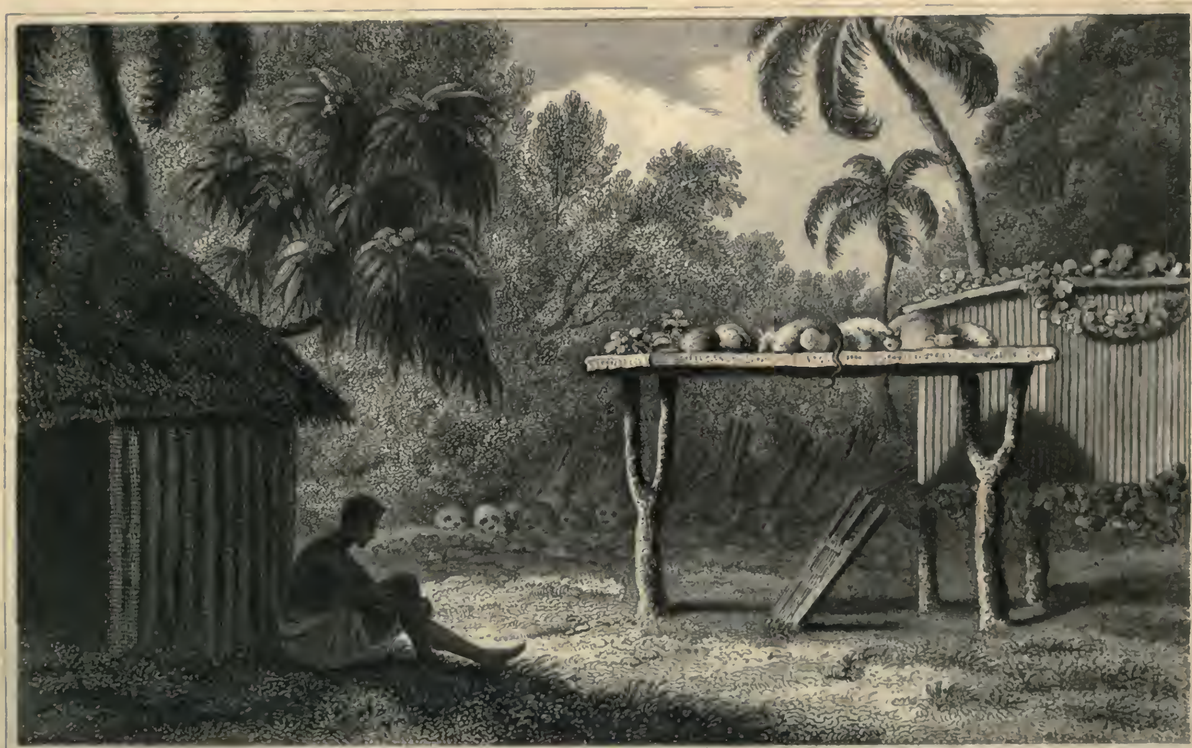

Engraved by Lacey from a Drawing by Craig

For the Gallery of Nature & Art

A MORAI, IN THE ISLAND OF TONGATABOO.

The Morai has since been found in the Sandwich Islands, and in almost all the various groups which belong to Australasia; but in Otaheite we meet with it in its most extensive and celebrated form. In this island it consists of a pile of stone raised pyramidically upon an oblong base or square two hundred and sixty-seven feet long, and eighty-seven wide. On each side is a flight of steps; those at the sides being broader than those at the ends; so that it terminated not in a square of the same figure with the base, but in a ridge like the roof of a house. There were eleven of these steps to one of the morais, each of which was four feet high, so that the height of the pile was forty-four feet; each step was formed of one course of white coral stone, which was neatly squared and polished; the rest of the mass (for there was no hollow within) con-

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ever, were over-ruled in this proceeding by a superior authority, which thought it sufficient to acquiesce generally in what the Bengal government, in their above-mentioned letter of the 16th May, 1806, proposed should be done.

By the same superior authority another dispatch was substituted to that effect, in which it was stated, that as the tax on pilgrims resorting to Allahabad and Juggernaut, was established during the Nawaub's and the Mahratta government, three did not appear to be any objecton to its continuance under the British government.

This substituted dispatch went, as the law directs, in the name of the Court of Directors, although it was in opposition to their sentiments. But, before it arrived in Bengal, the government there had passed, by their own authority, the regulation of April, 1809.

That part of the province of Orissa, which contains the Temple of Juggernaut, first became subject to the British Empire under the administration of Marquis Wellesley, who permitted the pilgrims at first to visit Juggernaut without paying tribute. It was proposed to his lordship, soon after, to pass the regulation first above-mentioned for the management of the temple, and levying the tax; but he did not approve of it, and actually left the government without giving his sanction to the opprobrious law. When the measure was discussed by the succeeding government, it was resisted by George Udney, Esq. one of the members of the Supreme Council, who recorded his solemn dissent on the proceedings of government, for transmission to England. The other members considered Juggernaut to be a legitimate source of revenue, on the principle, I believe, that money from other temples in Hindostan had long been brought into the treasury. It is just that I should state that these gentlemen are men of the most honourable principles and of unimpeached integrity. Nor would any one of them, I believe, (for I have the honour to know them) do any thing which he thought injurious to the honour or religion of his country. But the truth is this, that those persons who go to India in early youth, and witnes the Hindoo customs all their life, seeing little at the same time of the Christian religion to counteract the effect, are disposed to view them with complacency, and are sometimes in danger of at length considering them even as proper or necessary."

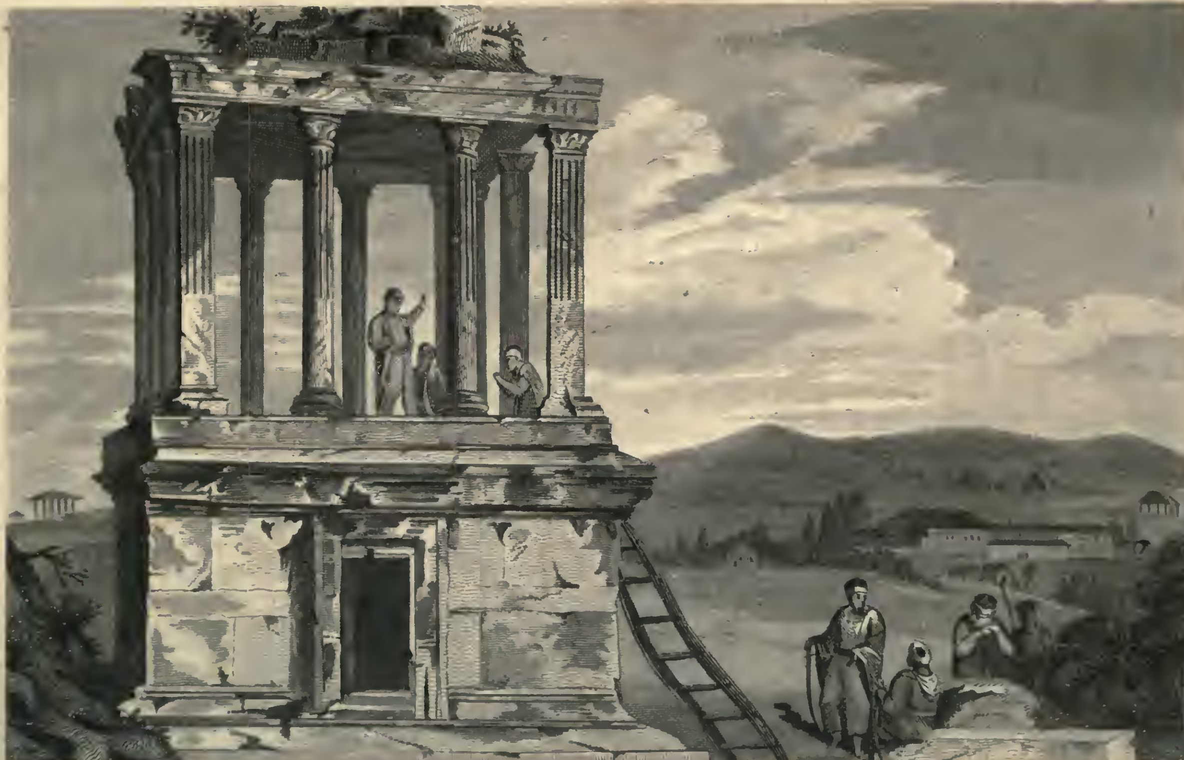
sisted of round pebble, which from the regularity of their figure, seem to have been wrought. The foundation was of rock stones, which were also squared. In the middle of the top stood an image of a bird carved in wood, and near it lay the broken one of a fish carved in stone. The whole of this pyramid made part of one side of a spacious area or square three hundred and sixty feet by three hundred and fifty-four, which was walled in with stone, and paved with flat stones in its whole extent. About one hundred yards to the west of this building was another paved area or court, in which were several small stages raised on wooden pillars about seven feet high, which are called by the Indians *ewattas*, and seem to be a kind of altars, as upon these are placed provisions of all kinds, as offerings to their gods. On some of them were seen whole hogs, and on others the skulls of above fifty, besides the skulls of many dogs. The principal object of ambition among the natives is to have a magnificent morai. The male deities (for they have them of both sexes) are worshipped by the men, and the female by the women; and each have morais, to which the other sex is not admitted, though they have also morais common to both.

[*Cook's Voyages. Hawkesworth.*

SECTION VIII.

Architectural Remains, at Mylasa.

MYLASA, or Mylassa, was the capital of Hecatomnus, king of Caria, and father of Mausolus. It has been described as situated by a very fertile plain, with a mountain rising above it, in which was a quarry of very fine white marble. This being near, was exceedingly convenient in building, and had contributed greatly to the beauty of the city, which, it is said, if any, was handsomely adorned with public edifices, porticoes, and temples. The latter was so numerous, that a certain musician entering the market-place, as if to make proclamation, began, instead of (Ακȣετε Λαοι) *Hear ye People*, with (Ακȣετε Ναοι) *Hear ye Temples*. The founders of the city were censured as inconsiderate in placing it beneath a steep precipice, by which it was commanded. Under the Romans it was a free city. Its distance from the sea, where nearest, or from Physcus opposite the island of Rhodes, was eighty stadia, or ten miles. It is still a large place, commonly called Melasso. The houses are numerous, but chiefly of plaster, and


Engraved by Angus from a Drawing by Hopkins

For the Gallery of Nature & Art

SEPULCHRAL MONUMENT

mean, with trees interspersed. The air is accounted bad; and scorpions abound as antiently; entering often at the doors and windows, and lurking in the rooms. The plain is surrounded by lofty mountains, and cultivated; but has long been parched and bare, except some spots green with the tobacco plant, which in flower is pleasing to the eye.

Our first enquiry was for the temple, erected about twelve years before the Christian æra, by the people of Mylasa, to Augustus Cæsar, and the Goddess of Rome; which was standing not many years ago. We were shown the basement, which remains; and were informed, the ruin had been demolished, and a new Mosque, which we saw on the mountain-side, above the town, raised with the marble. The house of a Turk occupying the site, we employed the Hungarian to treat with him for admission; but he affirmed we could see nothing; and added, that there was his harem, or the apartment of his women, which was an obstacle not to be surmounted. It had six columns in front, and the whole number had been twenty-two.

On the hill, and not far from the basement of the temple, is a column, of the Corinthian order, standing, with a flat-roofed cottage, upon a piece of solid wall. It has supported a statue; and on the shaft is an inscription *. "The people have erected it to Menander, son of Ouliades, son of Euthydemus, a benefactor to his country, and descended from benefactors." The Turk, who lived in the cottage, readily permitted a ladder to be placed on the terrace for measuring the capital, which was done as expeditiously as possible, but not before we were informed, that several of the inhabitants murmured, because their houses were overlooked. Besides this, two fluted columns, of the Ionic order, remained not many years since.

Euthydemus the ancestor of Menander, was contemporary with Augustus Cæsar. He was of an illustrious family, and possessed an ample patrimony. He was eloquent, and not only great in his own country, but respected as the first person of Asia Minor. His power was so advantageous to the city, that, if it savoured of tyranny, the odium was overcome by its utility. Hybreas concluded an oration, with telling him he was a necessary evil. This demagogue, who succeeded Euthydemus, had inherited only a mule

* Inscript. Ant. p. 27.

and its driver, employed then, as many now are, in bringing wood from the mountains for sale *.

Beneath the hill, on the east side of the town, is an arch or gateway of marble, of the Corinthian order. On the key-stone of the exterior front, which is eastward, we observed a double-hatchet, as on the two marbles near Myûs. It was with difficulty we procured ladders to reach the top; and some were broken, before we could find three sufficiently long and strong for our purpose. The going up, when these were united, was not without danger. The Aga had expressed some wonder at our employment, as described to him; and seeing one of my companions on the arch, from a window of his house, which was opposite, pronounced him, as we were told, a brave fellow, but without brains. We desired him to accept our umbrella, on his sending to purchase it for a present to a lady of his harem, who was going into the country. By the arch was a fountain, to which women came with earthen pitchers for water, and with their faces muffled.

We saw a broad marble pavement, with vestiges of a theatre, near the Corinthian column. Toward the centre of the town, we observed a small pool of water, and by it the massive arches of some public edifice. In the court of the Aga's house was an altar much ornamented. We found an altar likewise in the streets, and a pedestal or two half buried, with pieces of antient wall. Round the town are ranges of broken columns, the remnants of porticoes, now, with rubbish, bounding the vineyards. A large portion of the plain is covered with scattered fragments, and with piers of ordinary aquæducts; besides inscriptions, mostly ruined and illegible. Some altars, dedicated to Hecatomnus, have been discovered.

About a quarter of a mile from the town is a sepulchre †, of the species called by the ancients, *Distga* or *Double-roofed*. It consisted of two square rooms. In the lower, which has a door-way, were deposited the urns with the ashes of the deceased. In the upper, the relations and friends solemnized the anniversary of the funeral, and performed stated rites. A hole made through the floor, was designed for pouring libations of honey, milk, or wine, with which it was usual to gratify the manes or spirits. The roof is remarkable for its construction, but two stones are wanting, and some distorted. It is supported by pillars of the Corinthian order,

* Strabo, p. 659.

† See a similar edifice in Mountfaucon, t. 5. tab. 27.

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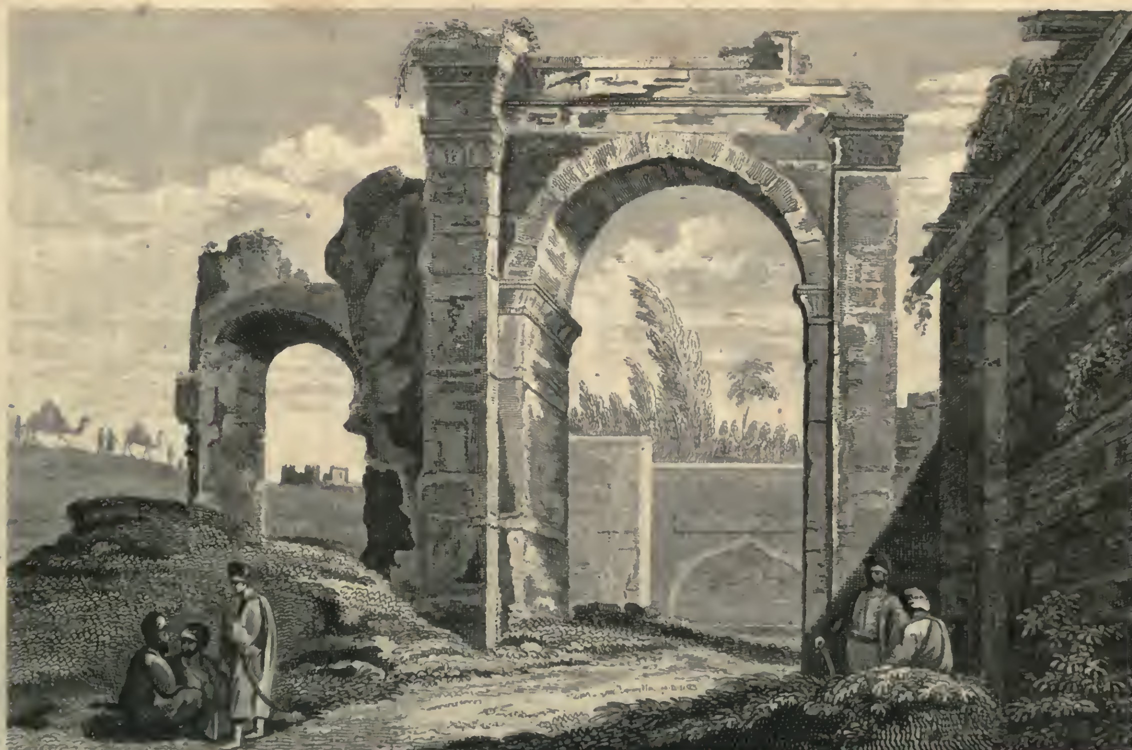


Engraved by Hay from a Drawing by Hopkin

For the Gallery of Nature & Art

ARCH OF MYLASSA.

fluted, some of which have suffered from violence, being hewn near the bases, with a view to destroy the fabric for the iron and materials. The shafts are not circular, but elliptical *; and in the angular columns square. The reason is, the sides, which are now open, were closed with marble pannels; and that form was necessary to give them a due projection. The inside has been painted blue. This structure is the first object, as you approach from Jasus, and stands by the road. The entrance was on the farther side, the ascent to it probably by a pair of steps, occasionally applied and removed. [*Chandler*.

SECTION IX.

Temple of Heliopolis or Balbeck.

Heliopolis, the Balbeck of more modern times, is mentioned by the Arabians as the wonder of Syria; and such of our European travellers as have visited it, are so charmed with what they beheld there, that they are at a loss how to express their admiration. On the south west of the town, which stands in a delightful plain on the west foot of Antilibanus, is an heathen temple, with the remains of some other edifices; and, among the rest, of a magnificent palace. These ancient structures have been patched and pieced in later times, and converted into a castle, as it is called. As you draw near to these venerable ruins, you meet with a rotunda, or round pile of building, incircled with pillars of the Corinthian order, which support a cornice that runs all round the structure; the whole of great elegance and stateliness, but now in a very tottering condition. It is mostly of marble, and, though round on the outside, is an octagon within; being, in the inside, adorned with eight arches, supported by eight Corinthian columns, each of one piece. It is now open at top, but appears to have been covered and embellished with the figures of eagles. The Greeks, who have converted this round into a church, have spoiled the beauty of the inside, by daubing it over with plaster. Leaving this, you come to a large, firm, and very lofty pile of building, through which you pass into a noble arched walk or portico, one hundred and fifty paces long, that leads to the temple.

* See a column described as singular by Tournefort, p. 339. See Pococke, p. 56,

This temple has resisted the injuries of time, and the madness of superstition, being yet almost entire. It is an oblong square, in its general form and proportion, exactly like St. Paul's, Covent Garden; but, for magnificence of structure and dimension, there is scarce any comparison, this temple being almost as big again every way. Its length on the outside is one hundred and ninety-two feet, and its breadth ninety-six; its length in the inside one hundred and twenty feet, and its breadth sixty. The pronaos, or ante-temple, took up fifty-four feet of the hundred and ninety, but is now ruined; and the pillars which supported it, are broken. The whole body of this temple, as it now stands, is surrounded with a noble portico, supported by pillars of the Corinthian order, six feet three inches in diameter, about fifty-four in height, and each of three stones apiece. Their distance from each other, and from the wall of the temple, is nine feet. There are fourteen of them on each side of the temple, and eight at each end, counting the corner pillars in each number. The architrave and cornice, which are supported all round by these pillars, are exquisitely carved. And, as you walk round this temple, between its wall and the pillars which go round it, you have, over head, a solid arcade all the way, of great stones hollowed out archwise; in the centre of each of which is a god, a goddess, or a hero struck out with that life, that is not to be conceived, and all round the foot of the wall of the temple itself is a double border of marble, the lowest part of which is a continued bas-relief in miniature, expressing heathen mysteries and ceremonies; where, without any confusion, you see a surprising mixture of men and beasts, in the most happy composition, and most agreeable variety.

Having thus described the outside of this temple, we proceed to the inside; but let us first take a view of the entrance, than which nothing can be more august. The ascent to it is by thirty steps, on each side bounded by a wall, that terminates in a pedestal, on which formerly stood a statue, as we may naturally suppose. The front is composed of eight Corinthian pillars, as we have already said, fluted, as are all the rest that go round the temple, and an ample and nobly proportioned triangular pediment. Within these eight pillars, at the distance of about six feet, are four others, like the former, and two pillars of three faces each, that terminate the walls of the temple, which come out a good way from the body of the temple itself. All these form a porch or portico before the door of the temple, in depth about twenty-four feet, and in breadth sixty odd: through these pillars appears the door of the temple, under the vault of the portico; but it there appears with great majesty, and without the least confusion; so nice are the proportions of the pillars, their distance from each other, and the recess of the door itself. The door-case, or portal, is square, and of marble, in proportion and construction just like the great marble portal at the west end of St. Paul's, but far richer in sculpture and larger, if we mistake not. The whole height of it is about forty feet, and its whole width about twenty-eight, with an opening of about twenty feet wide. You are no sooner under this portal, but, looking up, you see the bottom of the lintel, enriched with a piece of sculpture, hardly to be equalled. It is a vast eagle in bas-relief, expanding his wings, and carrying a caduceus in his pounce; and on each side of him is a Fame or Cupid supporting one end of a festoon by a string or ribband, the other being held in the eagle's beak.

As to the inside of the temple, it is divided into three isles, two narrow on the sides, and one broad in the middle, after the manner of our churches, being formed by two rows of fluted Corinthian pillars, of between three and four feet diameter, and in height, including the pedestal, about thirty-six. These pillars are twelve in number, six on a side, at the distance of about eighteen feet from each other, and about twelve from the walls of the temple. The walls are adorned with two rows or orders of pilasters one over another, and between each two of the lowermost is a round niche about fifteen feet high. The bottom of the niches is upon a level with the bases of the pillars, and the wall to that height is wrought in the proportions of a Corinthian pedestal, and the niches themselves are Corinthian in all their parts, with the strictest precision, and nicest delicacy. Over these round niches is a row of square ones between the pilasters of the upper order: the ornaments belonging to them are all marble, and they are each crowned with a triangular pediment. Towards the west end of the middle isle you ascend to a choir, as it is called, by thirteen steps, which are the whole breadth of this part. This choir is distinguished from the rest of the temple by two large square columns adorned with pilasters, which form a noble entrance, exactly corresponding with that of the temple itself. Here is a great profusion of astonishing sculpture; but the architecture is the same here as in the body of the temple, except that the pillars have no pedestals, and the niches stand upon the pavement. The two large square pillars, which so remarkably distiuguish this part of the temple, are thought to have supported a canopy; but nothing of that kind is to be seen now. In the bottom of this choir is a vast marble niche, where stood the principal deity here worshipped. In this choir are seen the most finely imagined sculptures, festoons, birds, flowers, fruits; and fine bas-reliefs, Neptunes, Tritons, fishes, sea-gods, Arion and his dolphin, and other marine figures. The cieling or vault of this temple is bold, and divided into compartments filled with excellent carvings. It is open towards the middle; but whether a cupola or lantern stood there for the admission of light, or whether it was always open, cannot be judged at this distance of time. In a word, the charming symmetry, the correct taste, and the height wherewith all the carvings are finished, even at such elevations, where so great niceness is thought unnecessary, are such, that it may be truly said, the whole pile is without the least blemish. The whole stands upon vaults of such excellent architecture, and so bold a turn, that it is thought they served for something more than merely the support of the superincumbent weight, and may have been a subterraneous temple, applied to some particular service in the Pagan worship. And, though this temple now stands by itself, there are evident marks that it was accompanied by other buildings, no way unworthy of it; among which are reckoned four different ascents to it, one upon each angle, with marble steps so long that eight or ten persons may go up abreast.

Within the walls of this castle, as it is now called, are also great remains of what must have been a palace scarce inferior to any royal seat that has ever been in the world; but, being by no means in so perfect a state as the temple, we shall speak of it in general terms, and of such parts only as deserve our greatest attention. But, first of all, it must be observed, that the old wall, which inclosed both this and the temple above described, is built of such monstrous blocks of stone, as exceed all belief, and have given birth to a tradition among the natives, that the whole is the work of the devil. There are particularly three, which lie end for end with each other, and which together extend one hundred eighty-three feet in length, whereof one is sixty-three feet long, and the other two sixty apiece. Their depth is twelve feet, and their breadth the same; and, what adds to the wonder, these stones are lifted twenty feet from the ground. The rest of the stones of this wall are of surprising dimensions, but none quite so large as these.

Going through the long arched walk, which we have already mentioned as leading to the temple, and which looks like a subterraneous passage, adorned with many busts, which for want of light cannot well be discerned, the first object which strikes the sight is a spacious hexagonal building or wall, forming a kind of a spacious theatre, which is open at the other end, and presents you with a terrace, to which you ascend by marble steps. This aperture admits you into a square court, larger than the first, round which are magnificent buildings. On each hand you have a double row of pillars, which form porticoes or galleries of sixty-six fathom in length, and eight in breadth. The bottom of this court was taken up by a third building, more sumptuous than the rest, and deeper, which seems to have been the body of the palace, fronting east, as all the fronts in this castle do. The columns belonging to this part are of such size, that they are compared with those of the hippodrome at Constantinople. Nine of these columns are standing, and a good piece of the entablature, which evince it to have been one of the wonders of Asia; and, to crown all, each of these nine pillars is but one block. Many considerable and distinct vestiges of the several parts of this palace are still extant. The Corinthian order prevails chiefly throughout the whole; and scarce are any where to be found such precious remains of architecture and sculpture. The ornaments are various, but without any of the wild extravagancies of modern architects. The fine taste of Greece, and the magnificence of Rome, here meet; statues without number, busts of all sorts, proud trophies, curiously wrought niches, walls and cielings enriched with bas-reliefs, incrustations, and other works of the finest marble; therms and caryatides, judiciously placed. Underneath the whole are vast vaults; where from time to time you discover, through the ruins, long flights of marble stairs, near two hundred in a flight. The turn and elevation of these vaults are bold and surprising: and in these subterraneous parts you find many rooms, halls, rich apartments entire, and many marble tombs. The walls here also are adorned with niches, bas-reliefs, and inscriptions in Roman characters; but these inscriptions are quite effaced by the length of time, and the damps. Some of these vault are quite dark, and must be visited with lights, either because of their great depth, or because the passages which may have given them light are stopped up by rubbish; but others receive light by great windows, which stand on the level of the ground above: and lastly, all these edifices are built with stones of the enormous size already mentioned, without any visible mortar, cement, or binding whatsoever. The temple and these ruins stand in the same inclosure, as we have said, and may challenge any monument of antiquity now exant, either at Athens or at Rome, or even in Egypt. All over and about the town, you, at every step, meet with some melancholy fragment of antiquity. The quarry from whence they had the stone for these works is a little way out of the town. It is cut out in steps something like an amphitheatre, where lies one stone ready hewn, which seems to surpass all that have been already described. A notion prevailed, that it was too heavy to be moved; but, upon a nice examination, it was found fastened to the rock. Such was the city of Balbeck, and from its surprising grandeur and magnificence we may well conclude it to have been once the most considerable place in Syria. and the delight of some mighty prince, who there chose to reside.

[*Anc. Univ. Hist.*

SECTION X.

Magnificent Ruins of Palmyra.

The splendid city of Palmyra, as it was called by the Greeks and Romans; by the scripture writers, Tadmor in the wilderness; by Josephus, Palmira and Thadamor; by the septuagint copies, Theodmor and Thedmor; and by the Arabs and Syrians at this day, Tadmor, Tadmur, and Tatmor; was once a noble city in the south-eastern parts of Syria. The origin of these names is dark and uncertain. It stood on a fertile island, if we may so call it, surrounded on all sides by a thirsty and barren desert. The first object that now occurs as you approach this forlorn place, is a castle of mean architecture, and uncertain foundation, though formerly by situation impregnable, about half an hour from the city. This castle stands on the north side of the city, and from thence you descry Tadmor, inclosed on three sides by long ridges of mountains; but to the south is a vast plain, which stretches out of sight. The air is exceeding good; but the soil is barren, affording nothing green but a few palm-trees in the gardens, and a few more scattered up and down. The city must have been of large extent by the space now taken up by the ruins; but there are no vestiges of the walls, whereby to judge of its ancient form. It is now a deplorable spectacle to behold, being only inhabited by thirty or forty miserable families, who have built poor huts of mud, within a spacious court, which once inclosed a magnificent heathen temple.

To begin the description here: This court, which stands about the south end of the city, is two hundred and twenty yards on each side, with an high and stately wall of large square stone, adorned with pilasters within and without, to the number, as near as could be judged, of sixty-two on a side. The beautiful cornices have been purposely beaten down by the Turks, who have thereby deprived the world of one of the finest works of the kind that perhaps was ever seen, as here-and-there a fragment, which has escaped their fury, abundantly evinces. The west side of this court, by which you enter it, is most of it broken down; and towards the middle of it there are remains of an old castle, built by the Mamlûks, as is supposed, out of part of the ruins which are here in such abundance. This castle shrouds the remains of an ancient fabric of exquisite beauty, as appears by what is still standing of its entrance, being two stones of thirty-five feet in length, carved with vines and clusters of grapes, exceeding bold, and to the life. They are both in their right places, and by them it appears, that the door or gate was fifteen feet wide. In this great court are the remains of two rows of very noble marble pillars thirty-seven feet high with capitals of the finest carved work; and the cornices must have been of equal beauty, though quite destroyed by the relentless superstition of the Mohammedans. Of these pillars fifty-eight are intire. They must have been many more in number; for, by what appears, they went quite round the court, and supported a most spacious double piazza or cloister. The walks on the west side of this piazza, which face the front of the temple, seem to have been the most spacious and stately of all; and at each end of it are two niches for statues at their full length, with their pedestals, borders, supporters, and canopies, carved with the greatest artifice and curiosity. The space within this once beautiful inclosure, is conceived to have been an open court, as we have already called it, in the midst of which stands the temple, incompassed with another row of pillars of a different order, and far exceeding the former in dimensions, being fifty feet high. Of these, sixteen are now standing; but there must have been about double that number, which, whether they formed an inner court, or supported the roof of a cloister, is uncertain. One great stone lies on the ground which seems to have reached from these pillars to the walls of the temple ; so that the latter conjecture may naturally enough take place. The whole space contained within these pillars, is one hundred and seventy-seven feet in length, and in breadth, eighty-four. In the midst of this space is the temple, extending ninety-nine feet in length, and in breadth, about forty. It has a sumptuous entrance on the west, exactly in the middle of the building, and, by what remains, it seems to have been one of the most glorious edifices in the world. You here see vines and clusters of grapes executed to the life ; and over the door you can just trace out a spread eagle, as at Balbeck, which takes up the whole width ; with some angels or Cupids accompanying it on the same stone, and several eagles seen upon stones that are fallen down. Nothing of this temple is standing but the walls, in which it is observable, that the windows, though not large, are narrower at top than at bottom, but mightily enriched with sculpture. It has been aukwardly patched up to serve for a mosque, all but the north end, where are very precious reliques; which, whether they were in the nature of canopies over altars, or to what use else they served, is not easy to conjecture. They are beautified with the most curious fret work and sculpture ; in the midst of which is a dome or cupola, six feet diameter, all of one piece ; but whether they are hewn out of the solid rock, or molded of fine cement or composition, is made a doubt.

When you leave this court and temple, a prodigious number of marble pillars present themselves to your sight, scattered up and down for the space of near a mile ; but, in such confusion, that there is no room to guess for what end they were framed.

Advancing towards the north, as you leave the temple, you have a tall and stately obelisk or pillar before you, consisting of seven large stones, besides its capital. It is wreathed ; and the sculpture here, as every-where else, extremely fine. It is above fifty feet in height, twelve feet and an half in compass just above the pedestal, and a statue is conceived to have once stood upon it. On the east and west of this, at the distance of a quarter of a mile, is a large pillar, and a piece of another near to the eastern pillar, which looks as if there had been once a continued row of them. The height of this eastern pillar, as taken by a quadrant, is above forty feet. Its circumference is proportionable, and on the body of it is a Greek inscription in commemoration of two patriots, by an order of the senate and people, which, with the others of the same and other kinds we may hereafter meet with, we shall pass over for the present, that we may not break in upon the thread of this description The western pillar has another inscription of the like sort; but not quite so perfect as the former.

Proceeding on from the obelisk or pillar last-mentioned, at the distance of one hundred paces, is a magnificent entrance, vastly large and lofty, and for workmanship nothing inferior to any piece hitherto described; but unhappily it has suffered the same fate with the rest. This entrance leads into a noble piazza, above half a mile long, and forty feet broad, formed by two rows of stately marble pillars twenty-six feet high, and eight or nine about. Of these pillars one hundred and twenty-nine are standing; but by a moderate calculation they cannot have been fewer at first, than five hundred and sixy. Covering over them there is none remaining, nor pavement beneath, that can be seen. Upon most of these pillars are inscriptions in Greek and Palmyrene characters; so that this seems to have been a much frequented and most conspicuous part of the city, aud therefore most proper for the daily and honourable commemoration of such as had deserved well of their fellow-citizens, or friends and relations. And, as if inscriptions were not sufficient, it seems as if here they placed the statues also of celebrated persons; there being pedestals jetting out from these pillars, sometimes one way, and sometimes more, whereon must have stood statues, which have long ago fallen victims to the furious and barbarous zeal of the Mohammedans; and upon these pedestals are incriptions, even when none are on the pillar they belong to, and sometimes too when there are. The upper end of this spacious piazza was shut in by a row of pillars, standing closer together than those on each side; and perhaps a banqueting-room stood upon them, though no sign of it remains. But, on the left hand, a little farther, appear the ruins of a very stately pile, which may have been of such a kind; of finer marble than is observed in the piazza, and with an air of delicacy throughout the whole, far surpassing what is observed in the piazza itself. The pillars which supported this last pile are all of one stone, twenty two feet long, and eight feet nine inches round. Among these ruins is found the only Latin inscription that was seen at this place.

In the west side of the above piazza are several openings, supposed to have been for gates, which led into the court of the palace. Two of these gates look as if they had been the most magnificent and glorious in the world, both for the elegance of the work in general, and for the stately porphyry pillars, wherewith they were adorned. Each gate had four, not standing in a line with those of the wall, but placed by couples in the front of the gate, facing the palace, two on the one hand, and two on the other. Of these porphyry pillars, there are bnt two intire, and but one standing in its proper place. They are about thirty feet in length, and nine in circumference, and of so very hard a consistence, that it is a difficult matter to injure them. These, of all the pieces of porphyry here found, are the most beautiful. The palace itself is so completely demolished, that there is no forming a judgment of what it has been, either for majesty or ornament. It plainly appears to have been thrown down by violence, which, together with the length of time, has quite defaced this once noble pile, there being only broken pieces of its walls left standing here-and-there. But it is very likely, that it fronted the famous piazza before-mentioned, and that it was surrounded with rows of pillars of different orders, many of which are still standing, some plain, and some wrought and chanelled, as those immediately encompassing the temple. To these pillars also there are pedestals with inscriptions.

On the east side of the same piazza is, if the expression may be allowed, a wood of marble pillars, some perfect, some deprived of their beautiful capitals, but so scattered and confused, that there is no reducing them to order, or conjecturing to what use they formerly served. In one place are eleven together, forming a square in this disposition,  paved with broad flat stone, but without any manner of roof.

At a little distance from hence, is a small ruined temple, which by what remains of it, appears to have been a very curious edifice. The entrance into this temple looks to the south, and before it is a piazza of six pillars, two on one side of the door, and two on the other, and one at each end. The pedestals of those in the front have been filled up with inscriptions in Greek and other characters, but scarce intelligible.

But of all the venerable remains of this desolate place, none more attract the admiration of the curious, than their costly sepulchres, which are square towers, four or five stories high, standing on each side of a hollow way, towards the north end of the city. They extend a mile, and may anciently have extended farther. At a distance they look like the steeples of decayed churches, or the bastions of a ruined fortification. Many of them, though built of marble, have sunk under the weight of years, or submitted to the malice of violent hands. They are all of one form, but of different size, in proportion to the fortune of the founder. In the ruins of one of them, that was entirely marble, were found pieces of two statues, the one of a man, the other of a woman, in a sitting, or rather leaning posture. By these it is discovered, that their habit was very noble, rather agreeing with the European, than the present eastern fashions; whence they are conjectured to have been Romans. Of all these sepulchres, there are two which seem to be more intire than the rest. They are square towers, five stories high, their outsides of common stone, but their partitions and floors within, of marble. They are beautified with very lively carvings and paintings, and figures both of men and women, as far as the breast and shoulders, but miserably defaced. Under them, or on one side, are Palmyrenian characters, which are thought to be the names of the persons there deposited. To judge of the construction of the rest of these sepulchres, by what is observed in one of them; they had a walk quite across from north to south, exactly in the middle, by which they entered. The vault below was divided in the same manner, and the division on each hand subdivided by thick walls into six, or more or less, partitions, each big enough to receive the largest corpse, and deep enough to contain at least six or seven one upon another. In the lowest, second, and third stories, these partitions were the same, excepting that the second had a partition, answering to the main entrance, for the convenience of a stair-case. Higher up this method was discontinued; because the building, growing narrower towards the top, could no longer admit of it. In the two uppermost rooms it is likely that no bodies were deposited, except that of the founder himself, whose statue, wrapt up in funeral apparal, and in a lying posture, is placed in a nich, or rather window, in the front of the monument, so as to be visible both within and without. Here is a Greek epitaph.

Such were once the magnificent abodes, and such the noble sepulchres of the Palmyrenians. From what we have said of both, we may well conclude, that the world never saw a more glorious city; a city not more remarkable for its stately buildings, than for the extraordinary personages who once flourished in it, among whom the renowned Zenobia, and the incomparable Longinus, must for ever be remembered with admiration and regret.

[*Wood. Phil. Trans. Ancient Univ. Hist.*]

SECTION XI.

Splendid Ruins of Persepolis.

As we had still two hours of day-light before us, we rode to Persepolis, and took a cursory view of the ruins. Our first, and indeed lasting impressions were astonishment at the immensity, and admiration at the beauties of the fabric. Although there was nothing, either in the architecture of the buildings, or in the sculptures and reliefs on the rocks, which could bear a critical comparison with the delicate proportions and perfect statuary of the Greeks, yet, without trying Persepolis by a standard to which it never was amenable, we yielded at once to emotions the most lively and the most enraptured.

At the distance of about five miles is a conspicuous hill, on the top of which, and visible to the eye from Persepolis, are the remains of a fortress. This hill is now called Istakhar, and is quite distinct from Persepolis. Persepolis itself is commonly styled by the people of the country "Takht Jemsheed," or the throne of Jemsheed: it is also called "Chehel Minar," or the Forty Pillars. Le Brun has given a drawing of this hill of Istakhar; and the original must strike every traveller the moment he enters the plain of Merdasht, as it has all the appearance of having been much fashioned by the hand of man.

Jan. 15th. After reading prayers to our society, I hastened to the ruins. I went on this principle, that I would endeavour to draw and ascertain all that former travellers had omitted; and for that purpose I took Cardin and Le Brun in my hand, that I might complete all that I found wanting in their views and notices. Finding, however, that they differed from each other (and one of course therefore from the reality) in many essential points, I thought that an entire description of the ruins in their present state would answer my purpose better than a partial and unconnected account, referring only to the mistakes or omissions of others.

The most striking feature, on a first approach, is the staircase and its surrounding walls. Two grand flights, which face each other, lead to the principal platform. To the right is an immense wall of the finest masonry, and of the most massive stones: to the left are other walls equally well built, but not so imposing. On arriving at the summit of the staircase, the first objects, which present themselves directly facing the platform, are four vast portals and two columns. Two portals first, then the columns, and then two portals again. On the front of each are represented, in basso-relievo, figures of animals, which, for want of a better name, we have called sphinxes. The two sphinxes on the first portals face outwardly, i. e. towards the plain and the front of the building. The two others, on the second portals, face inwardly, i. e. towards the mountain. From the first (to the right, on a straight line) at the distance of fifty-four paces, is a staircase of thirty steps, the sides of which are ornamented with bas-reliefs, originally in three rows, but now partly reduced by the accumulation of earth beneath, and by mutilation above. This staircase leads to the principal compartment of the whole ruins, which may be called a small plain, thickly studded with columns, sixteen of which are now erect. Having crossed this plain, on an eminence are numerous stupendous remains of frames, both of windows and doors, formed by blocks of marble of sizes most magnificent. These frames are ranged in a square, and indicate an apartment the most royal that can be conceived. On each side of the frames are sculptured figures, and the marble still retains a polish which, in its original state, must have vied with the finest mirrors. On each corner of this room are pedestals, of an elevation much more considerable than the surrounding frames; one is formed of a single block of marble. The front of this apartment seems to have been to the S. W. for we saw few marks of masonry on that exposure, and observed, that the base of that side of it was richly sculptured and ornamented. This front opens upon a square platform, on which no building appears to have been raised. But on the side opposite to the room which I have just mentioned, there is the same appearance of a corresponding apartment, although nothing but the bases of some small columns and the square of its floor attest it to have been such. The interval between these two rooms (on those angles which are the farthest distant from the grand front of the building) is filled up by the base of a sculpture similar to the bases of the two rooms; excepting that the centre of it is occupied by a small flight of steps. Behind, and contiguous to these ruins, are the remains of another square room, surrounded on all its sides by frames of doors and windows. On the floor are the bases of columns: from the order in which they appeared to me to have stood, they formed six rows, each of six columns. A staircase cut into an immense mass of rock (and from its small dimensions, probably the *escalier derobé* of the palace) leads into the lesser and enclosed plain below. Towards the plain are also three smaller rooms, or rather one room and the bases of two closets. Every thing on this part of the building indicates rooms of rest or retirement.

In the rear of the whole of these remains, are the beds of aqueducts which are cut into the solid rock. They met us in every part of the building; and are probably therefore as extensive in their course, as they are magnificent in construction. The great aqueduct is to be discovered among a confused heap of stones, not far behind the buildings (which I have been describing) on this quarter of the palace, and almost adjoining to a ruined staircase. We descended into its bed, which in some places is cut ten feet into the rock. This bed leads east and west; to the eastward its descent is rapid about twenty-five paces; it there narrows, so that we could only crawl through it; and again it enlarges, so that a man of common height may stand upright in it. It terminates by an abrupt rock.

Proceeding from this towards the mountains, (situated in the rear of the great hall of columns) stand the remains of a magnificent room. Here are still left walls, frames, and porticoes, the sides of which are thickly ornamented with bas-reliefs of a variety of compositions. This hall is a perfect square. To the right of this, and further to the southward are more fragments, the walls and component parts apparently of another room. To the left of this, and therefore to the northward of the building, are the remains of a portal, on which are to be traced the features of a sphinx. Still towards the north, in a separate collection, is the ruin of a column, which, from the fragments about it, must have supported a sphinx. In a recess of the mountain to the northward, is a portico. Almost in a line with the centre of the hall of columns, on the surface of the mountain is a tomb. To the southward of that is another, in like manner on the mountain's surface; between both (and just on that point where the ascent from the plain commences) is a reservoir of water.

These constitute the sum of the principal objects among the ruins of Persepolis, some of which I will now endeavour to describe in more detail. The grand staircase consists of a northern and a southern ascent, which spring from the plain at the distance of forty-six feet from each other. Each again is divided into two flights; the first, terminated by a magnificent platform, contains fifty-four steps on a base of sixty-six feet six inches, measured from the first step to a perpendicular dropt from the highest at the landing place: the second, to the extreme summit of the whole, consists of forty-eight steps on a base of forty-six feet eight inches. Each step is in breadth twenty-six feet six inches, and in height three inches and a half. So easy therefore is the ascent, that the people of the country always mount it on horseback. The platform, where the two grand divisions meet, is thirty-four feet from the ground, and in length seventy. From the front of this platform to the portals behind it is likewise seventy feet.

The portals are composed of immense oblong blocks of marble: their length is twenty-four feet six inches, breath five feet, and distance from one another thirteen feet. The two first are faced by spinxes; the remaining parts of whose bodies are delineated in a basso-relievo on the interior surface of the portal. In passing through these, the next objects before the more distant portals are two columns, but (as there is a sufficient space for two others, and as the symmetry would be defective without such an arrangement) I presume that the original structure was completed by four columns. The second portals correspond in size with the former, but differ from them not only in presenting their fronts towards the mountain, but in the subject of the sculptures with which they are adorned. The animals on the two first portals are elevated on a base. From the contour of the mutilation, the heads appear to have been similar to those of horses, and their feet have hoofs; on their legs and haunches the veins and muscles are strongly marked. Their necks, chests, shoulders, and backs, are encrustated with ornaments of roses and beads.

The sphinkes on the second portals appear to have had human heads, with crowned ornaments, under which are collected massive curls, and other decorations of a head-dress, which seems to have been a favourite fashion among the ancient Persians. Their wings are worked with great art and labour, and extend from their shoulders to the very summit of the wall. The intention of the sculptor is evidently, that these figures (emblematical perhaps of power and strength) should appear to bear on their backs the mass of the portico, including not only the block immediately above each, but the covering also, which, though now lost, certainly in the original state of the palace, connected the two sides and roofed the entrance. In these, as in the first portals, the faces of the animals form the fronts, and the bulk of their bodies, (called forth to a certain extent by the basso-relievo on the sides) is supposed to constitute the substance of the walls.

Under the staircase of the first sphinx on the right, are carved, scratched, and painted the names of many travellers; and amongst others we discovered those of Le Brun, Mandelsloe, and Niebuhr. Niebuhr's name is written in red chalk, and seems to have been done but yesterday.

A square reservoir of water, broken in many places, yet still appearing to have been of one single block, was in the space between the portals and the staircase which led to the grand hall of columns. The breadth of that staircase is fifteen feet four inches. It has two corresponding flights, the front of which, though now much mutilated, was originally highly carved and ornamented with figures in bass-relief. The stones which support the terrace of the columns are all carved in the same style, and are as perfect as when Le Brun made his drawings. On comparing, indeed, his designs with the originals, I found that he had given to some of the figures a mutilation which does not exist; for I discovered on a close inspection many interesting details of dress, posture, and character, which are omitted in his plates. One great defect pervades this part of his collection; in order to elucidate by the human form the comparative dimensions of the buildings, he has introduced figures so small, that, measured by them as a standard, the actual size of the objects represented would be three times their real magnitude. In fact, a man who stands close to the sculptured wall touches the summit with his chin, though the figures in the drawings of Le Brun would not reach half way.

Immediately on ascending this staircase, stands a single column, but on closer observation I counted the bases (or spots at least where once bases were) of eleven more columns of two rows;

forming, with the first, six in each row. They are quite distinct from the great cluster in the centre of the hall, and was therefore probably a grand entrance to it.

Passing forwards through this double range, we observed large blocks of stone, placed at symmetrical distances (to correspond with the arrangement of the columns at the entrance, and those in the centre), and forming, probably, the bases of sphinxes or other colossal figures. Having taken some pains to ascertain the real plan and the original number of the columns in the great hall, I came to the following conclusions: I observed, in the first place, that there were two orders of columns, distinct in their capitals as well as in their height, and that, of the highest, two rows were severally placed at the E. and W. extremities of the hall.

Between these and the mass of columns of less height and a different capital is the space on either side of one row, in which, however, no trace whatever of bases exists, and through which run the channels of aqueducts. The remainder in the centre consists of six columns in front, and composes with the four exterior rows a line of ten columns; each row contains in depth six bases, forming, with the twelve at the entrance, a grand total of seventy-two. On drawing out a plan of this arrangement, I find that it is symmetrical in all its points, and in every way in which I can view it satisfies my imagination; but, on comparing it with that laid down by Niebuhr, my own conceptions have accorded so exactly with those of that great traveller on this, (as well as on the ichnography of the general remains) that the introduction of my sketch becomes unnecessary.

On one of the highest columns is the remains of the sphinx, so common in all the ornaments at Persepolis; and I could distinguish on the summit of every one a something quite unconnected with the capitals. The high columns have, strictly speaking, no capitals whatever, being each a long shaft to the very summit, on which the sphinx rests. The capitals of the lesser columns are of a complicated order, composed of many pieces. I marked three distinct species of base. The shafts are fluted in the Doric manner, but the flutes are more closely fitted together. Their circumference is sixteen feet seven inches. Some of their bases have a square plinth, the side of one of which I measured, and found it to be seven feet; the diameter of the base was five feet four inches, diameter of columns four feet two inches, distance from centre of base to the next centre twenty-eight feet. To the eastward of one of these, and close at the foot of one of the highest columns, are the fragments of an immense figure. The head and part of the fore-legs I could easily trace; the head appeared to me more like that of a lion than of any other animal, and the legs confirmed this supposition; as it has claws so placed, as to indicate that the posture of the figure was couchant.

The grand collection of porticoes, walls, and other component parts of a magnificent hall, are situated behind the columns, at the distance perhaps of fifty paces, and are arranged in a square.

On the interior sides of the porticoes or door frames, are many sculptured figures, which have been drawn with accuracy by Le Brun. They represent the state and magnificence of a king, seated in a high chair with his feet resting on a footstool.

To the north of these remains is the frame of what was once a portico, and where the outlines of a sphinx are to be traced among the rude and stupendous masses of stone. Further on, nearly on the same line and bearing, is the head of a horse, part of which is buried in the ground. It is ornamented like the remains of that which we call the sphinx on the great portals, and is certainly the horse's head, which Le Brun drew, declaring that he could not discover the part to which it had belonged. Close to it, however, are the remains of an immense column, eight feet in diameter; the different parts of the shaft have fallen in a direct line with this head, and obviously formed with it one connected piece in the original structure, in which probably the fragment on the ground surmounted the capital, as the sphinx still crowns some of the remaining columns.

In the time of Mandelsloe, (who visited Persepolis, 27th January, 1638) the number of columns erect was nineteen: in a letter indeed to Olearius, (written from Madagascar on the 12th of July, 1639, and published by his correspondent) he states, that thirty remained; but, as he does not specify their position, he might have included those lying on the ground, and at any rate he was writing a private letter, from memory, in a distant country, at the interval of a year and a half. His own authority therefore in his book is a better evidence of the fact; and as he there omits another and much more curious circumstance which he had asserted in the same letter, the value of that document becomes still more suspicious. Speaking of the celebrated inscriptions at Persepolis, he says, 'on voit aussi plusieurs caractères anciens mais fort bien marqués, et conservant une partie de l'or, dont ils ont été remplis.' Sir Thomas Herbert also, however, mentions that the letters at Persepolis were gilt.

17th. On quitting Persepolis, I left our party in order to examine a ruined building on the plains, which at a distance is generally pointed out as a demolished caravanserai. I passed the stream of the Rood Khonéh Sewund to the north, nearly where the road takes a N. E. direction, and came to a fine mass of stone, thirty-seven feet four inches square, which appears to have formed the base of some building. It is composed of two layers of marble blocks, the lower range of which extends about two feet beyond the line of the upper. The largest blocks, according to my measurement, are ten feet four inches in length, four feet four in depth, and three feet four in breadth; all still retain a moulding, and traces here and there of masonry which must have connected them with others. The whole building is filled up in the middle by a black marble, and in its N. E. angle one stone is raised higher than the rest. In the same angle is a channel cut, as if something had been fitted into it. I took the following bearings: foot of the rocks of Nakshi Rustam, N. 10 W. two miles; foot of the mountain of Persepolis, S. two miles; our encampment S. 20 W. two miles; road to Ispahan, N. 80 E.

I was called from this spot by a chatter sent by the envoy to conduct me to some sculptures, which he had himself seen, (about four miles from the place on the same mountain of Persepolis,) by the side of the road to Ispahan. I found them indeed worthy of the minutest investigation, as no preceding traveller has described them with any sufficient accuracy. They are situated in a recess of the mountain, formed by projecting and picturesque rocks. The sculpture facing the road is composed of seven colossal figures and two small ones. The two principal characters are placed in the centre: the one to the left is the same (not in position indeed, but in general circumstance) as that which we had so often seen represented at Shapour and Nakshi Rustam. He has the distinguishing globe on his head, and offers a ring to the opposite figure; who, seizing it with his right hand, holds a staff or club in his left. Behind the personage with the globe, are two figures, one of whom, with a young and pleasing face holds the fan, the customary ensign of dignity: and the other, with hard and marked features, and a beard, rests on the pommel of his sword with one hand, and beckons with the other. Behind the chief on the right, are two figures, which from the feminine cast of their conutenances appear to be women; one wears an extraordinary cap, and the other, whose hair falls in ringlets on her shoulders, makes an expressive motion with her right hand, as if she were saying, 'Be silent.' Between the two principal figures are introduced two very diminished beings, who do not reach higher than the knees of their colossal companions. In dress they differ materially from each other, and one holds a long staff. To the left, on a fragment of the rock, is the bust of a figure, who also holds his hand in a beconing and significant posture. The largest of these figures I reckoned to be ten feet in height; the small ones two feet eight inches. The whole of this is so much disfigured, that it is difficult to ascertain its various and singular details.

In the same recess, and to the left of this sculptured rock, forming an angle with it, is another monument in a much higher state of preservation; parts of it indeed have suffered so little, that they appear to be fresh at this day from the chisel. The same royal personage so often represented with a globe on his head, and seated on horseback, here forms the principal character of the groupe. His face, indeed, has been completely destroyed by the Mahomedans, but the ornaments of his person and those of his horse, (more profusely bestowed on both, than on any of the similar figures which we had seen) are likewise more accurately preserred. They merit a particular description; because as the composition was probably designed to represent the king in his greatest state, every part of his dress is distinctly delineated. I assign this subject to the sculpture, because no other personage of rival dignity appears in the piece; and because the attitude of the chief announces parade and command; for he presents a full face to the spectator, and his right hand, though now much mutilated, still rests on his side to indicate his ease and his independence. Nine figures, of which the first is nine feet high, wait behind him; and, from the marks of respect in which they stand, can be attendants only on his grandeur. On each side of his head swells an immense circumference of curls; he wears an embossed necklace, which falls low on his breast, and is therefore, perhaps, rather the upper termination of his garment; but its counterpart, an ornament of the same description round the waist, is certainly a girdle. His cloak is fastened on his left breast by two massive clasps. A rich belt is carried from his right shoulder to his left hip, across an under garment, which, from the extreme delicacy of its folds, appears to be formed of a very fine cloth or muslin. The drapery of some loose trowsers, which cover his legs down to the very ancles, displays equal delicacy, and is probably, therefore, of the same texture. From the ancles a sort of bandage extends itself in flowing folds, and adds a rich finish to the whole. On the thigh there appears to hang a dagger. The horse is splendidly accoutred with chains of a circular ornament: his length, from the breast to the tail, is seven feet two inches; and on the chest is a Greek inscription, of which the letters are about an inch in height, and correspond in form with those of the latter empire.

[*Morier.*

SECTION XII.

Ruins and present Appearance of Jerusalem.

At three P. M. we again mounted our horses, and proceeded on our route. No sensation of fatigue or heat could counterbalance the eagerness and zeal which animated all our party, in the approach to Jerusalem; every individual pressed forward, hoping first to announce the joyful intelligence of its appearance. We passed some insignificant ruins, either of antient buildings or of modern villages; but had they been of more importance, they would have excited little notice at the time, so earnestly bent was every mind towards the main object of interest and curiosity. At length, after about two hours had been passed in this state of anxiety and suspense, ascending a hill towards the south—'Hagiopolis!' exclaimed a Greek in the van of our cavalcade; and instantly throwing himself from his horse, was seen bare-headed, upon his knees, facing the prospect he surveyed. Suddenly the sight burst upon us all. Who shall describe it? The effect produced was that of total silence throughout the whole company. Many of the party, by an immediate impulse, took off their hats, as if entering a church, without being sensible of so doing. The Greeks and Catholics shed torrents of tears; and presently beginning to cross themselves, with unfeigned devotion, asked if they might be permitted to take off the covering from their feet, and proceed, barefooted, to the Holy Sepulchre. We had not been prepared for the grandeur of the spectacle which the city alone exhibited. Instead of a wretched and ruined town, by some described as the desolated remnant of Jerusalem, we beheld, as it were, a flourishing and stately metropolis; presenting a magnificent assemblage of domes, towers, palaces, churches, and monasteries; all of which, glittering in the sun's rays, shone with inconceivable splendour. As we drew nearer, our whole attention was engrossed by its noble and interesting appearance. The lofty hills whereby it is surrounded give to the city itself an appearance of elevation inferior to that which it really possesses. About three quarters of an hour before we reached the walls, we passed a large ruin upon our right hand, close to the road. This, by the reticulated style of masonry upon its walls, as well as by the remains of its vaulted foundations of brick-work, evidently denoted a Roman building. We could not obtain any account of it; neither is it mentioned by the authors who have described the antiquities of the country.

At this place, two Turkish officers, mounted on beautiful horses sumptuously caparisoned, came to inform us, that the governor, having intelligence of our approach, had sent them to escort us into the town. When they arrived, we were all assembled upon an eminence, admiring the splendid appearance of the city; and being impressed with other ideas than those of a vain ostentation, would gladly have declined the parade, together with the interruption caused by a public entry. This was, however, said to be unavoidable; it was described as a necessary mark of respect due to Gjezzar Pacha, under whose protection we travelled: as well as of consequence to our future safety. We therefore confined ourselves to all the etiquette of our Mahometan masters of ceremony, and were marshalled accordingly. Our attendants were ordered to fall back in the rear; and it was evident, by the manner of placing us, that we were expected to form a procession to the governor's house, and to appear as dependants, swelling the train of our Moslem conductors. Our British tars, not relishing this, would now and then prance towards the post of honour, and were with difficulty restrained from taking the lead. As we approached the city, the concourse of people became very great, the walls and the road side being covered with spectators. An immense multitude, at the same time, accompanied us on foot; some of whom, welcoming the procession with compliments and caresses, cried out ' Bon' Inglesi! Viva l'Ingilterra!" others, cursing and reviling, called us a set of rascally Christian dogs, and filthy infidels. We could never learn wherefore so much curiosity had been excited; unless it were, that of late, owing to the turbulent state of public affairs, the resort of strangers to Jerusalem had become more uncommon; or that they expected another visit from Sir Sidney Smith, who had marched into Jerusalem with colours flying and drums beating, at the head of a party of English sailors. He protected the Christian guardians of the Holy Sepulchre from the tyranny of their Turkish rulers, by hoisting the British standard upon the walls of their monastery. Novelty, at any period, produces considerable bustle at Jerusalem: the idleness of its inhabitants, and the uniform tenor of their lives, rendered more monotonous by the cessation of pilgrimage, naturally dispose them to run after a new sight, or to listen to new intelligence. The arrival of a Tartar courier from the vizier's army, or the coming of foreigners to the city, rouses Christians from their prayers, Jews from their traffic, and even Moslems from their tobacco or their opium, in search of something new.

Thus attended, we reached the gate of Damascus about seven o'clock in the evening. Châteaubriand calls this Bab-el-Hamond, or Bab-el-Cham, the Gate of the Column. "When," says he, "Simon the Cyrenian met Christ, he was coming from the gate of Damascus;" thereby adopting a topography suited to the notions generally entertained of the relative situation of Mount Calvary and the Prætorium, with regard to this gate; Simon being described as coming out of the country, and therefore, of course, entering by that gate of the city contiguous to the dolorous way. It were, indeed, a rash undertaking to attempt any refutation of opinions so long entertained, concerning what are called the Holy Places of this memorable city. "Never," says the author now cited, "was subject less known to modern readers, and never was subject more completely exhausted." Men entitled to the highest consideration, under whose authority even reverence is due, have written for its illustration: and some of the ablest modern geographers, quitting more extensive investigations, have applied all their ingenuity, talents, and information, to the topography of Jerusalem. It would therefore seem like wanton temerity, to dispute the identity of places whose situation has been so ably discussed and so generally admitted, were there not this observation to urge, that the descriptions of Jerusalem since the Crusades have principally issued from men who had no ocular evidence concerning the places they describe. Like Thevenot, writing an account of scenes in Asia without ever having quitted Europe, they have proved the possibiliy of giving to a fiction an air of so much reality, that it has been cited, even by historians, as authority. If, as spectators upon the spot, we confessed ourselves dissatisfied with the supposed identity of certain points of observation in Jerusalem, it is because we refused to tradition alone, what appeared contradictory to the evidence of our senses. Of this it will be proper to expiate more fully in the sequel. It is now only necessary to admonish the reader, that he will not find in these pages a renewal of the statements made by Sandys, and Maundrell, and Pococke, with the host of Greek and Latin pilgrims from the age of Phocas down to Breidenbach and Quaresmius. We should no more think of enumerating all the absurdities to which the Franciscan friars direct the attention of travellers, than of copying, like another Cotovic, the whole of the hymns sung by the pilgrims at every station. Possessing as much enthusiasm as might be necessary in travellers viewing this hallowed city, we still retain the power of our understandings sufficiently to admire the credulity for which no degree of preposterousness seemed too mighty; which converted even the parables of our Saviour into existing realities; exhibiting, as holy reliques, the house of Dives, and the dwelling-place of the good Samaritan. There is much to be seen at Jerusalem, independently of its monks and monasteries; much to repay pilgrims of a very different description from those who usually resort thither, for all the fatigue and danger they must encounter. At the same time, to men interested in tracing, within the walls, antiquities referred to by the documents of Sacred History, no spectacle can be more mortifying than the city in its present state. The mistaken piety of the early Christians, in attempting to preserve, either confused or annihilated the memorials it endeavoured to perpetuate. On viewing the havoc they have made, it may now be regretted that the Holy Land was ever rescued from the dominion of Saracens, far less barbarous than their conquerors. The absurdity of hewing the rocks of Judæa, whether of Mount Calvary or any other mount, into gilded chapels, and of disguising the face of nature with painted domes and marble coverings, by way of commemorating the scenes of our Saviour's life and death, is so evident and so lamentable, that even Sandys, with all his credulity, could not avoid a happy application of the reproof directed by the Roman satirist against a similar violation of the Egerian Fountain.

We were conducted to the house of the governor, who received us in very great state; offering his protection, and exhibiting the ordinary pomp of Turkish hospitality, and in the number of slaves richly dressed, who brought fuming incense, coffee, conserved fruit, and pipes, to all the party, profusely sprinkling us, as usual, with rose and orange-flower water. Being then informed of all our projects, he ordered his interpreter to go with us to the Franciscan Convent of St. Salvador, a large building like a fortress, the gates of which were thrown open to receive our whole cavalcade. Here, when we were admitted into a court, with all our horses and camels, the vast portals were again closed, and a party of the most corpulent friars we had ever seen from the warmest cloisters of Spain and of Italy, waddled round us, and heartily welcomed our arrival.

From the court of the Convent we were next conducted, by a stone staircase, to the refectory, where the monks who had received us introduced us to the superior, not a wit less corpulent than any of his companions. In all the convents I had ever visited (and these are not few in number) I had never beheld such friars as the Franciscans of St. Salvador. The figures sometimes brought upon the stage, to burlesque the monasterial character, may convey some notion of their appearance. The influence which a peculiar mode of life has upon the constitution, in this climate, might be rendered evident by contrasting one of these jolly fellows with the Propaganda Missionaries. The latter are as meagre and as pale, as the former are corpulent and ruddy. The life of the missionaries is necessarily a state of constant activity and of privation. The guardians of the Holy Sepulchre, or, according to the name they bear, the Terra-Santa friars, are confined to the walls of their comfortable convent, which, when compared with the usual accommodations of the Holy Land, is like a sumptuous and well-furnished hotel, open to all comers whom curiosity or devotion may bring to this mansion of rest and refreshment.

After being regaled with coffee, and some delicious lemonade, we were shewn to our apartments, to repose ourselves until supper. The room allotted to our English party we found to be the same which many travellers have before described. It was clean, and its walls were white-washed. The beds, also, had a cleanly appearance; although a few bugs warned us to spread our hammocks upon the floor, where we slept for once unmolested. Upon the substantial door of this chamber, whose roof was of vaulted stone, the names of many English travellers had been carved. Among others, we had the satisfaction to notice that of Thomas Shaw, the most learned writer who has yet appeared in the descriptions of the Levant. Dr. Shaw had slept in the same apartment seventy-nine years before our coming.

A plentiful supper was served, in a large room called the Pilgrim's Chamber. Almost all the monks, together with their superior, were present. These men did not eat with us; having their meals private. After we had supped, and retired to the dormitory, one of the friars, an Italian, in the dress worn by the Franciscans, came into our apartment, and, giving us a wink, took some bottles of Noyau from his bosom, desiring us to taste it; he said that he could supply us with any quantity, or quality, of the best liqueurs, either for our consumption while we staid, or for our journey. We asked him whence it was obtained; and he informed us, that he had made it; explaining the nature of his situation in the monastery, by saying, that he was a confectioner; that the monks employed him in works of ornament suited to his profession; but that his principal employment was the manufacturing of liqueurs. A large part of this convent, surrounding an elevated open court or terrace, is appropriated to the reception of pilgrims; for whose maintenance the monks have considerable funds, the result of donations from catholics of all ranks, but especially from catholic princes. These contributions are sometimes made in cash, and often in effects, in merchandize, and stores for the convent. To mention, by way of example, one article, equally rare and grateful to weary English travellers in the Levant; namely, tea. Of this they had an immense provision, and of the finest quality. Knowing, from long habit in waiting upon pilgrims, the taste of different nations, they most hospitably entertain their comers according to the notions they have thus acquired. If a table be provided for Englishmen or for Dutchmen, they supply it copiously with tea. This pleasing and refreshing beverage was served every morning and evening while we remained, in large bowls, and we drank it out of pewter porringers. For this salutary gift the monks positively refused to accept our offers of compensation, at a time when a few drachms of any kind of tea could with difficulty be procured from the English ships in the Mediterranean, at the most enormous prices. Persons who have not travelled in these latitudes will perhaps not readily conceive the importance of such an acquisition. The exhaused traveller, reduced by continual fever, and worn by incessant toil, without a hope of any comfortable repose, experiences in this infusion the most cooling and balsamic virtues: the heat of his blood abates; his spirits revive; his parched skin relaxes; his strength is renovated. As almost all the disorders of the country, and particularly those to which a traveller is most liable, originate in obstructed perspiration, the medicinal properties of tea in this country may perhaps explain the cause of its long celebrity in China. Jerusalem is in the same latitude with Nankin, and it is eight degrees further to the south than Pekin; the influence of climate and of medicine, in disorders of the body, may therefore, perhaps, be similar. Certain it is, that travellers in China, so long ago as the ninth century, mention an infusion made from the leaves of a certain herb, named Sah, as a cure for all diseases; which is proved to be the same now called tea by European nations.

In the commotions and changes that have taken place in Jerusalem, the convent of St. Salvador has been often plundered and stripped of its effects. Still, however, the riches of the treasury are said to be considerable; but the principal part of its wealth is very properly concealed from all chance of observation. At present, it has a small library, full of books of little value, the writings of polemical divines, and stale dissertations upon peculiar points of faith. We examined them carefully, but found nothing so much worth notice as the Oxford edition of Maundrell's Journey. This volume some traveller had left; the worthy monks were very proud of it, although unable to read a syllable it contained. In the church, as well as in the chambers of the monastery, we noticed several pictures; all of these were bad, although some of them appeared to have been copied from originals that possessed greater merit. In the pilgrim's chamber, a printed advertisement, pasted upon a board, is suspended from the wall, giving notice, that 'no pilgrim shall be allowed to remain in the convent longer than one month:'

a sufficient time, certainly, for all purposes of devotion, rest, or curiosity. The Franciscans complain heavily of the exactions of the Turks, who make frequent and large demands upon them for money; but the fact of their being able to answer these demands, affords a proof of the wealth of the convent. Sir Sydney Smith, during his visit to Jerusalem, rendered them essential service, by remonstrating with the Turkish governor against one of these avanïas, as they are called, and finally compelling him to withdraw the charge. The monks assured us, that the English, although protestants, are the best friends the catholics have in Jerusalem, and the most effectual guardians of the holy sepulchre. This served, indeed, as a prelude to a request that we would also intercede for them with the governor, by representing to him, that any ill usage offered to christians would be resented by the British nation. We rendered them all the service in our power, and they were very thankful.

Friday, July 10.—This morning our room was filled with Armenians and Jews, bringing for sale the only produce of the Jerusalem manufactures; beads, crosses, shells, &c. The shells were of the kind we call mother-of-pearl, ingeniously, although coarsely, sculptured, and formed into various shapes. Those of the largest size, and the most perfect, are formed into clasps for the zones of the Greek women. Such clasps are worn by the ladies of Cyprus, Crete, Rhodes, and the islands of the Archipelago. All these, after being purchased, are taken to the church of the Holy Sepulchre, where they receive a sort of benediction; exactly after the manner in which the beads and crosses, purchased at Loretto in Italy, are placed in a wooden bowl belonging to the house of the Virgin Mary. Afterwards, they are worn as reliques. The beads are manufactured, either from date stones, or from a very hard kind of wood, whose natural history we could not learn. It was called Mecca fruit, and, when first wrought, appeared of the colour of box: it is then dyed yellow, black, or red. The beads are of various sizes; and they are all strung as rosaries; the smaller being the most esteemed, on account of the greater number requisite to fill a string, and the greater labour necessarily required in making them. They sell at higher prices when they have been long worn, because they have then acquired, by friction, a higher polish. This sort of trumpery is ridiculed by all travellers, but we cannot say it is scouted by any of them; for there has not been one who did not encourage the Jerusalem manufactories by the purchases he made. It offers an easy method of obtaining a large quantity of acceptable presents, which occupy little space, for the inhabitants of Greek and catholic countries, as well as for Turks and Arabs. We provided ourselves with a considerable cargo, and found them useful in our subsequent journey. The custom of carrying such strings of beads was in use long before the Christian æra; and the practice of bearing them in the hand prevails, among men of rank, all over the east. It is not so easy to account for the origin of the shell, as a badge worn by pilgrims: but it decidedly refers to much earlier oriental customs than the journeys of Christians to the Holy Land, and its history will probably be found in the mythology of eastern nations. Among the substances which they had wrought in the manufacture of rosaries, and for amulets, we were glad to notice the black fetid limestone of the Lake Asphaltites; because it enabled us to procure very large specimens of that mineral, in its natural state. It is worn in the east as a charm against the plague; and that a similar superstition attached to this stone in very early ages, is evident from the circumstance of our having afterwards found amulets of the same substance in the subterranean chambers below the pyramids of Saquâra, in Upper Egypt. The cause of the fetid effluvia emitted from this stone, when partially decomposed by means of friction, is now known to be owing to the presence of sulphureted hydrogen. All bituminous limestone does not possess this property. It is very common in the sort of limestone called black marble in England, though not always its characteristic. The workmen employed by stone-masons often complain of the unpleasant smell which escapes from it during their labours. The ancient Gothic monuments in France frequently consisted of fetid limestone. The fragments which we obtained from the Dead Sea had this property in a very remarkable degree; and it may generally be observed, that the oriental specimens are more strongly impregnated with hydro-sulpuret than any which are found in Europe. The water of the Dead Sea has a similar odour. The monks of St. Salvador kept it in jars, together with the bitumen of the same lake, among the articles of their pharmacy; both the one and the other being also esteemed on account of their medical virtues.

We set out to visit what are called the Holy Places. These are all amply described by at least an hundred authors. From the monastery we descended to the church of the holy sepulchre; attended by several pilgrims, bearing with them rosaries and crucifixes for consecration in the tomb of Jesus Christ. Concerning the identity of this most memorable relique, there is every evidence but that which should result from a view of the sepulchre itself. After an attentive perusal of all that may be adduced, and all that has been urged, in support of it, from Eusebius, Lactantius, Sozomen, Jerom, Severus, and Nicephorus, it may be supposed that the question is for ever decided. If these testimonies be insufficient, "we might," says Châteaubriand, "adduce those of Cyril, of Theodoret, and even of the itinerary from Bourdeau to Jerusalem," in the middle of the fourth century. From the time of the Emperor Adrian, when the crucifixion and burial of our Saviour was almost in the memory of man, unto the age of Constantine, an image of Jupiter marked the site of the holy sepulchre, and Mount Calvary continued to be profaned by a statue of Venus. This powerful record of the means used by the pagans to obliterate the rites of christianity, seems to afford decisive evidence concerning the locality of the tomb, and to place its situation beyond the reach of doubt. Theodoret affirms, that Helena, upon her arrival, found the fane of Venus, and ordered it to be thrown down. To what then can be attributed the want of every document within the building now called the church of the holy sepulchre, which might denote the site of such a monument? The sepulchres of the Jews, as has been already maintained, were, in the age of the crucifixion, of a nature to withstand every attack of time: they were excavations made in the heart of solid rocks, which even earthquakes would scarcely remove or alter. Indeed, we have evidence from the Gospel itself, that earthquakes, in certain instances, had no power over them; for the sepulchre of Joseph of Arimathea, made before the earthquake which accompanied the crucifixion, is described, after that event had taken place, as his own new tomb, which he had hewn out of the rock. Even the grooving for the stone at the door was unchanged and entire, for he rolled the great stone to the door of the sepulchre, and departed; and it was afterwards sealed and made sure. Quaresmius, by an engaving for the illustration of the mode of burial then practised, has shewn, according to a model familiar to the learned monk, from his residence in the Holy Land where such sepulchres now exist, the sort of tomb described by the Evangelists. But there is nothing of this kind in the church of the holy sepulchre; nothing that can be reconciled with the history of our Saviour's burial. In order to do away this glaring inconsistency, it is affirmed that Mount Calvary was levelled for the foundations of the church; that the word ὄρος, *mons*, does not necesssarily signify a mountain, but sometimes a small hill; that the sepulchre of Christ alone remained after this levelling had taken place, in the centre of the area; and that this was incased with marble!—not a syllable of which is supported by any existing evidence offered in the contemplation of what is now called the Tomb. Let us therefore proceed to describe what really remains.

We came to a goodly structure, whose external appearance resembled that of any ordinary Roman catholic church. Over the door we observed a bas-relief, executed in a style of sculpture meriting more attention than it has hitherto received. At first sight, it seemed of higher antiquity than the existence of any place of christian worship; but, upon a nearer view, we recognised the history of the Messiah's entry into Jerusalem—the multitude strewing palm branches before him. The figures were very numerous. Perhaps it may be considered as offering an example of the first work in which pagan sculptors represented a christian theme. Entering the church, the first thing they shewed to us was a slab of white marble in the pavement, surrounded by a rail. It seemed like one of the grave-stones in the floor of our English churches. This, they told us, was the spot where our Saviour's body was anointed by Joseph of Arimathea. We next advanced towards a dusty fabric, standing, like a huge pepper-box, in the midst of the principal aisle, and beneath the main dome. This rested upon a building, partly circular, and partly oblong, as upon a pedestal. The interior of this strange fabric is divided into two parts. Having entered the first part, which is a kind of ante-chapel, they shew you, before the mouth of what is called the sepulchre, the stone whereon the angel sat: this is a block of white marble, neither corresponding with the mouth of the sepulchre, nor with the substance from which it must have been hewn; for the rocks of Jerusalem are all of a common compact limestone. Shaw, speaking of the holy sepulchre, says, that all the surrounding rocks were cut away, to form the level of the church; so that now it is a grotto above ground: but even this is not true; there are no remains whatsoever of any ancient known sepulchre, that, with the most attentive and scrupulous examination, we could possibly discover. The sides consist of thick slabs of that beautiful breccia, vulgarly called verd-antique marble; and over the entrance, which is rugged and broken, owing to the pieces carried off as reliques, the substance is of the same nature. All that can therefore now be affirmed with any shadow of reason, is this; that, if Helena had reason to believe she could identify the spot where the sepulchre was, she took especial care to remove every existing trace of it, in order to introduce the fanciful and modern work which now remains. The place may be the same pointed to her; but not a remnant of the original sepulchre can now be ascertained. Yet, with all our sceptical feelings thus awakened, it may prove how powerful the effect of sympathy is, if we confess that, when we entered into the sanctum sanctorum, and beheld, by the light of lamps, there continually burning, the venerable figure of an aged monk, with streaming eyes, and a long white beard, pointing to the place where the body of our Lord was, and calling upon us to kneel and experience pardon for our sins—we knelt, and participated in the feelings of more credulous pilgrims. Captain Culverhouse, in whose mind the ideas of religion and of patriotism were inseparable, with firmer emotion, drew from its scabbard the sword he had so often wielded in the defence of his country, and placed it upon the tomb. Humbler comers heaped the memorials of an accomplished pilgrimage; and while their sighs alone interrupted the silence of the sanctuary, a solemn service was begun. Thus ended our visit to the sepulchre.

If the reader has caught a single spark of this enthusiasm, it were perhaps sacrilegious to dissipate the illusion. But much remains untold. Every thing beneath this building seems discordant, not only with history, but with common sense. It is altogether such a work as might naturally be conjectured to arise from the infatuated superstition of such an old woman as was Helena, subsequently enlarged by ignorant priests. Forty spaces from the sepulchre, beneath the roof of the same church, and upon the same level, are shewn two rooms, one above the other. Close by the entrance to the lower chamber, or chapel, are the tombs of Godfrey of Boulogne, and of Baldwin, kings of Jerusalem, with inscriptions in Latin, in the old Gothic character. These have been copied into almost every book of travels, from the time of Sandys to the present day. At the extremity of this chapel they exhibit a fissure or cleft in the natural rock; and this, they say, happened at the crucifixion. Who shall presume to contradict the tale? But, to complete the *naivete* of the tradition, it is also added, that the head of Adam was found within the fissure. Then, if the traveller has not already heard and seen enough to make him regret his wasted time, he may ascend by a few steps into a room above. There they will shew him the same crack again; and immediately in front of it, a modern altar. This they venerate as Mount Calvary, the place of crucifixion; exhibiting upon this contracted piece of masonry the marks, or holes, of the three crosses, without the smallest regard to the space necessary for their erection. After this he may be conducted through such a farrago of absurdities, that it is wonderful the learned men, who have described Jerusalem, should have filled their pages with any serious detail of them. Nothing, however, can surpass the fidelity with which Sandys has particularized every circumstance of all this trumpery; and his rude cuts are characterized by equal exactness. Among others, should be mentioned the place where the cross was found; because the identity of the timber, which has since supplied all christendom with its reliques, was confirmed by a miracle,—proof equally infallible with that afforded by the eagle at the tomb of Theseus, in the isle of Scyra, when Cimon the Athenian sought the bones of the son of Ægeus

It is time to quit these degrading fallacies: let us break from our monkish instructors; and, instead of viewing Jerusalem as pilgrims, examine it by the light of history, with the Bible in our hands. We shall thus find many interesting objects of contemplation. If Mount Calvary has sunk beneath the overwhelming influence of superstition, studiously endeavouring to modify and to disfigure it, through so many ages; if the situation of Mount Sion yet remains to be ascertained; the Mount of Olives, undisguised by fanatical labours, exhibits the appearance it presented in all the periods of its history. From its elevated summit almost all the principal features of the city may be discerned, and the changes that eighteen centuries have wrought in its topography may perhaps be ascertained. The features of nature continue the same, though works of art have been done away: the beautiful gate of the temple is no more; but Siloa's fountain haply flows, and Kedron sometimes murmurs in the valley of Jehosaphat.

It was this resolve, and the determination of using our own eyes, instead of peering through the spectacles of priests, that led, to the discovery of antiquities undescribed by any author: and marvellous it is, considering their magnitude, and the scrutinizing inquiry which has been so often directed to every object of the place, that these antiquities have hitherto escaped notice. It is possible that their position, and the tenor of their inscriptions, may serve to throw new light upon the situation of Sion, and the topography of the ancient city. This, however, will be a subject for the investigation of future travellers. We must content ourselves with barely mentioning their situation, and the circumstances of their discovery. We had been to examine the hill which now bears the name of Sion: it is situated upon the south side of Jerusalem, part of it being excluded by the wall of the present city, which passes over the top of the mount. If this be indeed Mount Sion, the prophecy concerning it, that the plough shall pass over it, has been fulfilled to the latter; for such labours were actually going on when we arrived. Here the Turks have a mosque over what they call the tomb of David. No christian can gain admittance; and as we did not choose to loiter among the other legendary sanctities of the mount, having quitted the city by what is called Sion Gate, we descended into a dingle or trench, called Tophet, or Gehinnon, by Sandys. As we reached the bottom of this narrow dale, sloping towards the valley of Jehosaphat, we observed, upon the sides of the opposite mountain, which appears to be the same called by Sandys the hill of offence, facing Mount Sion, a number of excavations in the rock, similar to those already described among the ruins of Telmessus, in the gulph of Glaucus: and answering to the account published by Shaw of the Cryptæ of Laodicea, Jebilee, and Tortosa. We rode towards them; their situation being very little elevated above the bottom of the dingle, upon its southern side. When we arrived, we instantly recognised the sort of sepulchres which had so much interested us in Asia Minor, and, alighting from our horses, found that we should have ample employment in their examination. They were all of the same kind of workmanship, exhibiting a series of subterranean chambers, hewn with marvellous art, each containing one, or many, repositories for the dead, like cisterns carved in the rock upon the sides of those chambers. The doors were so low, that, to look into any one of them, it was necessary to stoop, and, in some instances, to creep upon our hands and knees: these doors were also grooved, for the reception of immense stones, once squared and fitted to the grooves, by way of closing the entrances. Of such a nature were, indisputably, the tombs of the sons of Heth, of the kings of Israel, of Lazarus, and of Christ. This has been also proved by Shaw; but the subject has been more satisfactorily elucidated by the learned Quaresmius, in his dissertation concerning ancient sepulchres. The cemetries of the ancients were universally excluded from the precincts of their cities. In order, therefore to account for the seeming contradiction implied by the situation of the place now shewn as the tomb of the Messiah, it is pretended that it was originally on the outside of the walls of Jerusalem; although a doubt must necessarily arise as to the want of sufficient space for the population of the city, between a boundary so situated, and the hill which is now called Mount Sion. The sepulchres we are describing carry, in their very nature, satisfactory evidence of their being situated out of the ancient city, as they are now out of the modern. They are not to be confounded with those tombs, commonly called the sepulchres of the kings, to the north of Jerusalem, believed to be the burial-place of Helena, queen of Adiebéné. What therefore are they? Some of them, from their magnificence, are the immense labour necessary to form the numerous repositories they contain, might lay claim to regal honours; and there is one which appears to have been constructed for the purpose of inhuming a single individual. The Karæan Jews, of all other the most tenacious in adhering to the customs of their ancestors, have, from time immemorial, been in the practice of bringing their dead to this place for interment; although this fact was not wanted to prove it an ancient Jewish cemetry, as will be seen in the sequel. The sepulchres themselves, according to the ancient practice, are stationed in the midst of gardens. From all these circumstances, are we not authorised to seek here for the sepulchre of Joseph of Arimathea, who, as a pious Jew, necessarily had his burying-place in the cemetry of his countrymen, among the graves of his forefathers? The Jews were remarkable for their rigid adherence to this custom: they adorned their burial-places with trees and gardens: and the tomb of this Jew is accordingly described as being in a garden; and it was in the place where our Saviour was crucified. Of what nature was that place of crucifixion? It is very worthy of observation, that every one of the Evangelists (and among these he that saw it, and bare record), affirm, that it was the place of a scull; that is to say, a public cemetry, called in the Hebrew, Golgotha; without the city, and very near to one of its gates. St. Luke calls it Calvary, which has the same signification. The church, supposed to mark the site of the holy sepulchre, exhibits no where the slightest evidence which might entitle it to either of these appellations. Can there be, therefore, aught of impiety or of temerity in venturing to surmise, that upon the opposite summit, now called Mount Sion, without the walls, the crucifixion of the Messiah was actually accomplished? Perhaps the evidence afforded by existing documents may further illustrate this most interesting subject.—These will now be enumerated.

Upon all the sepulchres at the base of this mount, which, as the place of a scull, we have the authority of the gospel for calling either Calvary or Golgotha, whether the place of crucifixion or not, there are inscriptions, in Hebrew and in Greek. The Hebrew inscriptions are the most effaced: of these it is difficult to make any tolerable copy. Besides the injuries they have sustained by time, they have been covered by some carbonaceous substance, either bituminous or fumid, which rendered the task of transcribing them yet more arduous. The Greek inscriptions are brief and legible, consisting of immense letters deeply carved in the face of the rock, either over the door, or by the side, of the sepulchres. Upon the first we observed these characters:

+ THCAΓIAC
CIWN
OF . THE . HOLY
SION

Having entered by the door of this sepulchre, we found a spacious chamber cut in the rock, connected with a series of other subterranean apartments; one leading into another, and containing an extensive range of receptacles for the dead, as in those excavations before alluded to, (but which appear of more recent date,) lying to the north of Jerusalem, at a more considerable distance from the city; and also as in the Cryptæ of the Necropolis near Alexandria in Egypt. Opposite to the entrance, but lower down in the rock, a second, and a similar aperture, led to another chamber beyond the first. Over the entrance to this, also, we observed an inscription, nearly obliterated, but differing from the first, by the addition of two letters:

+ HN . . . . THC
ΑΓΙΑCCIWN

Having reached the extremity of this second chamber, we could proceed no further, owing to the rubbish which obstructed our passage. Perhaps the removal of this may, at some future period, lead to other discoveries. It was evident that we had not attained the remotest part of these caverns. There were others with similar Greek inscriptions, and one which particularly attracted our notice, from its extraordinary coincidence with all the circumstances attaching to the history of our Saviour's tomb. The large stone that once closed its mouth had been, perhaps for ages, rolled away. Stooping down to look into it, we observed, within, a fair sepulchre, containing a repository, upon one side only, for a single body; whereas, in most of the others, there were two, and in many of them more than two. It is placed exactly opposite to that which is now called Mount Sion. As we viewed this sepulchre, and read upon the spot the description given of Mary Magdalene and the disciples coming in the morning, it was impossible to divest our minds of the probability that here might have been the identical tomb of Jesus Christ; and that up the steep which led to it, after descending from the gate of the city, the disciples strove together, when John did outrun Peter, and came first to the sepulchre. They are individually described as stooping down to look into it; they express their doubts as to the possibility of removing so huge a stone, that when once fixed and sealed, it might have baffled every human effort. But upon this, as upon the others already mentioned, instead of a Hebrew or a Phœnician inscription, there were the same Greek characters, destitute only of the Greek cross prefixed in the former instances. The inscription stood thus,

THCΑΓΙΑC
CIWN

the letters being very large, and deeply carved in the rugged surface of the rock.

The Hebrew inscriptions, instead of being over the entrances, were by the side of the doors. Having but little knowledge of the characters with which they were written, all that could be attempted was, to make as faithful a representation as possible of every incision upon the stone, without attempting to supply any thing by conjecture; and even admitting, in certain instances, doubtful traces, which were perhaps casualties caused by injuries the stone had sustained, having no reference to the legend.

The words of the inscription are supposed to be Arabic, expressed in Hebrew and Phœnician characters. The arrow-headed character occurs here, as in the inscriptions at Telmessus.

All the face of this mountain, along the dingle, supposed to be the Vale of Gehinnon, by Sandys, is marked by similar excavations. Some of these, as may be seen by reference to a former note, did not escape his searching eye; although he neglected to observe their inscriptions, probably from keeping the beaten track of pilgrims going from Mount Sion to the Mount of Olives, and neglecting to cross the valley in order to examine them more nearly. The top of the mountain is covered by ruined walls and the remains of sumptuous edifices: these he also noticed; but he does not even hint at their origin. Here again we are at a loss for intelligence: and future travellers will be aware of the immense field of inquiry which so many undescribed remains belonging to Jerusalem offer to their observation. If the foundations and ruins as of a citadel may be traced all over this eminence, the probability is, that this was the real Mount Sion; that the Gehinnon of Sandys, and of many other writers, was in fact the Valley of Millo, called Tyropœon by Josephus, which separated Sion from Mount Moriah, and extended as far as the Fountain Siloa, where it joined the Valley of Jehosaphat. The sepulchres will then appear to have been situated beneath the walls of the citadel, as was the case in many antient cities. Such was the situation of the Grecian sepulchres in the Crimea, belonging to the ancient city of Chersonesus, in the Minor Peninsula of the Heracleotæ. The inscriptions already noticed seem to favour this position; and if hereafter it should ever be confirmed, the remarkable things belonging to Mount Sion, of which Pococke says there are no remains in the hill now bearing that appellation, will in fact be found here. The Garden of the Kings, near the Pool of Siloam, where Manasseh and Amon, kings of Judah, were buried; the cemetery of the kings of Juhah; the traces and remains of Herod's palaces, called after the names of Cæsar and Agrippa; together with the other places mentioned by Nehemiah. All along the side of this mountain, and in the rocks above the Valley of Jehosaphat, upon the eastern side of Jerusalem, as far as the sepulchres of Zechariah and Absalom, and above these, almost to the top of the Mount of Olives, the Jews resident in the city bury their dead, adhering still to the cemetry of their ancestors: but having long lost the art of constructing the immense sepulchres now described, they content themselves in placing Hebrew inscriptions upon small upright slabs of marble, or of common limestone, raised after the manner at present generally in use throughout the East. [*Dr. Clarke.*

SECTION XIII.

Interesting Ruins of the Plain of Troy.

We crossed the Mender by a wooden bridge, immediately after leaving Koum-kalé; and ascertained its breadth, in that part, to equal an hundred and thirty yards. We then entered an immense plain, in which some Turks were engaged hunting wild boars. Peasants were also employed in ploughing a deep and rich soil of vegetable earth. Proceeding towards the east, and round the bay distinctly pointed out by Strabo, as the harbour in which the Grecian fleet was stationed, we arrived at the Sepulchre of Ajax, upon the antient Rhœtean Promontory. Concerning this tumulus there is every reason to believe our information correct. If we had only the text of Strabo for our guidance, there would be little ground for incredulity; and, by the evidence afforded in a view of the monument itself, we have the best comment upon this accuracy. It is one of the most interesting objects to which the attention of the literary traveller can possibly be directed. Instead of the simple Stêlé, usually employed to decorate the summit of the most antient sepulchral mounds, all writers, who have mentioned the tomb of Ajax, relate, that it was surmounted by a shrine, in which a statue of the hero was preserved. Religious regard for this hallowed spot continued through so many ages, that even to the time in which Christianity decreed the destruction of the Pagan idols, the sanctity of the Aïanteum was maintained and venerated. Such importance was annexed to the inviolability of the monument, that after Anthony had carried into Egypt the consecrated image, it was again recovered by Augustus, and restored to its pristine shrine. These facts may possibly serve to account for the present appearance of the tomb, on whose summit that shrine itself, and a considerable portion of the superstructure, remain unto this hour. Pliny, moreover, mentions the situation of the tomb as being in the very station of the Grecian fleet; and, by giving its exact distance from Sigeum, not only adds to our conviction of its identity, but marks at the same time, most decisively, the position of the Portus Achæorum. In all that remains of former ages, I know of nothing likely to affect the mind by emotions of local enthusiasm more powerfully than this most interesting tomb. It is impossible to view its sublime and simple form, without calling to mind the veneration so long paid to it; without picturing to the imagination a successive series of mariners, of kings and heroes, who from the Hellespont, or by the shores of Troas and Chersonesus, or on the sepulchre itself, poured forth the tribute of their homage; and finally, without representing to the mind the feelings of a native, or of a traveller, in those times, who, after viewing the existing monument, and witnessing the instances of public and private regard so constantly bestowed upon it, should have been told the age was to arrive when the existence of Troy, and of the mighty dead entombed upon its plain, would be considered as having no foundation in truth.

The present appearance of the shrine, and of a small circular superstruction, do not seem to indicate higher antiquity than the age of the Romans. Some have believed, from the disclosure of the shrine, that the tomb itself was opened; mistaking it for a vault, although its situation near the summit might have controverted the opinion. This was perhaps constructed when Augustus restored the image Anthony had taken from the Aïanteum. A cement was certainly employed in the work; and the remains of it to this day offer an opportunity of confuting every prevailing error concerning the buildings of the antients. The Greeks erected many of their most stupendous edifices without cementation; hence it has been supposed that the appearance of mortar in a building precludes its claim to antiquity. This notion is however set aside at once by reference to the pyramids of Egypt: in building these, mortar was undoubtedly used.

The view here afforded of the Hellespont and the Plain of Troy is one of the finest the country affords. Several plants, during the season of our visit, were blooming upon the soil. Upon the tomb itself we noticed the silvery mezereon, the poppy, the beardless hypecoum, and the field star of Bethlehem.

From the Aïanteum we passed over a heathy country to Halïl Elly, a village near the Thymbrius, in whose vicinity we had been instructed to seek the remains of a temple once sacred to the Thymbrean Apollo. The ruins we found were rather the remains of ten temples than of one. The earth to a very considerable extent was covered by subverted and broken columns of marble granite, and of every order in architecture. Doric, Ionic, and Corinthian capitals, lay dispersed in all directions, and some of these were of great beauty. We observed a bas-relief representing a person on horseback pursued by a winged figure; also a beautiful representation, sculptured after the same manner of Céres in her car drawn by two scaly serpents. Of three inscriptions which I copied among these ruins, the first was engraven upon the shaft of a marble pillar. This we removed, and brought to England. It is now in the vestibule of the public library at Cambridge; and commemorates the public services of a phrontistes of Drusus Cæsar. The names of persons belonging to the family of Germanicus occur frequently among inscriptions found in and near Troas. Drucus, the son of Germanicus, was himself appointed to a government in the district. Whatsoever tends in any degree to illustrate the origin of the ruins in which it was discovered, will be considered interesting; although, after all, we must remain in a state of the greatest uncertainty with regard to the city alluded to in either of these documents. Possibly it may have been Scamandria, but in the multitude of cities belonging to Troas, a mere conjecture, without any positive evidence, is less pardonable than silence. The inscription, offering our only remaining clue, sets forth that the tribe Attalis commemorated Sextus Julius Festus, a magistrate of the city, and præfect of the Flavian cohort, who had been Gymnasiarch, and given magnificently and largely, to the senators and all citizens, oil and ointment for some public festival.

The third inscription and perhaps the most important, had these remarkable words—

"THE ILIEANS TO THEIR COUNTRY'S GOD ÆNEAS."

If this had been found by a late respectable and learned author, it might have confirmed him in the notion that the Thymbrius was in fact the Simoïs as he believed; and perhaps have suggested, in the present name of the place, Halïl Ili, (or, as I have written it Halïl Elly, to conform to the mode of pronunciation,) an etymology from Λ ON.

From the ruins at Halïl Elly, we proceeded through a delightful valley, full of vineyards, and almond-trees in full bloom, intending to pass the night at the village of Thymbreck. We found no antiquities, nor did we hear of any in the neighbourhood. The next day returning toward Halïl Elly, we left it upon our right, and crossed the Thymbrius by a ford. In summer this river becomes almost dry; but during winter it often presents a powerful torrent, carrying all before it. Not one of the maps, or of the works yet published upon Troas, has informed us of its termination: according to some, it empties itself into the Mender near its embouchure; others describe it as forming a junction near Tchiblack; a circumstance of considerable importance; for if this last position be true, the ruins at Tchiblack may be those of the Temple of the Thymbræan Apollo. Strabo expressly states the situation of the temple to be near the place where the Thymbrius discharges itself into the Scamander. After we had passed the ford, we ascended a ridge of hills, and found the remains of a very ancient paved way. We then came to the town or village of Tchiblack, where we noticed very considerable remains of ancient sculpture, but in such a state of disorder and ruin, that no precise description of them can be given. The most remarkable are upon the top of a hill called Beyan Mezaley, near the town, in the midst of a beautiful grove of oak trees, towards the village of Callifat. Here the ruins of a Doric Temple of white marble lay heaped in the most striking manner, mixed with broken stélæ, Cippi, Sarcophagi, cornices and capitals of very enormous size, entablatures, and pillars. All of these have reference to some peculiar sanctity by which this hill was anciently characterized. It is of a conical form, and stands above the town of Tchiblack, appearing as large as the Castle Hill at Cambridge. The first inquiry that suggests itself, in a view of this extraordinary scene, naturally involves the original cause of the veneration in which the place was anciently held. Does it denote the site of Pagus Iliensium, whose inhabitants believed that their village stood on the site of Ancient Troy? This place was distant thirty stadia from the New Ilium of Strabo; and the distance corresponds with the relative situation of this Hill and Palaio-Callifat, or Old Callifat, where New Ilium stood; as will hereafter be proved. Or may it be considered the eminence described by Strabo as the beautiful Colone, five stadia in circumference, near which Simoïs flowed; and Tchiblack, the Pagus Iliensium? It was rather more than a mile distant from the village of the Ilieans, and stood above it; exactly as this hill is situated with regard to Tchiblack.

It will now be curious to observe, whether an inscription we discovered here does not connect itself with these inquiries. It was found upon the fluted marble shaft of a Doric pillar two feet in diameter; so constructed, as to contain a Cippus, or inscribed slab, upon one side of it.

The inscription records the consecration of a Stoa, and all things belonging to it, to Tiberius Claudius Cæsar Germanicus, the emperor, and to Julia Augusta Agrippina, his wife, and their children, and to Minerva of Ilium. The reason why the emperor Claudius and his children were honoured by the Ilienses, is given by Suetonius, and Tacitus. Eckhel mentions, I know not on what authority, a fane consecrated to the Ilican Minerva, as having existed in the Pagus Iliensium, which Alexander adorned after his victory at Granicus. Arrian states merely the offerings to Minerva of Ilium, making no mention of the fane; but Strabo, who expressly alludes to the temple, places it in the Iliensian city. But whence originated the sanctity of this remarkable spot, still shaded by a grove of venerable oaks, beneath whose branches a multitude of votive offerings yet entirely cover the summit of the hill? An inscription commemorating the pious tribute of a people in erecting a portico to the family of Claudius Cæsar and the Ilean Minerva, can only be referred to the inhabitants of that district of Troas who were styled Iliences. It has been shewn that Claudius, after the example of Alexander, had perpetually exempted them from the payment of any tribute. In their district stood the Pagus Iliensium, with the (Callicone) beautiful hill; and nearly thirty stadia farther towards the west, reversing the order of the bearing given by Strabo, the Hiliensium Civitas. If therefore this hill, so pre-eminently entitled to the appellatión of Callicolone, from the regularity of its form, and the groves by which it seems for ages to have been adorned, be further considered, on account of its antiquities, an indication of the former vicinity of the Iliensian village, it should follow, that observing a westward course, the distance of three miles and three quarters, or nearly so, would terminate in the site of the Iliensian city: and any discovery ascertaining either of these places would infallibly identify the position of the other. This line of direction we observed in our route, advancing by a cross road into the Plain.

There were other inscriptions, commemorating the good offices of Roman emperors; but these were so much mutilated, that no decisive information could be obtained from them. Upon one we read—

"THE ALEXANDRIAN TRIBE HONOUR SEXTUS JULIUS, THE MAGISTRATE OF THE CITY, PRÆFECT OF THE FLAVIAN COHORT," &c.

Another, inscribed upon the cover of a large Sarcophagus, mentioned a portico, and the daughter of some person for whom both the ΣΤΟΑ and the ΣΟΡΟΣ had been constructed.

As we journied from this place, we found, in a corn field below the hill, a large block of inscribed marble; but owing to the manner in which the stone was concealed by the soil, as well as the illegibility of the inscription, we could only discern the following characters, in which the name of Julius again occurs:

ΙΟΥΛΙΟΥ . . . . .
ΑΡΧΩΝ . . . . .
. . . . . ΚΟΣΜΟΝ

sustaining what was before advanced concerning the prevalence of names belonging to the family of Germanicus, or of persons who flourished about his time. Upon a medal of Claudius, described by Vaillant, belonging to Cotyæium, a city of Phrygia, bordering upon Troas, we read the words ΕΠΙ ΙΟΥΛΙΟΥ ΥΙΟΥ ΚΟΤΙΑΕΩΝ. We proceeded hence towards the plain; and no sooner reached it, than a tumulus of very remarkable size and situation drew our attention, for a short time, from the main object of our pursuit.

This Tumulus, of a high conical form and very regular structure, stands altogether insulated. Of its great antiquity no doubt can be entertained by persons accustomed to view the everlasting sepulchres of the Antients. On the southern side of its base is a long natural mound of lime-stone: this, beginning to rise close to the artificial tumults, extends towards the village of Collifat, in a direction nearly from north to south across the middle of the plain. It is of such height, that an army, encamped on the eastern side of it, would be concealed from all observation of persons stationed upon the coast, by the mouth of the Mender. It reaches nearly to a small and almost stagnant river, hitherto unnoticed, called Callifat Osmack, or Callifat Water, taking its name from the village near which it falls into the Mender: our road to that place afterwards led us along the top of the mound. Here then both art and nature have combined to mark the plain by circumstances of feature and association not likely to occur elsewhere; although such as any accurate description of the country might well be expected to include: and if the Poems of Homer, with reference to the Plain of Troy, have similarly associated an artificial tumulus and a natural mound, a conclusion seems warranted, that these are the objects to which he alludes. This appears to be the case in the account he has given of the Tomb of Ilus and the Mound of the Plain.

Upon the surface of the Tomb itself, in several small channels caused by rain, we found fragments of the vases of Antient Greece. I know not any other cause to assign for their appearance, than the superstitious veneration paid to the tombs of Troas in all the ages of history, until the introduction of Christianity. Whether they be considered as the remains of offerings and libations made by Greeks or Romans, they are indisputably not of modern origin. The antiquity of earthen-ware, from the wheel of a Grecian potter, is as easily cognizable as any work left for modern observation; and, as a vestige of that people, denoting the site of their cities, towns, and public monuments, may be deemed perhaps equal in importance to medals and inscriptions.

From this tomb we rode along the top of the mound of the plain, in a south-western direction, towards Callifat. After we had proceeded about half its length, its inclination became southward. Having attained its extremity in that direction, we descended into the plain, when our guides brought us to the western side of it, near its southern termination, to notice a tumulus, less considerable than the last described, about three hundred paces from the mound, almost concealed from observation by being continually overflowed, upon whose top two small oak trees were then growing. This tumulus will not be easily discerned by future travellers, from the uniformity of its appearance at a distance with the rest of the vast plain in which it is situated, being either covered with corn, or furrowed by the plough. The view it commands of the coast, towards the mouth of the Mender, may possibly entitle it to their subsequent consideration, with reference to the sepulchre of Myrinna.

We now proceeded to the Califat Osmack, or Califat water, a river that can scarce be said to flow towards the Mender; yet so deep, that we were conducted to a ford in order to pass. Hundreds of tortoises, alarmed at our approach, were falling from its banks into the water, as well as from the overhanging branches and thick underwood, among which these animals, of all others the least adapted to climb trees, had singularly obtained a footing. Wild-fowl also were in great abundance, and in the corn-land partridges were frequently observed I have no hesitation in stating, that I conceive this river to be the Simois; nor would there perhaps remain a doubt upon the subject, if it were not for the prejudice excited in consequence of a marvellous error, which has prevailed throughout all the recent discussion concerning Troas, with regard to the sources of the Scamander. Pope seems first of all to have fallen into the notion of the double origin of that river: since his time, Wood, Chevalier, and their followers, have maintained that the Scamander had two sources, one of which was hot, and the other cold. The whole of this representation has been founded upon a misconstruction of the word ΠΗΓΑΙ. The Scamander has therefore been described as having its rise from two sources in the Plain, near the Scæan gate of the city; hence all the zeal which has been shewn in giving to the springs of Bonarbashy the name of those sources, although they are many in number, and all of them warm springs, as will hereafter appear. Having once admitted this palpable delusion concerning the sources of the Scamander, notwithstanding the very judicious remonstrances of Mr. Bryant upon this part of the subject, and the obvious interpretation of the text of Homer, the wildest theories ensued. All attention to the Plain of Troas on the north-eastern side of the Mender was abandoned; nothing was talked of excepting Bonarbashy, and its warm fountains; and these being once considered as the source of the Scamander, were further reconciled with Homer's description, by urging the absurdity of believing Achilles to have pursued Hector on the heights of Ida, when the chace is said to have happened near the walls of Troy. But the plain matter of fact is, that Homer, in no part of his poems, has stated either the temperature of the Scamander at its source, or its double origin. In no part of his poems is there any thing equivocal, or obscure, concerning the place whence that river issues, or the nature of its torrent. It is with him, Scamander, flowing from Idean Jove; ΜΕΓΑΣ ΠΟΤΑΜΟΣ ΒΑΘΥΔΙΝΗΣ, the great vortiginous river; bearing on his giddy tide the body of Polydorus to the sea; the angry Scamander. The springs by which Achilles pursues Hector were two fountains, or rivulets, near the bed of the river, as expressly stated by the Poet; but they had no connection with the source of the Scamander, and therefore the rise of that river in Mount Ida causes no objection to Homer's narrative. The whole country abounds both with hot and with cold springs; so that unauthorized by the poet to ascend to the source of the Scamander in search of them, we may rest satisfied with their position elsewhere.

Continuing along the southern side of Callifat Water, after having crossed the ford, we came to some suins upon its banks, by which the ground was covered to a considerable extent. These consisted of the most beautiful Doric pillars, whose capitals and shafts, of the finest white marble, were lying in the utmost disorder. Among them we also noticed some entire shafts of granite. The temple of Jupiter being always of the Doric order, we might suppose these ruins to mark the site of a fane consecrated to Idean Jove; but Doric was evidently the prevailing order among the ancient edifices of the Troas, as it is found every where in the district, and all the temples in that part of Phrygia could not have been consecrated to the same deity. The ruins by the Callifat Water have not been hitherto remarked by any traveller; although Akerblad obtained, and published in a very inaccurate manner, an inscription I also copied there. It is as old as the Archonship of Euclid. Having already twice before published it, both in the account of the Greek marbles preserved in the Vestibule of the Public Library at Cambridge, and also in the Appendix to the Dissertation on the Soros of Alexander, the introduction of the original legend here would be deemed an unnecessary repetition. It was inscribed upon the lower part of a plain marble pillar: this we removed to the Dardanelles, and afterwards sent to England. The interpretation sets forth, that those partaking of the sacrifice, and of the games, and of the whole festival, honoured Pytha, daughter to Scamandrotimus, native of Ilium, who performed the office of Canephoros in an exemplary and distinguished manner, for her piety towards the goddess. In the conjecture already offered, that the stream, on the banks of which those edifices were raised, and these vows offered, was the Simoïs of the antients, some regard was necessarily intended, both to the ruins here situated, and the inscription to which reference is now made. A certain degree of collateral, although no positive evidence, may possibly result from the bare mention of places and ceremonies, connected by their situation, and consecrated by their nature, to the history of the territory where Simoïs flowed.

Near the same place, upon a block of Parian marble, I found another inscription, but not equally perfect.

We afterwards proceeded to the Greek village of Callifat, situated near the spot where the Callifat Osmack joins the Mender. In the streets and court yards of this place were lying several capitals of Corinthian pillars; and upon a broken marble tablet, placed in a wall, I noticed part of an inscription in metre; the rest having perished.

While I was copying it, some peasants of the place came to me with Greek medals. They were all of copper, in high preservation, and all medals of Ilium, struck in the time of the Roman emperors. On one side was represented the figure of Hector combating, with his shield and spear, and the words ΕΚΤΩΡΙΛΙΕΩΝ; and upon the other, the head either of Antoninus, Faustina, Severus, or some later Roman emperor or empress. As there were so many of these Iliean medals, I asked where they were found; and was answered, in modern Greek, at Palaio Callifat, Old Callifat, a short distance from the present village in the plain towards the east. I begged to be conducted thither; and took one of the peasants with me as a guide.

We came to an elevated spot of ground, surrounded on all sides by a level plain, watered by the Callifat Osmack, and which there is every reason to believe the Simoïsian. Here we found, not only the traces, but also the remains of an antient citadel. The Turks were then employed raising enormous blocks of marble, from the foundations surrounding the place; possibly the identical works constructed by Lysimachus, who fenced New Ilium with a wall. The appearance of the structure exhibited that colossal and massive style of architecture which bespeaks the masonry of the early ages of Grecian history. All the territory within these foundations was covered by broken pottery, whose fragments were parts of those antient vases now held in such high estimation. Here the peasants said they found the medals they offered to us, and most frequently after heavy rains. Many had been discovered in consequence of the recent excavations made there of the Turks, who were removing the materials of the old foundations for the purpose of constructing works at the Dardanelles. As these medals, bearing indisputable legends to designate the people by whom they were fabricated, have also, in the circumstances of their discovery, a peculiar connection with the ruins here, they may be considered as indicating, with tolerable certainty, the situation of the city to which they belonged. Had we observed, in our route from Tchiblack, precisely the line of direction mentioned by Strabo, and continued a due course from east to west, instead of turning towards the south in the Simoïsian Plain to visit the village of Callifat, we should have terminated the distance he has mentioned, of thirty stadia, (as separating the city from the village of the Iliensians) by the discovery of these ruins. They may have been the same which Kauffer noticed in his map, by the title of Ville de Constantine; but evidently appear to be the remains of New Ilium; whether we regard the testimony afforded by their situation, as accordant with the text of Strabo; or the discovery there made of medals of the city. Once in possession of this importantpoint a light breaks in upon the dark labyrinth of Troas; we stand with Strabo upon the very spot whence he deduced his observations concerning other objects in the district; looking down upon the Simoïsian Plain, and viewing the junction of the two rivers (one flowing towards Sigeum, and the other towards Rhæteum, precisely as described by him) in front of the Iliensian city; being guided, at the same time, to Callicolone, the village of the Ilieans, and the sepulchres of Æsyetes, Batieia, and Ilus, by ths clue he has afforded. From the natural or artificial elevation of the territory on which the city stood, (an insulated object in the plain) we beheld almost every landmark to which that author has alluded. The splended spectacle presented towards the west by the snow-clad top of Samothrace, towering behind Imbrus, would baffle every attempt of delineation: it rose with indescribable grandeur, to a height beyond all I had seen for a long time; and while its æthereal summit shone with inconceivable brightness in a sky without a cloud, seemed, notwithstanding its remote situation, as its vastness would overwhelm all Troas, should an earthquake heave it from its base. Nearer to the eye appeared the mouth of the

Hellespont, and Sigeum. On the south, the tomb of Æsyete, by the road leading to Alexandria Troas; and less remote, the Scamander, receiving Simoïs or Callifat water, at the boundary of the Simoïsian Plain. Towards the east, the Throsmos, with the sepulchres of Batieia and Ilus: and far beyond, in the great chain of Ida, Gargarus opposed to Samothrace, dignified by equal if not superior altitude, and beaming the same degree of splendor from the snows by which it was invested.

[*Dr. Clarke.*

SECTION XIV.

Sculpture and Architecture of Athens.

In the year 1799, when lord Elgin was appointed his majesty's ambassador extraordinary to the Ottoman Porte, he happened to be in habits of frequent intercourse with Mr. Harrison, an architect of great eminence in the west of England, who had there given various very splendid proofs of his professional talents especially in a public building of Grecian architecture at Chester. Mr. Harrison had besides studied many years, and to great purpose at Rome. Lord Elgin consulted him, therefore, on the benefits that might possibly be derived to the arts in this country, in case an opportunity could be found for studying minutely the architecture and sculpture of ancient Greece; and his opinion very decidedly was, that although we might possess exact measurements of the buildings at Athens, yet a young artist could never form to himself an adequate conception of their minute details, combinations, and general effects, without having before him some such sensible representation of them as might be conveyed by *casts*. This advice, which laid the groundwork of lord Elgin's pursuits in Greeee, led to the further consideration, that, since any knowledge which was possessed of these buildings had been obtained under the peculiar disadvantages which the prejudices and jealousies of the Turks had ever thrown in the way of such attempts, any favourable circumstances which lord Elgin's embassy might offer should be improved fundamentally; and not only modellers, but architects and draftsmen, might be employed, to rescue from oblivion, with the most accurate detail, whatever specimens of architectures and sculptures in Greece had still escaped the ravages of time, and the barbarism of conquerors.

On this suggestion, lord Elgin proposed to his majesty's government, that they should send out English artists of known eminence, capable of collecting this information in the most perfect manner; but the prospect appeared of too doubtful an issue for ministers to engage in the expence attending it. Lord Elgin then endeavoured to engage some of these artists at his own charge; but the value of their time was far beyond his means. When, however, he reached Sicily, on the recommendation of Sir William Hamilton, he was so fortunate as to prevail on Don Tita Lusieri, one of the best general painters in Europe, of great knowledge in the arts, infinite taste, and most scrupulously exact in copying any subject he is to represent, to undertake the execution of this plan; and Mr. Hamilton, who was then accompanying lord Elgin to Constantinople, immediately went with Mr. Lusieri to Rome; where, in consequence of the late revolutions in Italy, they were enabled to engage two of the most eminent formatori to make the madreformi for the casts: Signior Balestra, the first architect there, along with Ittar, a young man of great talent, to undertake the architectural part of the plan; and one Theodore, a Calmouk, who had distinguished himself during several years at Rome, in the capacity of figure painter.

After much difficulty, lord Elgin obtained permission from the Turkish government to establish these six artists at Athens; where they prosecuted the business of their several departments during three years, acting on one general system, with the advantage of mutual control, and under the general superintendance of M. Lusieri. They at length completed lord Elgin's plan in all its parts.

"Accordingly, every monument, of which there are any remains in Athens, has been thus most carefully and minutely measured; and, from the rough draughts of the architects, (all of which are preserved, finished drawings have been made of the plans, elevations, and details of the most remarkable objects; in which the Calmouk has restored and inserted all the sculpture, with exquisite taste and ability. He has beside drawn, with astonishing accuracy all the bas-reliefs on the several temples, in the precise state of decay and mutilation in which they at present exist.

Most of the bas-reliefs, and nearly all the characteristic features of architecture, in the various monuments at Athens, have been moulded, and the moulds of them have been brought to London.

Besides the architecture and sculpture at Athens, all remains of them which could be traced through several other parts of Greece, have been measured and delineated, with the most scrupulous exactness, by the second architect, Ittar.

And picturesque views of Athens, of Constantinople, of various parts of Greece, and of the Islands of the Archipelago, have been executed by Don Tita Lusieri.

In the prosecution of this undertaking, the artists had the mortification of witnessing the very wilful devastation, to which all the sculpture, and even the architecture, were daily exposed, on the part of the Turks and travellers. The Ionic Temple, on the Hyssus, which, in Stuart's time, (about the year 1759,) was in tolerable preservation, had so completely disappeared, that its foundation can no longer be ascertained. Another temple, near Olympia, had shared a similar fate, within the recollection of man. The Temple of Minerva had been converted into a powder magazine, and been completely destroyed, from a shell falling upon it, during the bombardment of Athens by the Venetians towards the end of the seventeenth century; and even this accident had not deterred the Turks from applying the beautiful Temple of Neptune and Erectheus to the same use, whereby it is constantly exposed to a similar fate. Many of the statues on the posticum of the temple of Minerva, (Parthenon,) which had been thrown down by the explosion, had been absolutely pounded for mortar, because they furnished the whitest marble within reach; and the parts of the modern fortification, and the miserable houses where this mortar was so applied, were discovered. Besides, it is well known that the Turks will frequently climb up the ruined walls, and amuse themselves in defacing any sculpture they can reach; or in breaking columns, statues, or other remains of antiquity, in the fond expectation of finding within them some hidden treasures.

Under these circumstances, lord Elgin felt himself impelled, by a stronger motive than personal gratification, to endeavour to preserve any specimens of sculpture he could, without injury, rescue from such impending ruin. He had, besides, another inducement, and an example before him, in the conduct of the last French embassy sent to Turkey before the revolution. French artists did then remove several of the sculptured ornaments from several edifices in the Acropolis, and particularly from the Parthenon. In lowering one of the metopes, the tackle failed, and it was dashed to pieces; but other objects from the same temple were conveyed to France, where they are held in the very highest estimation, and some of them occupy conspicuous places in the gallery of the Louvre. And the same agents were remaining at Athens during lord Elgin's embassy, waiting only the return of French influence at the Porte to renew their operations. Actuated by these inducements, lord Elgin made use of all his means, and ultimately with such success, that he had brought to England, from the ruined temples at Athens, from the modern walls and fortifications, in which many fragments had been used as so many blocks of stone, and from excavations made on purpose, a greater quantity of original Athenian sculpture, in statues, alti and bassi relievi, capitals, cornices, frizes, and columns, than exists in any other part of Europe.

Lord Elgin is in possession of several of the original metopes from the Temple of Minerva. These represent the battles between the Centaurs and Lapithæ, at the nuptials of Pirithous.—Each metope contains two figures, grouped in various attitudes; sometimes the Lapithæ victorious, sometimes the Centaurs. The figure of one of the Lapithæ, who is lying dead and trampled on by a Centaur, is one of the finest productions of the art; as well as the groupe adjoining to it, of Hyppodamia, the bride, carried off by the Centaur Eurytion; the furious style of whose galloping in order to secure his prize, and his shrinking from the spear that has been hurled after him, are expressed with prodigious animation. They are all in such high relief, as to seem groups of statues; and they are in general finished with as much attention behind as before. They were originally continued round the entablature of the Parthenon, and formed ninety-two groups. The zeal of the early Christians, the barbarism of the Turks, and the explosions which took place when the temple was used as a gun-powder magazine, have demolished a very large portion of them: so that, with the exception of those preserved by lord Elgin, it is in general difficult to trace even the outlines of the original subject.

The frize, which was carried along the top of the walls of the cell, offered a continuation of sculptures in low relief, and of the most interesting kind. This frize being unbroken by triglyphs, had presented much more unity of subject than the detached and the insulated groups on the metropes of the peristyle. It represented the whole of the solemn procession to the Temple of Minerva during the Panathenaic festival: many of the figures are on horseback; others are about to mount: some are in chariots; others on foot: oxen, and other victims are leading to sacrifice: the nymphs called Canephoræ, Skiophoræ, &c. carrying the sacred offerings in baskets and vases; priests, magistrates, warriors, &c. &c. forming altogether a series of most interesting figures, in great variety of costume, armour, and attitude. Some antiquaries, who have examined this frize with minute attention, seem to think it contained portraits of many of the leading characters of Athens, during the Peloponnesian war, particularly the Pericles, Phidias, Socrates, Alcibiades, &c. The whole frize, which originally was six hundred feet in length, is, like the temple itself, of pentelic marble, from the quarries in the neighbourhood of Athens.

The tympanum over each of the porticoes of the Parthenon, was adorned with statues. That over the grand entrance of the temple from the west, containing the mythological history of Minerva's birth from the brain of Jove. In the centre of the group was seated Jupiter, in all the majesty of the sovereign of the gods. On his left, were the principal divinities of Olympus; among whom Vulcan came prominently forward, with the axe in his hand which had cleft a passage for the goddess. On the right was Victory, in loose floating robes, holding the horses of the chariot which introduced the new divinity to Olympus. One of the bombs fired by Morsini, the Venetian, from the opposite hill of the Museum, injured many of the figures in this tympanum; and the attempt of General Kœnigsmark, in 1687, to take down the figure of Minerva, ruined the whole. By purchasing the house of one of the Turkish janizaries, built immediately under and against the columns of the portico, and by demolishing it in order to excavate, lord Elgin has had the satisfaction of recovering the greatest part of the statue of Victory, in a drapery which discovers the fine form of the figure, with exquisite delicacy and taste. Lord Elgin also found there the torsi of Jupiter and Vulcan, the breast of the Minerva, together with other fragments.

On the opposite tympanum had been represented the contest between Minerva and Neptune for the honour of giving a name to the city. One or two of the figures remained on this tympanum, and others were on the top of the wall, thrown back by the explosion which destroyed the temple; but the far greater part had fallen: and a house being built immediately below the space they had occupied, lord Elgin, encouraged by the succession of his former excavations, obtained leave, after much difficulty, to pull down this house also, and continue his researches. But no fragments were here discovered; and the Turk, who had been induced, though most reluctantly, to give up his house to be demolished, then exultingly pointed out the places in the modern fortification, and in his own buildings, where the cement employed had been formed from the very statues which lord Elgin had been in hopes of finding. And it was afterwards ascertained, on incontrovertible evidence, that these statues had been reduced to powder, and so used. Then, and then only, did lord Elgin employ means to rescue what still remained from a similar fate. Among these objects is a horse's head, which far surpasses any thing of the kind, both in the truth and spirit of the execution. The nostrils are distended, the ears erect; the veins swollen, one might almost say throbbing: his mouth is open, and he seems to neigh with the conscious pride of belonging to the ruler of the waves. Besides this inimitable head, lord Elgin has procured, from the same pediment, two colossal groups, each consisting of two female figures. They are formed of single massive blocks of Pentelic marble: their attitudes are most graceful; and the lightness and elegance of the drapery exquisite. From the same pediment has also been procured a male statue in a reclining posture, supposed to represent Neptune. And, above all, the figure denominated the Theseus, which is universally admitted to be superior to any piece of statuary ever brought into England. Each of these statues is worked with such care, and the finishing even carried so far, that every part, and the very plinth itself in which they rest, are equally polished on every side.

From the Opisthodomos of the Parthenon, lord Elgin also procured some valuable inscriptions, written in the manner called Kionedon or Columnar, next in antiquity to the Boustrophedon. The greatest care is taken to preserve an equal number of letters in each line; even monosyllables are separated occasionally into two parts, if the line has had its complement, and the next line then begins with the end of the broken word. The letters range perpendicularly, as well as horizontally, so as to render it almost impossible to make any interpolation or erasure of the original text. The subject of these monuments are public decrees of the people; accounts of the riches contained in the treasury, and delivered by the administrators to their successors in office; enumerations of the statues; the silver, gold, and precious stones, deposited in the temples; estimates for the public works, &c.

The Parthenon itself, independently of its decorative sculpture, is so chaste and perfect a model of Doric architecture, lord Elgin conceived it to be of the highest importance to the arts, to secure original specimens of each member of that edifice. These consist of a capital; assizes of the columns themselves, to shew the exact form of the curve used in channelling; a triglyph, and motules from the cornice, and even some of the marble tiles with which the ambulatory was roofed: so that, not only the sculptor may be gratified by studying every specimen of his art, from the colossal statue to the basso-relievo, executed in the golden age of Pericles, by Phidias himself, or under his immediate direction; but the practical architect may examine into every detail of the building, even to the mode of uniting the tambours of the columns, without the aid of mortar, so as to give to the shafts the appearance of single blocks.

Equal attention has been paid to the Temple of Theseus; but as the walls, and columns, and sculpture of this monument, are in their original position, no part of the sculpture has been displaced, nor the minutest fragment of any kind separated from the building. The metopes in mezzo-relievo, containing a mixture of the labours of Hercules and Theseus, have been modelled and drawn, as well as the frize representing the battle between the Centaur and Lapithæ, some incidents of the battle of Marathon, and some mythological subjects. The temple itself is very inferior in size and decorative sculpture to the Parthenon; having been built by Cimon, the son of Miltiades, before Pericles had given to his countrymen a taste for such magnificence and expense, as he displayed on the edifices of the Acropolis.

The original approach to the Acropolis, from the plain of Athens, was by a long flight of steps, commenced near the foot of the Areopagus, and terminating at the Propylæa. The Propylæa was a hexastyle colonnade, with two wings, and surmounted by a pediment. Whether the metopes and tympanum were adorned with sculpture, cannot now be ascertained; as the pediment and entablature have been destroyed, and the intercolumniations built up with rubbish, in order to raise a battery of cannon on the top. Although the plan of this edifice contains some deviations from the pure tase that reigns in the other structures of the Acropolis, yet each member is so perfect in the details of its execution, that lord Elgin was at great pains to obtain a Doric and an Ionic capital from its ruins. On the right hand of the Propylæa, was a temple dedicated to victory without wings; an epithet to which many explanations have been given. This temple was built from the sale of the spoils won in the glorious struggles for freedom at Marathon, Salamis, and Platæa. On its frize were sculptured many incidents of these memorable battles; in a syle that has been thought by no means inferior to the metopes of the Parthenon. The only fragments of it that had escaped the ravages of barbarians, were built into the wall of a gun-powder magazine near it, and the finest block was inserted upside downwards. It required the whole of lord Elgin's influence at the Porte, very great sacrifices, and much perseverance to remove them; but he at length succeeded. They represent the Athenians in close combat with the Persians, and the sculptor has marked the different dresses and armour of the various forces serving under the great king. The long garments and zones of the Persians, had induced former travellers, from the hasty and imperfect view they had of them, to suppose the subject was the battle between Theseus and the Amazons, who invaded Attica, under the command of Antiope; but the Persian tiares, the Phrygian bonnets, and many other particulars, prove them to be mistaken. The spirit with which the groups of combatants are portrayed, is wonderful:—one remarks, in particular, the contest of four warriors to rescue the dead body of one of their comrades, which is expressed with uncommon animation. These bas-reliefs, and some of the most valuable sculpture, especially the representation of a marriage, taken from the parapet of the modern fortification, were embarked in the Mentor, a vessel belonging to lord Elgin, which was unfortunately wrecked off the island of Cerigo: but Mr. Hamilton, who was at the time on board, and most providentially saved, immediately directed his whole energies to discover some means of rescuing so valuable a cargo; and, in the course of several months directed to that endeavour, he succeeded in procuring some very expert divers from the islands of Syme and Calymno, near Rhodes; who were able, with immense labour and perseverance, to extricate a few of the cases from the hold of the ship, while she lay in twelve fathoms water. It was impossible to recover the remainder, before the storms of two winters had effectually destroyed the timbers of the vessel.

Near the Parthenon are three temples, so connected by their structure, and by the rites which were celebrated in them, that they might be almost considered as a treple temple. They are of small dimensions, and of the Ionic order: one of them dedicated to Neptune and Erecteus; the second to Minerva Polias, the protectress of citadels; the third to the nymph Pandrosos. It was on the spot where these temples stand, that Minerva and Neptune were said to have contended for the honour of naming the city. Athenian superstition long shewed the mark of Neptune's trident, and a briny fountain, which attested his having there opened a passage for his horse; and the original olive tree produced by Minerva was venerated in the temple of Pandrosos, as late as the time of the Antonines.

This temple of Minerva Polias is of the most delicate and elegant proportions of the Ionic order: the capitals and bases of the columns are ornamented with consummate taste; and the sculpture of the frize and cornice is exquisitely rich. It is difficult to conceive how marble has been wrought to such a depth, and brought to so sharp an edge: the palmetti, ovetti, &c. have all the delicacy of works in metal. The vestibule of the temple of Neptune, is of more masculine proportions; but its Ionic capitals have great merit. This beautiful vestibule is now used as a powder magazine; and no other access to it could be had but by creeping through an opening in a wall which had been recently built between the columns. Lord Elgin was enabled to keep it open during his operations within; but it was then closed, so that future travellers will be prevented from seeing the inner door of the temple, which is, perhaps, the most perfect specimen in existence of Ionic architecture. Both these temples have been measured; and their plans, elevations and views, made with the utmost accuracy.—All the ornaments have been moulded; some original blocks of the frize and cornice have been obtained from the ruins, as well as a capital and a base.

The little adjoining chapel of Pandrosos is a most singular specimen of Athenian architecture: instead of Ionic columns to support the architrave, it had seven statues of Caryan women, or Caryatides. The Athenians endeavoured, by this device, to perpetuate the infancy of the inhabitants of Carya, who were the only Peloponnesians who sided with Xerxes in his invasion of Greece. The men had been reduced to the deplorable state of Helotes;

and the women not only condemned to the most servile employments, but those of rank and family forced in this abject condition, to wear their ancient dresses and ornaments. In this state they are here exhibited. The drapery is fine, the air of each figure is braided in a different manner, and a kind of diadem they wear on their head forms the capital. Besides drawings and mouldings of all these particulars, Lord Elgin has brought to England one of the original statues. The Lacedæmonians had used a species of vengeance similar to that above mentioned in constructing the Persian Portico, which they had erected at Sparta, in honour of their victory over the forces of Mardonius at Platæa : placing statues of Persians in their rich oriental dresses, instead of columns, to support the entablature.

The architects have also made a ground plan of the Acropolis, in which they have not only inserted all the existing monuments, but have likewise added those, the position of which could be ascertained from traces of their foundations. Among these are the temple and cave of Pan ; to whom the Athenians thought themselves so much indebted for the success of the battle of Marathon, as to vow him a temple. All traces of it are now nearly obliterated ; as well as of that of Aglauros, who devoted herself to death to save her country. Here the young citizens of Athens received their first armour, enrolled their names, and swore to fight to the last for the liberties of their country. Near this spot the Persians scaled the wall of the citadel, when Themistocles had retired with the remainder of the army, and the whole Athenian navy, to Salamis.

The remains of the original wall may still be traced in the midst of the Turkish and Venetian additions, and they are distinguishable by three modes of construction at very remarkable epochs,—the Pelasgic, the Cecropian, and that of the age of Cimon and Pericles: It was at this last brilliant period, that the Acropolis, in its whole extent, was contemplated with the same veneration as a consecrated temple ; consistent with which sublime conception, the Athenians crowned its lofty walls with an entablature of grand proportions surmounted by a cornice. Some of the massy triglyphs and motules still remain in their original position, and producing a most imposing effect.

The ancient walls of the city of Athens, as they existed in the Peloponnesian war, have been traced by Lord Elgin's artists in their whole extent, as well as the long walls that led to the Munychia and the Piræus. The gates mentioned in ancient authors, have been ascertained: and every public monument, that could be recognised, has been inserted in a general map ; as well as detailed plans given of each. Extensive excavations were necessary for this purpose, particularly at the Great Theatre of Bacchus ; at the Pnyx, where the assemblies of the people were held, where Pericles Alcibiades, Demosthenes, and Æschines, delivered their orations, and at the theatre built by Herodes Atticus, to the memory of his wife Regilla. The supposed Tumuli of Antiope, Euripides, and others, have also been opened ; and from these excavations, and various others in the environs of Athens, has been procured a complete and valuable collection of Greek vases. The colonies sent from Athens, Corinth, &c. into Magna Grecia, Sicily and Etruria, carried with them this art of making vases, from their mother country; and, as the earliest modern collection of vases were made in those colonies, they have improperly acquired the name of Etruscan. Those found by Lord Elgin at Athens, Æginæ, Argos, and Corinth, will prove the indubitable claim of the Greeks to the invention and perfection of this art. Few of those in the collections of the King of Naples at Portici, or in that of Sir William Hamilton, excel some which Lord Elgin has procured, with respect to the elegance of the form, the fineness of the materials, the delicacy of the execution, or the beauty of the subjects delineated on them ; and they are, for the most part, in very high preservation. A tumulus, into which an excavation was commenced under Lord Elgin's eye during his residence at Athens, has furnished a most valuable treasure of this kind. It consists of a large marble vase five feet in circumference, enclosing one of bronze thirteen inches in diameter, of beautiful sculpture, in which was a deposit of burnt bones, and a lachrymatory of alabaster, of exquisite form ; and on the bones lay a wreath of myrtle in gold, having, besides leaves, both buds and flowers, This tumulus is situated on the road which leads from Port Piræus to the Salaminian Ferry and Eleusis. May it not be the tomb of Aspasia ?

From the Theatre of Bacchus, Lord Elgin has obtained the very ancient sun-dial, which existed there during the time of Æschylus, Sophocles, and Euripides ; and a large statue of the Indian, or bearded Bacchus, dedicated by Thrasyllus in gratitude for his having obtained the prize of tragedy at the Panatheniac festival.

A beautiful little temple near it, raised for a similar prize gained by Lysicrates, and commonly called the Lantern of Demosthenes, has also been drawn and modelled with minute attention. It is one of the most exquisite productions of Greek architecture. The elevation, ground-plan, and other details of the octagonal temple, raised by Andronitus Cyrrhestes to the winds, have also been executed wish care; but the sculpture on its frize is in so heavy a style that it was not judged worthy of being modelled in plaister.

Permission was obtained from the archbishop of Athens, to examine the interior of all the churches and convents in Athens and its neighbourhood, in search of antiquities; and his authority was frequently employed, to permit Lord Elgin to carry away several curious fragments of antiquity. This search furnished many valuable bas-reliefs, inscriptions, ancient dials, a Gymnasiarch's chair in marble, on the back of which are figures of Harmodius and Aristogiton. with daggers in their hands, and the death of Leæna, who bit out her tongue during the torture, rather than confess what she knew of the conspiracy against the Pisistratidæ. The fountain in the court-yard of the English consul Logotheti's house was decorated with a bas-relief of Bacchantes, in the style called Græco Etruscam; Lord Elgin has obtained this, as well as a quadriga in bas-relief, with a victory hovering over the charioteer, probably an *ex voto*, for some victory at the Olympic games. Amongst the funeral Cippi found in different places, are some remarkable names, particularly that of Socrates; and in the Ceramicus itself Lord Elgin discovered an inscription in elegiac verse, on the Athenians who fell at Potidæa, and whose eulogy was delivered with pathetic eloquence in the funeral oration of Pericles.

The peasants at Athens generally put into a niche over the door of their cottages, any fragment they discover in ploughing the fields. Out of these, were selected and purchased many curious antique votive tablets, with sculpture and inscriptions. A complete series has also been formed of capitals, of the only three orders known in Greece, the Doric, the Ionic, and the Corinthian; from the earliest dawn of art in Athens, to its zenith under Pericles; and from thence, through all its degradations, to the dark ages of the lower empire.

At a convent called Daphne, about half way between Athens and Eleusis, where the remains of an Ionic temple of Venus, equally remarkable for the brilliancy of the marble, the bold style of the ornaments, the delicacy with which they are finished, and their high preservation. Lord Elgin procured from thence two of the capitals, a whole fluted column, and a base.

[*Lord Elgin's memorandums of his pursuits.*

SECTION XV.

Magnificent remains of Ruins in Egypt.

The whole country is crowded with monuments of the gigantic architecture of former times, and of different æras. Among the most ancient are the Pyramids, so generally known that we need not dwell upon them. But among those of comparatively later times, and more elegant proportions, may be mentioned the ruins at Luxor and Edfû.

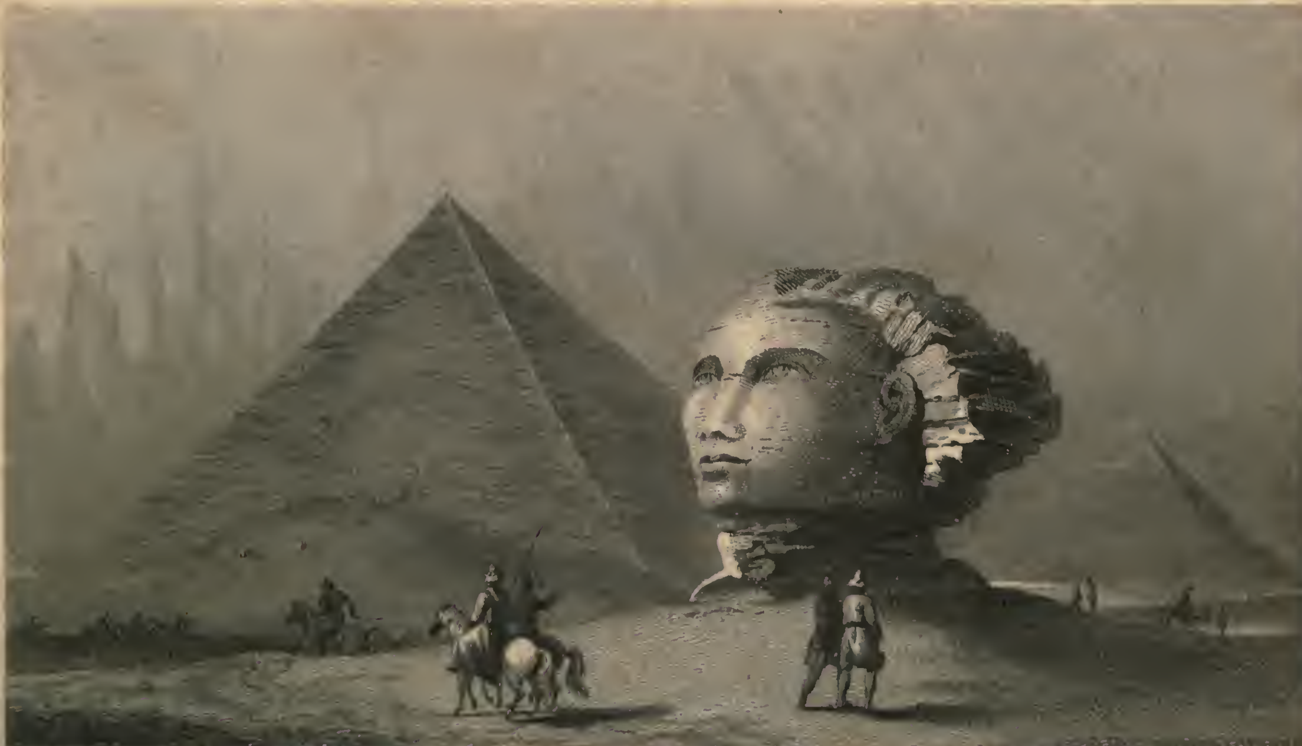
Luxor is one of the finest village towns of the country; it is united to Karnac by a superb avenue of sphinxes; and like the latter is built on the ruins of a magnificent temple, whose name is now lost to us. Nothing can be more awfully grand than the entrance into the town of which the annexed drawing, copied from M. Denon's superb work, gives a faint sketch. The inhabitants amount to between two and three thousand, whose puny buildings are niched among the ruins, or are supported on the platforms of the decayed temple.

The magnificent ruins of Edfû, are known to be more extensive: and it is here we meet with the sublime remains of the temple of Apollinopolis, the most beautiful of Egypt, and next to those of Thebes, the largest; erected at an epoch in which the arts and sciences had acquired all their splendour. All the parts are equally finished, the hieroglyphics are elaborately executed, and the figures more varied, and the architecture more perfect than in the edifices of Thebes, which must be referred to a much earlier age. We have given two views of this magnificent relic from Denon, and we may safely say, that they are among the most sumptuous and interesting of his superb drawings. [*Editor.*

SECTION XVI.

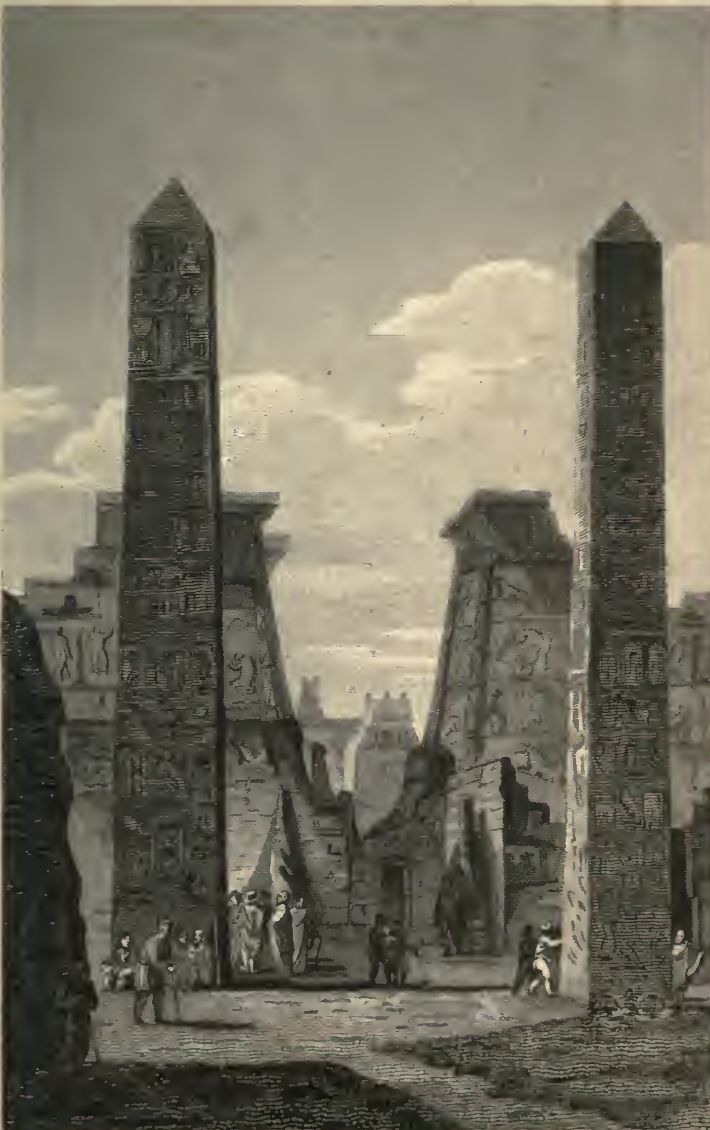
Porcelain Tower at Nankin.

We have taken this elegant and commodious building as a specimen of the oriental pagodas. The tower is about two hundred



THE FIRST & SECOND PYRAMID OF GIZAH, ANTIENT MEMPHIS
AND HEAD OF THE COLOSSAL SPHINX.

560

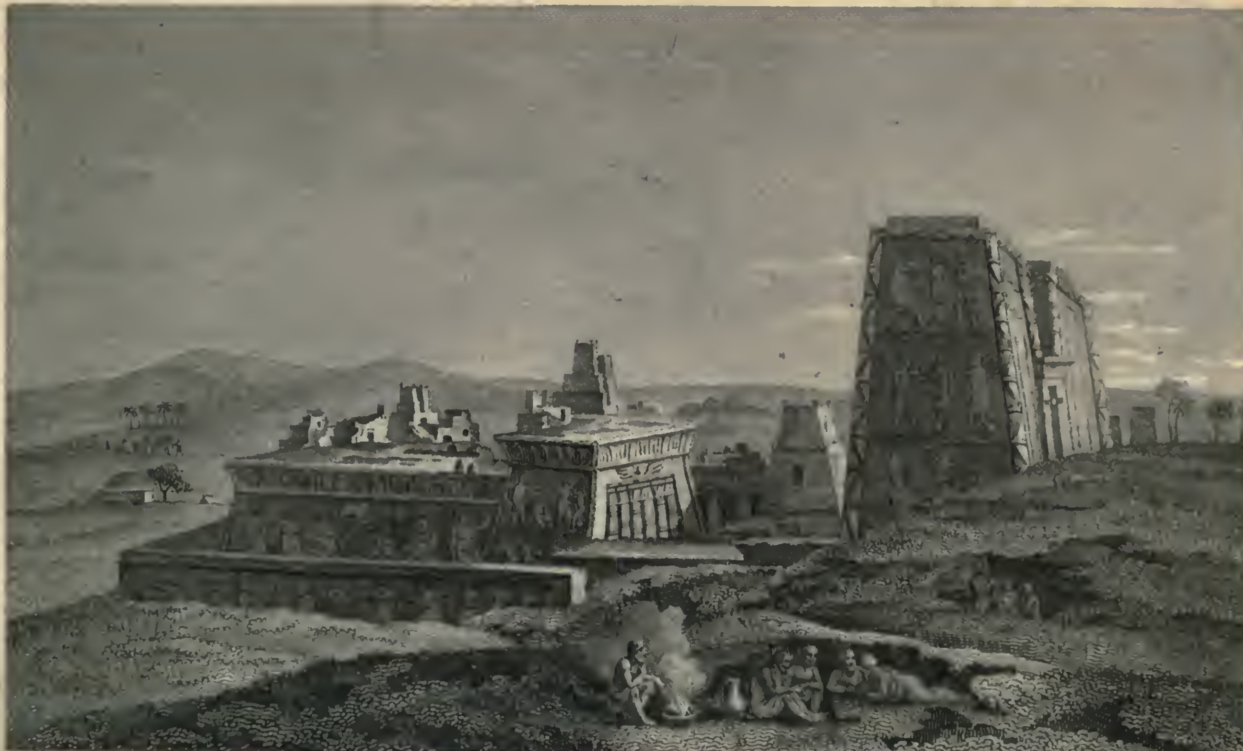


Engraved by Scott from a Drawing by [illegible] ... of Nature & Art

ENTRANCE TO THE TOWN OF LUXOR, IN EGYPT.

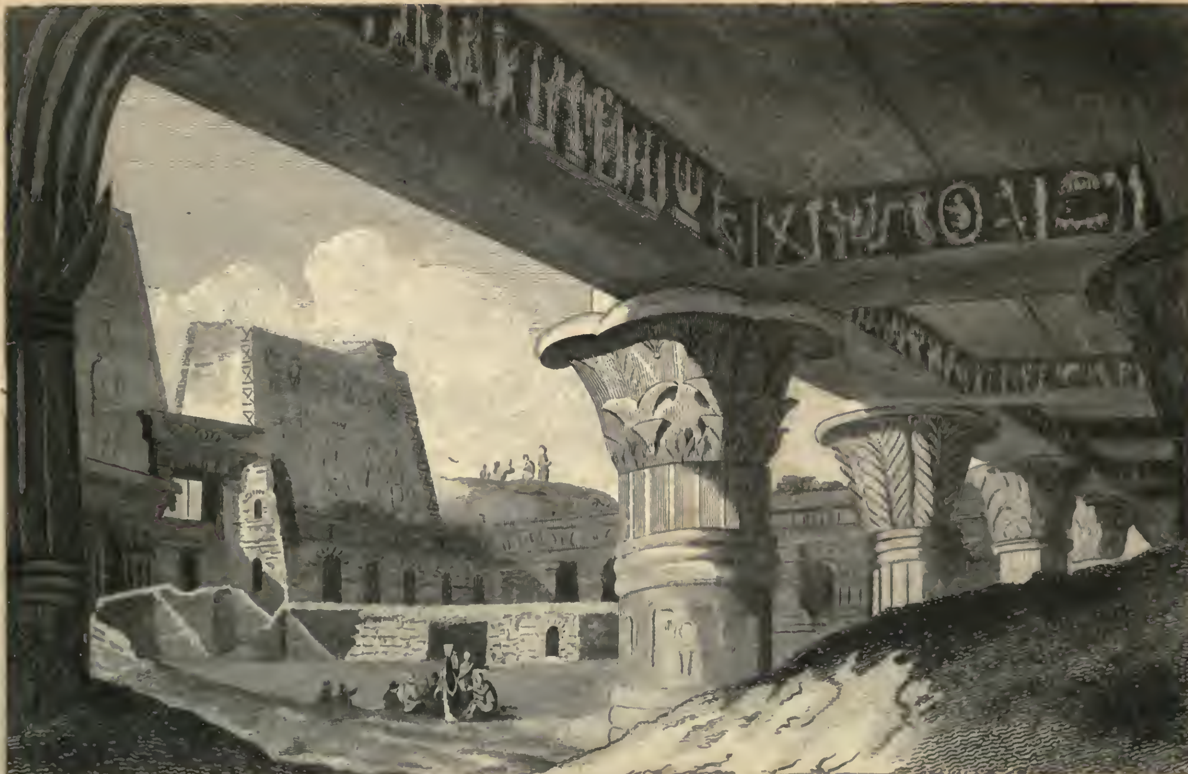
London Published [illegible] Chancery Lane [illegible]

560



THE TEMPLE OF APOLLINOPOLIS MAGNA,
at Edfu.

56



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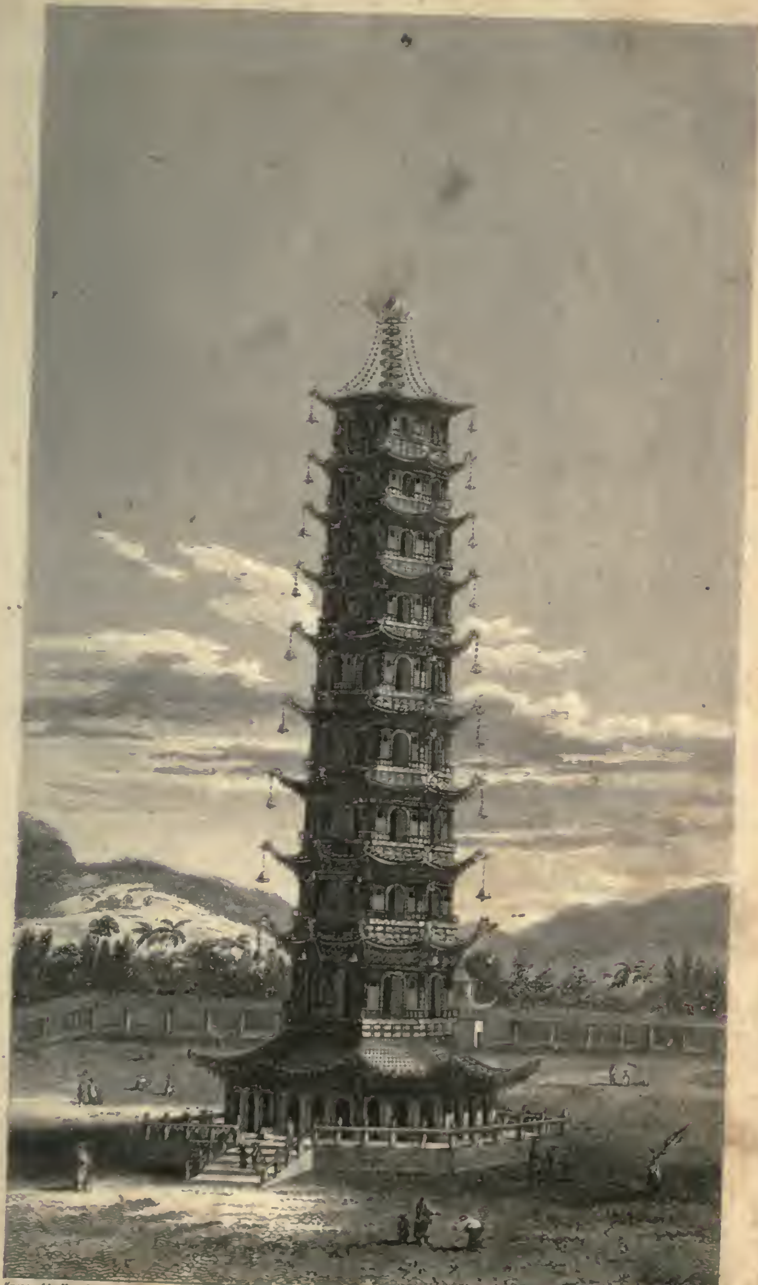
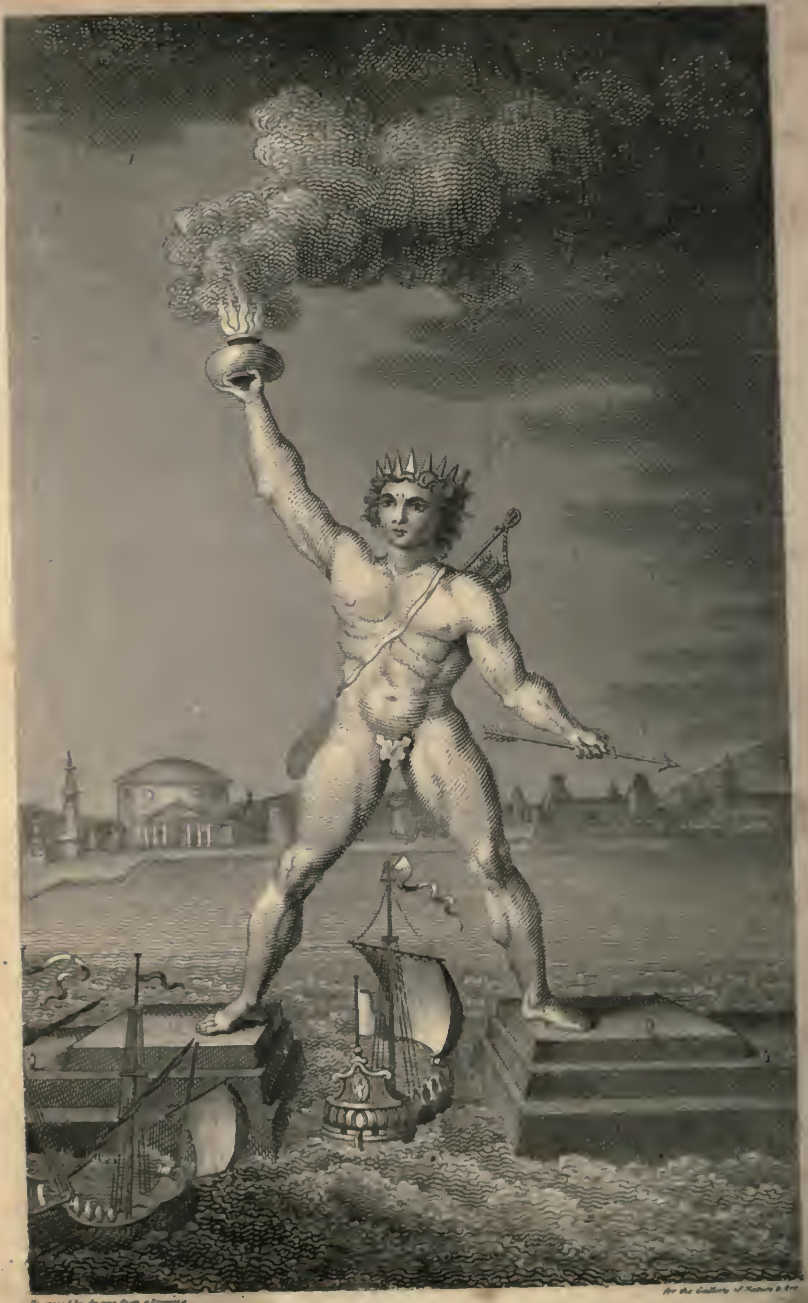
for the Gallery of Nature & Art

INTERIOR OF THE TEMPLE OF APOLLINOPOLIS AT ETFU.



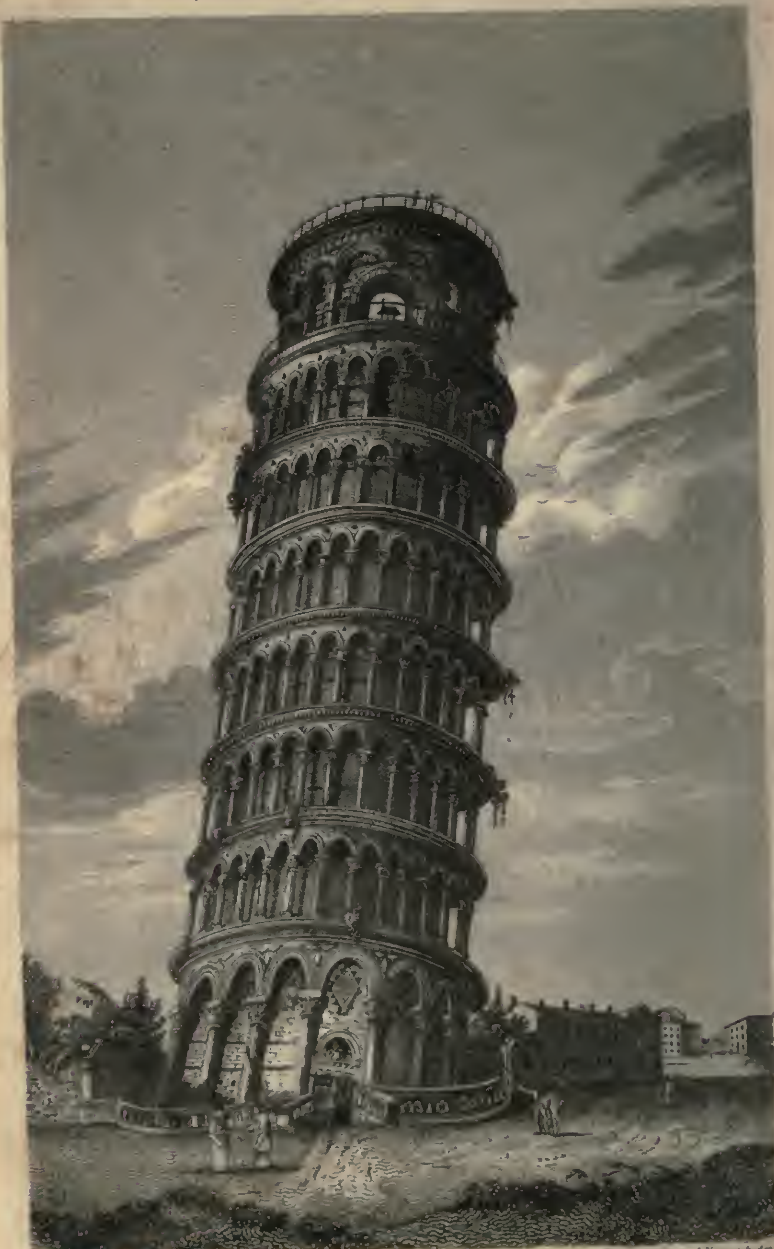
THE PORCELAIN TOWER, AT NANKIN IN CHINA.



Engraved by Angus from a Drawing

For the Gallery of Nature & Art

THE COLOSSUS OF RHODES.



Engraved by Dobbie, from a Drawing

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THE HANGING TOWER OF PISA, IN TUSCANY.

London Published by R. Wilkes [illegible] Chancery Lane, Sept. [illegible] feet in height, and derives its name from its having a china or porcelain coating. Of its founder, antiquity, or the cause of its erection, we have no information. It was the Portuguese who first gave to these edifices the name of pagodas, and attributed them to devotional purposes; but there can be little doubt that in many instances they have been rather erected as public memorials or ornaments, like the columns of the Greeks and Romans.

[*Editor.*

SECTION XVII.

Colossus of Rhodes.

THIS enormous building has justly been classed among the wonders of ancient architecture. It was a vast structure of brass, or statuary metal, erected in honour of Apollo or the sun, the tutelary god of the island; whose stride was fifty feet asunder, each foot being placed on a rock at this distance from each other, and which bounded the entrance into the haven: its height, according to Pliny, was not less than a hundred and five feet, or seventy cubits: and hence ships of considerable burden were capable of sailing between its legs. It is said to have been erected by the Rhodians with the money produced by the sale of the engines of war which Demetrius Poliorcetes employed in fruitlessly besieging the city for a twelvemonth, and which he gave to them upon his reconciliation. Pliny affirms that it was commenced by Chares of Lindus, a disciple of Lysippus, and finished upon his death by Laches of the same town. It was thrown down by an earthquake sixty years after its completion. [*Plin. Euseb. Editor.*

SECTION XVIII.

Italian Monuments and Architecture.

ITALY, like Egypt, abounds so largely with magnificent ruins and relics of different ages, that we can only indicate a few of the most singular or most celebrated.

From the former we may select for description the famous campanill or leaning tower, erected in a square close to the great church at Pisa. It is composed wholly of white marble, and was built for the purpose of containing the bells. Its height is about two hundred feet, and its inclination nearly fifteen feet from the perpendicular. The cause of this very extraordinary inclination is supposed to be a want of care in the laying the foundation. Upon which subject the reader may consult Mr. Tappen, who has given a very interesting description of this town in his "Architecture of France and Italy."

Of far higher antiquity is the celebrated column of Trajan at Rome, which we have selected for representation from an infinite multiplicity of superb remains which yet mark the universal sway which the mistress of the world once exercised. This was erected together with a long list of other public and magnificent edifices by the emperor whose name it bears; but it is regarded as his masterpiece. It stands in the middle of a square, to form which he levelled a hill of a hundred and forty feet high, and intended it both as a tomb for himself, and to show the height of the hill he had thus levelled, as appears from the inscription on its base, bearing date the seventeenth year of his tribunitial power, equivalent to the year of Christ, 114. The emperor Constantius, two centuries and a half afterwards, regarded this column and square as the most magnificent edifice by which Rome was even at that time embellished.

Nor can we avoid, while thus treading on classic ground, glancing at the far-famed colosseum or amphitheatre, the stately remains of which are to be seen in our own day, commenced by Vespasian, and finished by Titus, in the eighteenth year of the Christian æra. Upon its dedication, by this last emperor, on account of its completion, he gratuitously indulged the Roman people with public spectacles of the utmost magnificence, which lasted more than a hundred days. According to Dio Cassius, this sumptuous building was erected in what then constituted the heart of the city; but such are the changes which Rome has since undergone, that its ruins are in the present day in the outskirts.

[*Ammiam. Dio. Editor.*

SECTION XIX.

Temple of Sancta Sophia, at Constantinople.

Constantine designed the metropolis that was built by himself and still bears his name, as the rival of Rome; and his successors pursued the same intention. With this view, Justinian in the sixth century, erected the venerable and magnificent monument before

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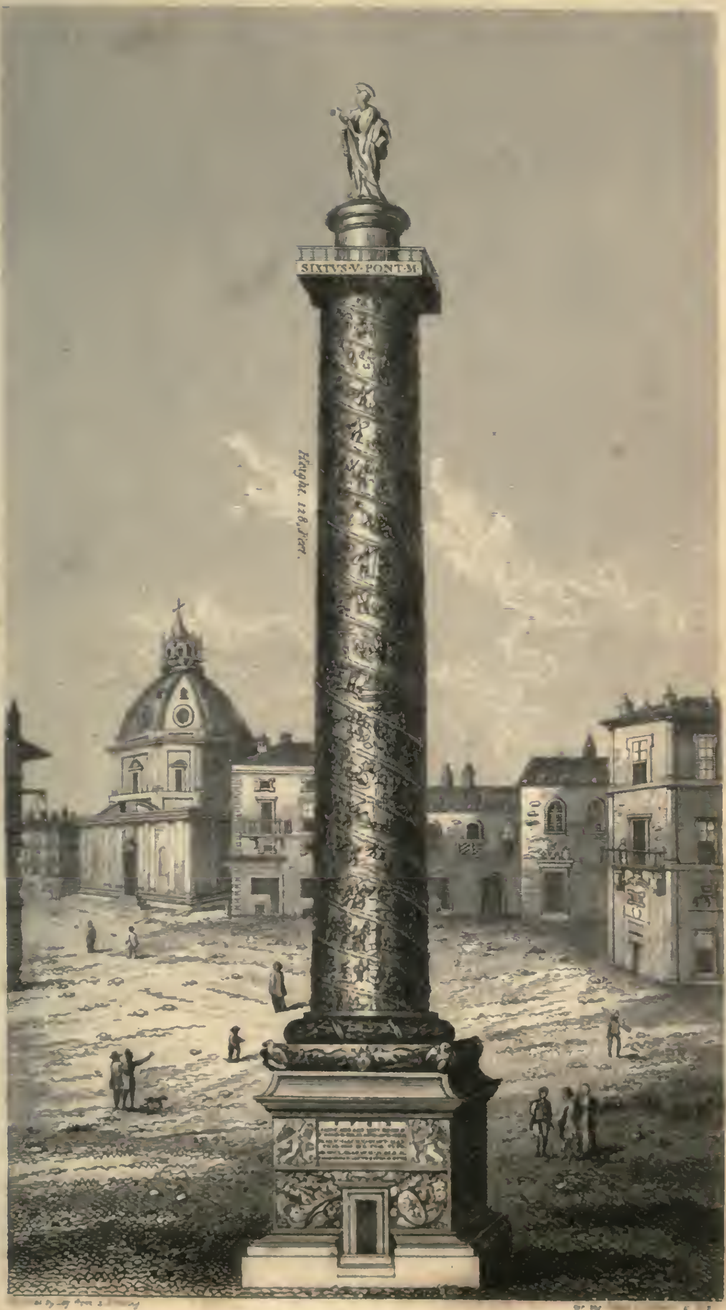
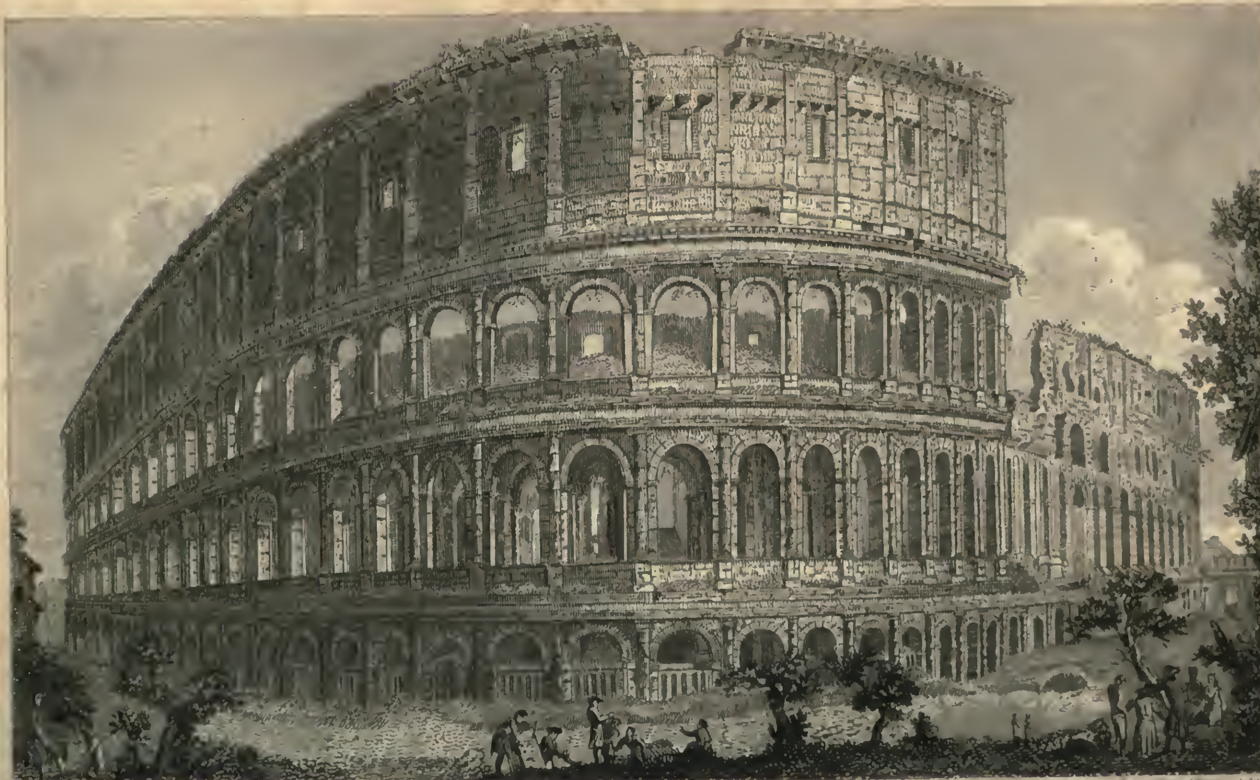


TRAJAN'S PILLAR.



ROMAN COLOSSEUM.

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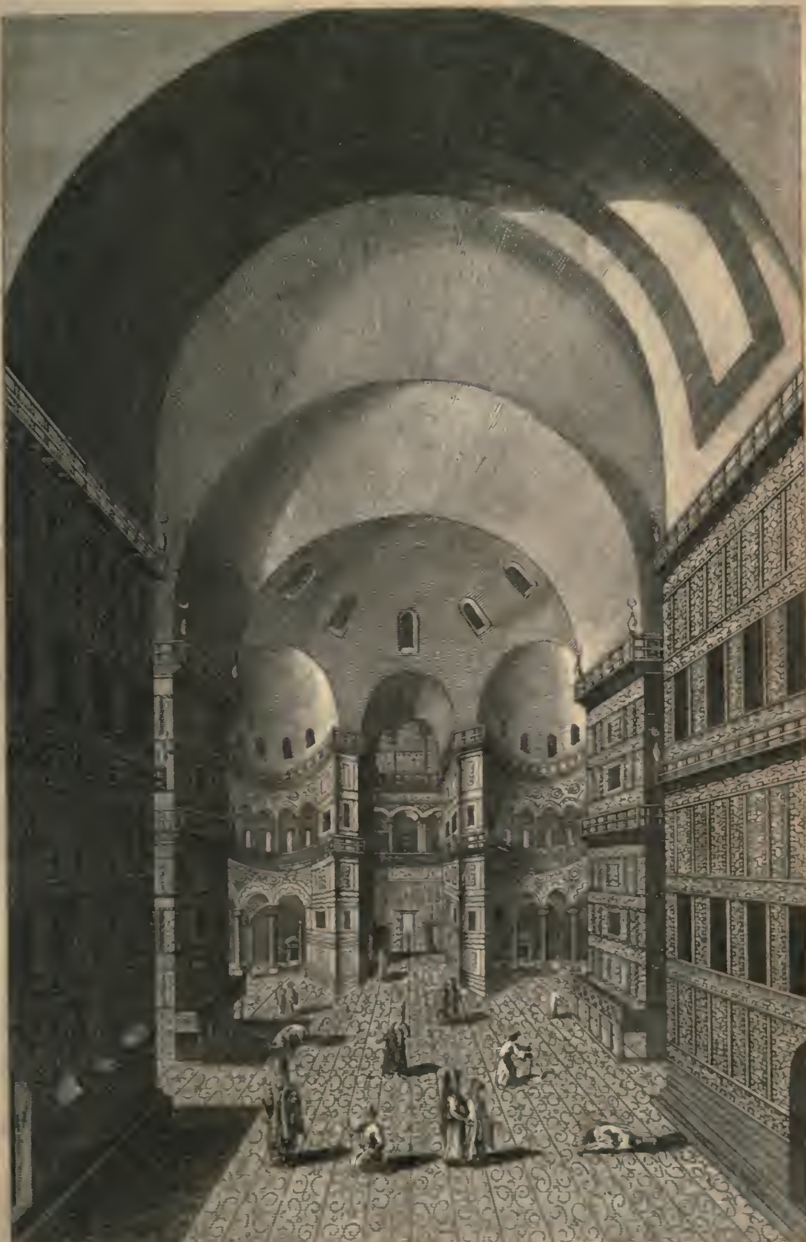
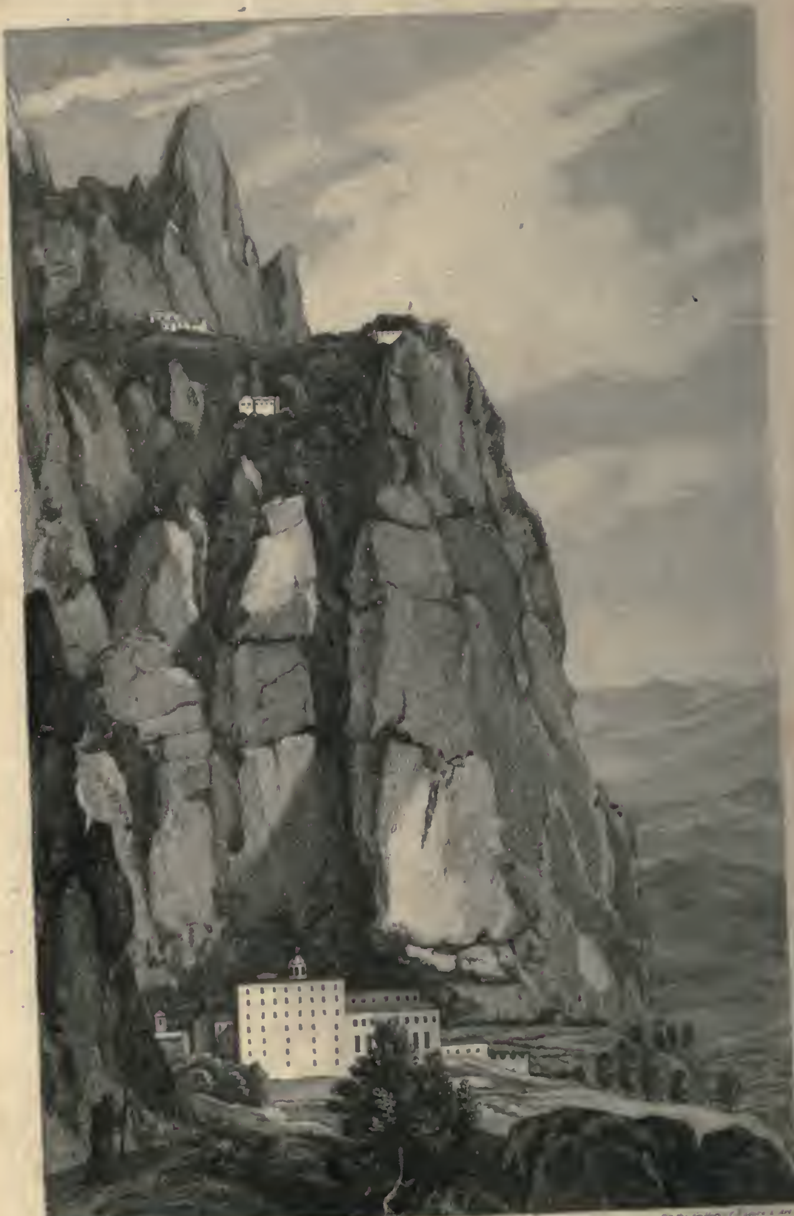
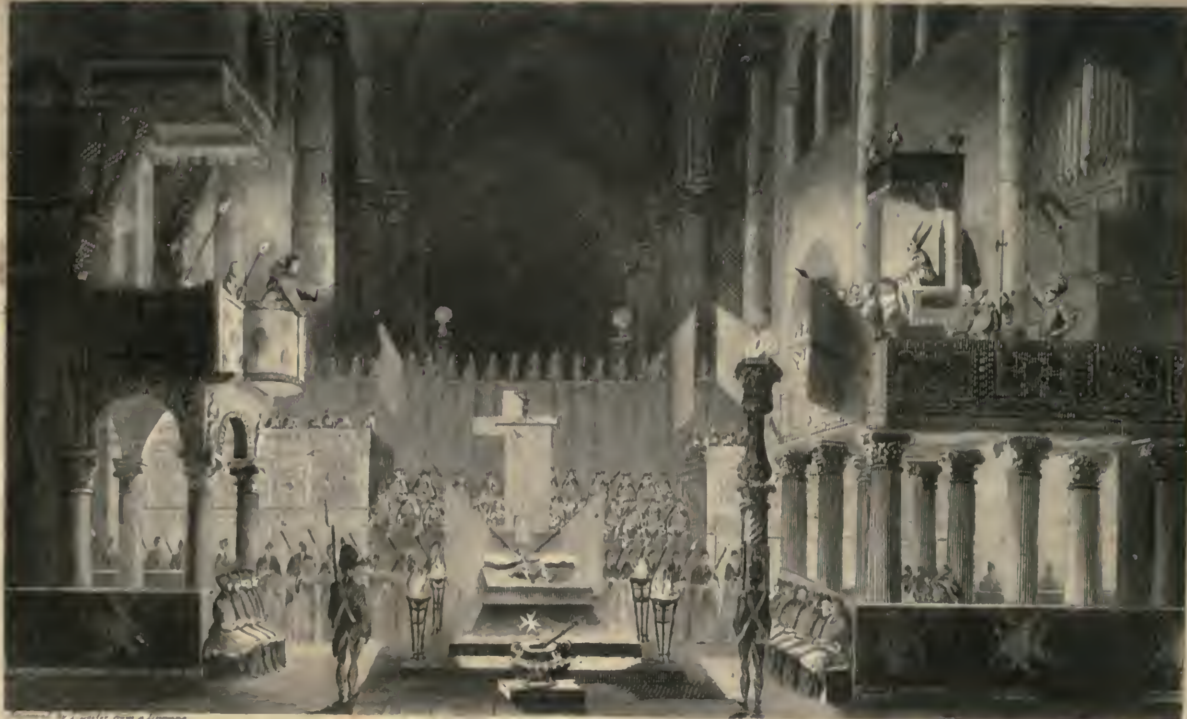


MOSQUE OF ST. SOPHIA,
at Constantinople.



CONVENT & HERMITAGES OF MONTSERRAT.



INTERIOR VIEW OF THE CATHEDRAL CHURCH AT SALERNO IN ITALY

London Published by R. Wilks 89 Chancery Lane Sept 1 1823.

us, dedicating it, as the Latin name briefly denotes, to *Divine Wisdom*. Its architecture indeed, is greatly inferior to that of a higher and more classical period; yet the effect is grand and impressive, and the copola is admired as a bold and skilful effect of the art, while the seeming weight is diminished by the lightness of the materials, which are bricks formed of a particular clay that will float in the water. The interior is adorned with a profusion of marble columns of various beautiful descriptions, the purple Phrygian, green Spartan, red and white Carian, African of a saffron colour, and many other kinds.

There is a very beautiful cathedral at Salerno, which, though less expressive, may be compared with the temple of Sancta Sophia in point of splendour, and in some part of it has a considerable resemblance to it.

The temple of Sancta Sophia, however, has been less happy in its fate; for upon the triumph of the Ottomans, it was converted into a Turkish Mosque, and continues such to the present day.

[*Editor*.

SECTION XX.

Monastery of Montserrat.

MONTSERRAT is well known to be one of the most romantic mountains of Spain: it is situated in the vicinity of Barcelona, and has given its name to one of the Leeward Carabbee Islands from a supposed resemblance to it. Towards the summit of this craggy and perpendicular steep, are erected a monastery and chapel dedicated to the Virgin Mary. The scenery is highly picturesque; and from the difficulty of the ascent, it has long been resorted to by pilgrims, who wish to show a proof of their zeal and superiority to fatigue. It is inhabited by monks of several nations, who entertain gratuitously, for some days, all who visit them, whether from curiosity or devotion.

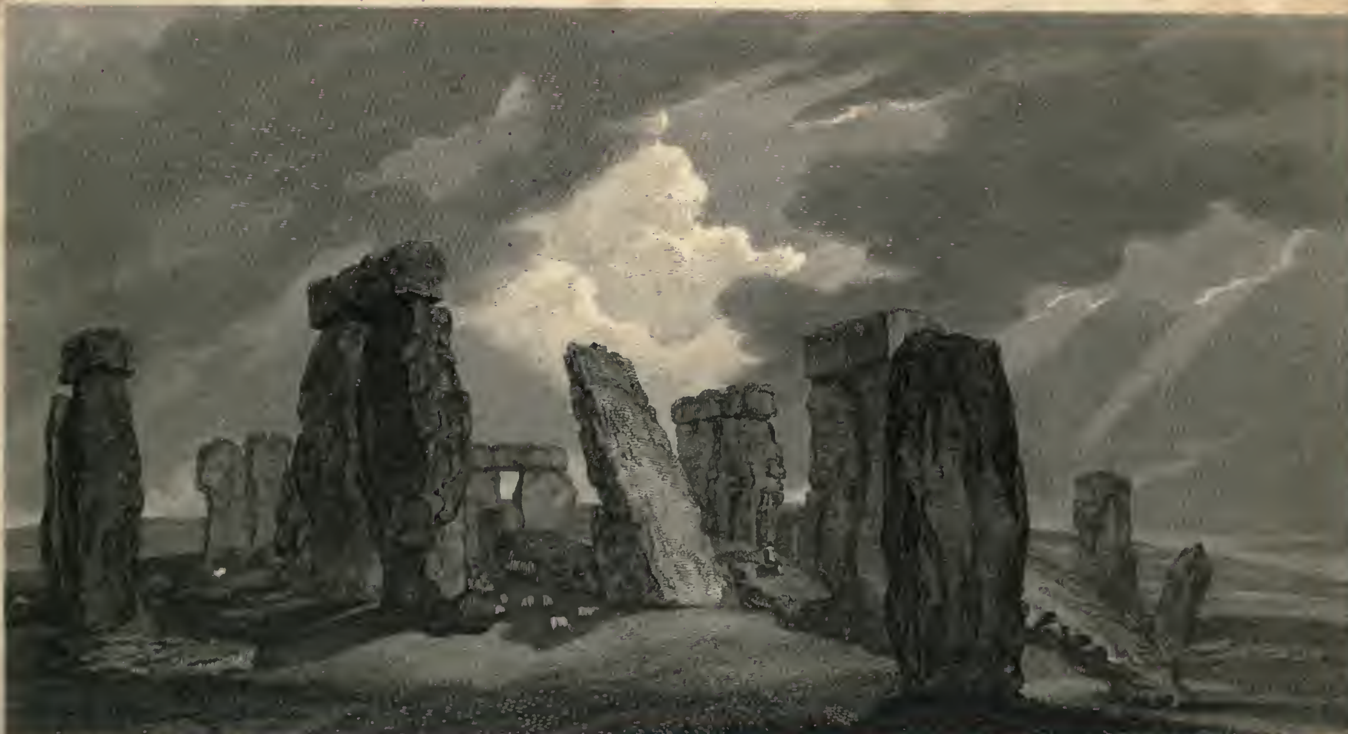
The mountain is calculated at ten miles in circumference, and three thousand three hundred feet above the level of the sea; towering over a hilly country like a pile of grotto-work, or Gothic spires.

SECTION XXI.

Stone-henge.

This celebrated monument of antiquity, is of very uncertain date. That it is very ancient is admitted by every one, but its origin, intention, and era, are points of the most doubtful controversy. Its situation is on Salisbury-plain, six miles from the city of this name.

It is described by Camden as a huge and monstrous piece of work, such as Cicero termeth *insanem substructionem.* For within the circuit of the ditch, he says, there are erected, in manner of a crown, in three ranks or courses, one within another, certain mighty and unwrought stones, whereof some are 28 feet high, and seven broad; upon the heads of which others, like overthwart pieces, do bear and rest cross-wise, with small tenons and mortises, so that the whole frame seemeth to hang: on which account we call it Stone-heng, as our old historians termed it, because of its magnitude, *chorea gigantum*, the giant's dance. The perpendicular stones are called corse-stones, and the overthwart ones are called cronets. This antiquity says Mr. Inigo Jones, because the architraves are set upon the heads of the upright stones, and hang, as it were, in the air, is generally known by the name of Stone-heng. The whole work, in general, being of a circular form, is a hundred and ten feet in diameter; double winged about, without a roof; anciently environed with a deep trench, still appearing about thirty feet broad: so that betwixt it and the work itself, a large and void space of ground being left, it had from the plain three open entrances, the most conspicuous of which lies north-east; at each of which was raised, on the outside of the trench, two huge stones, gate-wise; parallel to which, on the inside, are two others, of less proportion. The inner part of the work, consisting of an hexagonal figure, was raised, by due symmetry, upon the bases of four equilateral triangles, which formed the whole structure. This inner part was likewise double, having within it also another hexagon raised; and all that part within the trench, situated upon a commanding ground, eminent, and much higher than the surrounding plain; in the midst of which, upon a foundation of hard chalk, the work itself was placed; insomuch that, from whatsoever part they came into it, they rose by a hill of easy ascent. In the inmost part of the work is a stone, appearing not much above the surface of the earth, and lying



Engraved by ..., from a Drawing. | for the Gallery of Nature & Art.

STONE HENGE, SALISBURY PLAIN.

towards the east, four feet broad, and sixteen feet long; which, whether it be an altar or no, this author refers to the judgment of others. The great stones which are made the entrances from the outside of the trench, are seven feet broad, three feet thick, and twenty feet high. The parallel stones on the inside of the trench are four feet broad, and three feet thick; but they are so broken, that their proportions in height cannot be exactly measured. The stones which make the outward circle are seven feet broad, three feet and a half thick, and fifteen feet and a half high; each stone having two tenons mortised into the architrave continuing upon them, throughout the whole circumference. For these architraves being jointed exactly in the middle of each of the perpendicular stones, that their weight might have an equal bearing; and upon each side of the joint a tendon wrought (as remains yet to be seen) it may hence positively be concluded, that the architrave is continued round about this outward circle. The smaller stones of the inner circle are one foot and a half broad, one foot thick, and six feet high. These had no architrave upon them, but were raised perpendicular, of a pyramidal form. The stones of the greater hexagon are seven feet and a half broad, three feet and three-quarters thick, and twenty feet high, each stone having one tenon in the middle. The stones of the inner hexagon are two feet and a half broad, one foot and a half thick, and eight feet high, in form pyramidal, like those of the inner circle. The architrave lying round about upon the perpendicular stones of the outward circle, is three feet and a half broad, and two feet and a half high. The architrave on the top of the great stones of the outward hexagon, is sixteen feet long, $3\frac{3}{4}$ feet broad, and $3\frac{1}{4}$ feet high. This architrave, continuing only from stone to stone, left betwixt every two and two, a void space free to the air, uncovered. The vulgar have thought it ominous, and indeed absolutely impossible, to count the number of stones composing this ancient monument. To this legendary tale Sydney refers in his sonnet of the wonders of England, when he says,

Near Wilton sweet, huge heaps of stones are found,
But so confused, that neither any eye
Can count them just, nor reason try,
What force brought them to so unlikely ground.

In reference to this absurd superstition, Mr. Jones says, that if any one will observe the orders of the circles as they now appear, without passing from one to another confusedly, and note where he begins, he may easily find the number. Dr. Stukely computes them in the following manner: "the great oval," he says, "consists of ten uprights; the inner with the altar, of twenty; the great circle of thirty; the inner of forty; which are a hundred upright stones; five imposts of the great oval; thirty of the great circle; the two stones on the bank of the area, the stone lying within its entrance, and that standing without; and another on the ground directly opposite to the entrance of the avenue; so that the whole number is a hundred and forty." This writer observes, that, according to the intention of the founders, the whole circle of the work was to consist of thirty stones, each stone to be four cubits (a cubit being $20\frac{4}{5}$ inches English measure) broad, each interval two cubits; 30 times 2 cubits 60; and, therefore, thrice 60 cubits complete a circle, whose diameter is 60. A stone 4 cubits broad, and 2 thick, is double the interval, which is a square of 2 cubits. [*Camden. Archæl. Trans. Pantolog.*

SECTION XXII.

Tumuli; including Barrows, Cairns, Cromlechs, Kist-vaens, Logan, or Rocking-stones, and similar Monumental remains.

Several of these singular elevations of ancient times are occasionally confounded, and mistaken for each other; and we shall briefly point out their characteristic distinctions, before we enter upon a more minute account of them.

A *Barrow* is an artificial hillock or mount, common to many parts of the world, composed of earth or earths, and stones promiscuously, and containing human bones in its interior. This is sometimes made to include the next.

A *Cairn*, *Kairn*, or *Carne*, is a barrow surmounted with large stones placed irregularly, but crowned with a broad flat stone on the apex or top.

A *Cromlech* is a monument of huge, rude, broad, and oftentimes irregularly shaped, but flat stones raised upon others that are set up on end for this purpose, without any attention to the hillock, and frequently occurring on a plain or even in a hollow.

It happens at times that one or more of the horizontal stones will *rock* or move with the slightest touch, though no lever can throw them down. These are called *Rocking-stones*, and we are not without instances of them produced naturally.

The cromlech is usually found open at the sides; if it be inclosed, so as to form a kind of rude coffin or sarcophagus, it is called a *Kist-vaen*.

BARROWS.

Of these Dr. Plott takes notice of two sorts in Oxfordshire; one placed on the military ways, the other in the fields, meadows, or woods; the first fort doubtless of Roman erection, the other more probably erected by the Britons or Danes. We have an examination of the barrows in Cornwall by Dr. Williams, in the Phil. Trans. N° 458, from whose observations we find that they are composed of foreign or adventitious earth; that is, such as does not originally belong to the place, but is fetched from some distance. Monuments of this kind are also very frequent in Scotland. On digging into the barrows, urns have been found in some of them, made of calcined earth, and containing burnt bones and ashes; in others, stone chests containing bones entire; in others, bones neither lodged in chests nor deposited in urns. These tumuli are round, not greatly elevated, and generally at their bases surrounded with a foss. They are of different sizes; in proportion, it is supposed, to the greatness, rank, and power, of the deceased person. The links or sands of Skail, in Sandwich, one of the Orkneys, abound in round barrows. Some are formed of earth alone, others of stone covered with earth. In the former was found a coffin, made of six flat stones. They are too short to receive a body at full length: the skeletons found in them lie with the knees pressed to the breast, and the legs doubled along the thighs. A bag, made of rushes, has been found at the feet of some of these skeletons, containing the bones, most probably, of another of the family. In one were to be seen multitudes of small beetles; and as similar insects have been discovered in the bag which enclosed the sacred *Ibis*, we may suppose that the Egyptians, and the nation to whom these tumuli belong, might have had the same superstition respecting them. On some of the corpses interred in this island, the mode of burning was observed. The ashes deposited in the urn which was covered on the top with a flat stone, have been found in the cell of one of the barrows. This coffin or cell was placed on the ground, then covered with a heap of stones, and that again cased with earth and sods. Both barrow and contents evince them to be of a different age from the former. These tumuli were in the nature of family vaults: in them have been found two tiers of coffins. It is probable, that on the death of any one of the family, the tumulus was opened, and the body interred near its kindred bones.

Ancient Greece and Latium concurred in the same practice with the natives of this island. Patroclus among the Greeks, and Hector among the Trojans, received but the same funeral honours with our Caledonian heroes; and the ashes of Dercennus the Laurentine monarch had the same simple protection. The urn and pall of the Trojan warrior might perhaps be more superb than those of a British leader: the rising monument of each had the common materials from our mother earth.

> The snowy bones his friends and brothers place,
> With tears collected, in a golden vase.
> The golden vase in purple palls they roll'd
> Of softest texture and unwrought with gold.
> Last o'er the urn the sacred earth they spread,
> And rais'd a tomb, memorial of the dead.
>
> *Pope's Homer's Iliad*, xxiv. 1003.

Or, as it is more strongly expressed by the same elegant translator, in the account of the funeral of Patroclus;

> High in the midst they heap the swelling bed
> Of rising earth, memorial of the dead. *Ibid.* xxiii. 319.

The Grecian barrows, however, do not seem to have been all equally simple. The barrow of Alyattes, father of Crœsus king of Lydia, is described by Herodotus as a most superb monument, inferior only to the works of the Egyptians and Babylonians. It was a vast mound of earth heaped on a basement of large stones by three classes of the people; one of which was composed of girls who were prostitutes. Alyattes died, after a long reign, in the year 562 before the Christian era. Above a century intervened, but the historian relates, that to this time five stones (ουροι, *termini*, or *stelæ*) on which letters were engraved, had remained on the top, recording what each class had performed; and from the measurement it had appeared, that the greater portion was done by the girls. Strabo has likewise mentioned it as a huge mound raised on a lofty basement by the multitude of the city. The circumference was six stadia or three quarters of a mile; the height two plethra or two hundred feet; and the width thirteen plethra. It was customary among the Greeks to place on barrows either the image of some animal, or *stelæ*, commonly round pillars with inscriptions. The famous barrow of the Athenians in the plain of Marathon, described by Pausanias, is an instance of the latter usage. An ancient monument in Italy by the Appian-way, called without reason the sepulchre of the Curiatii, has the same number of *termini* as remained on the barrow of Alyattes; the basement which is square, supporting five round pyramids. Of the barrow of Alyattes the original magnitude is described by travellers as now much diminished, and the bottom rendered wider and less distinct than before, by the gradual increase of the soil below. It stands in the midst of others by the lake Gygæus; where the burying-place of the Lydian princes was situated. The barrows are of various sizes, the smaller made perhaps for children of the younger branches of the royal family. Four or five are distinguished by their superior magnitude, and are visible as hills at a great distance. That of Alyattes is greatly supereminent. The lake it is likely furnished the soil. All of them are covered with green turf; and all retain their conical form without any sinking in of the top.

Barrows, or similar tumuli, are also found in great numbers in America. These are of different sizess, according to Mr. Jefferson's account; some of them constructed of earth, and some of loose stones. That they were repositories of the dead has been obvious to all; but on what particular occasion constructed, was matter of doubt. Some have thought they covered the bones of those who have fallen in battles fought on the spot of interment. Some ascribed them to the custom said to prevail among the Indians, of collecting at certain periods the bones of all their dead, wheresoever deposited at the time of death. Others again supposed them the general sepulchres for towns, conjectured to have been on or near these grounds; and this opinion was supported by the quality of the lands in which they are found (those constructed of earth being generally in the softest and most fertile meadow grounds on river sides), and by a tradition, said to be handed down from the aboriginal Indians, that when they settled in a town, the first person who died was placed erect, and earth put about him, so as to cover and support him; that when another died, a narrow passage was dug to the first, the second reclined against him, and the cover of the earth replaced, and so on.—"There being one of these barrows in my neighbourhood (says Mr. Jefferson), I wished to satisfy myself whether any, and which of these opinions were just. For this purpose I determined to open and examine it thoroughly. It was situated on the low grounds of the Rivanna, about two miles above its principal fork, and opposite to some hills, on which had been an Indian town. It was of a spheroidical form, of about 40 feet diameter, at the base, and had been of about 12 feet altitude, though now reduced by the plough to seven and a half, having been under cultivation about a dozen years. Before this it was covered with trees of 12 inches diameter, and round the base was an excavation of five feet depth and width, from whence the earth had been taken of which the hillock was formed. I first dug superficially in several parts of it, and came to collections of human bones, at different depths, from six inches to three feet below the surface. These were lying in the utmost confusion, some vertical, some oblique, some horizontal, and directed to every point of the compass, entangled, and held together in clusters by the earth. Bones of the most distant parts were found together; as, for instance, the small bones of the foot in the hollow of the skull, many skulls would sometimes be in contact, lying on the face, on the side, on the back, top or bottom, so as on the whole to give the idea of bones emptied promiscuously from a bag or basket, and covered over with earth, without any attention to their order. The bones of which the greatest numbers remained, were skulls, jaw-bones, teeth, the bones of the arms, the thighs, legs, feet, and hands. A few ribs remained, some vertebræ of the neck and spine, without their processes, and one instance only of the bone which serves as a base to the vertebral column. The skulls were so tender, that they generally fell to pieces on being touched. The other bones were stronger. There were some teeth which were judged to be smaller than those of an adult: a skull which, on a slight view, appeared to be that of an infant, but it fell to pieces on being taken out, so as to prevent satisfactory examniation; a rib, and a fragment of the under-jaw of a person about half-grown; another rib of an infant; and part of the jaw of a child, which had not yet cut its teeth. The last furnishing the most decisive proof of the burial of the children here, I was particular in my attention to it. It was part of the right half of the under-jaw. The processes by which it was articulated to the temporal bones were entire; and the bone itself firm to where it had been broken off, which, as nearly as I could judge, was about the place of the eye tooth. Its upper edge, wherein would have been the sockets of the teeth, was perfectly smooth. Measuring it with that of an adult, by placing their hinder processes together, its broken end extended to the penultimate grinder of the adult. This bone was white, all the others of a sand colour. The bones of infants being soft, they probably decay sooner, which might be the case so few were found here. I proceeded then to make a perpendicular cut through the body of the barrow, that I might examine its internal structure. This passed about three feet from its centre, was opened to the former surface of the earth, and was wide enough for a man to walk through and examine its sides. At the bottom, that is on the level of the circumjacent plain, I found bones; above these a few stones, brought from a cliff a quarter of a mile off, and from the river one-eighth of a mile off; then a large interval of earth, then a stratum of bones, and so on. At one end of the section were four strata of bones plainly distinguishable; at the other, three; the strata in one part not ranging with those in another. The bones nearest the surface were least decayed. No holes were discovered in any of them, as if made with bullets, arrows, or other weapons. I conjectured that in this barrow might have been a thousand skeletons. Every one will readily seize the circumstances above related, which militate against the opinion that it covered the bones only of persons fallen in battle; and against the tradition also which would make it the common sepulchre of a town, in which the bodies were placed upright, and touching each other. Appearances certainly indicate that it has derived both origin and growth from the accustomary collection of bones, and deposition of them together; that the first collection had been deposited on the common surface of the earth, a few stones put over it, and then a covering of earth; that the second had been laid on this, had covered more or less of it in proportion to the number of bones, and was then also covered with earth, and so on. The following are the particular circumstances which give it this aspect. 1, The number of bones. 2. Their confused position. 3. Their being in different strata. 4. The strata in one part having no correspondence with those in another. 5. The different states of decay in these strata, which seem to indicate a difference in the time of inhumation. 6. The existence of infant bones among them. But on whatever occasion they may have been made, they are of considerable notoriety among the Indians: for a party passing, about thirty years ago, through the part of the country where this barrow is, went through the woods directly to it, without any instructions or enquiry; and having staid about it some time, with expressions which were construed to be those of sorrow, they returned to the high road, which they had left about half a dozen miles to pay this visit, and pursued their journey. There is another barrow, much resembling this in the low grounds of the south branch of Shenandoah, where it is crossed by the road leading from Rock-fish gap to Staunton. Both of these have, within these dozen years, been cleared of their trees and put under cultivation, are much reduced in their height, and spread in width, by the plough, and will probably disappear in time. There is another on a hill in the Blue ridge of mountains, a few miles north of Wood's gap, which is made up of small stones thrown together. This has been opened and found to contain human bones as the others do. There are also many others in other parts of the country."

CAIRNS.

These are to be seen in many places of Britain, particularly Scotland and Wales. They are composed of stones of all dimensions thrown together in a conical form, a flat stone crowning the apex.

Various causes have been assigned by the learned for these heaps of stones. They have supposed them to have been, in times of inauguration, the places where the chieftain elect stood to show himself to the best advantage to the people; or the place from whence judgement was pronounced; or to have been erected on the road side in honour of Mercury; or to have been formed in memory of solemn compact, particularly where accompanied by standing pillars of stones; or for the celebration of certain religious ceremonies. Such might have been the reasons, in some instances, where the evidences of stone chests and urns are wanting; but these are so generally found that they seem to determine the most usual purpose of the piles in question to have been for sepulchral monuments. Even this destination might render them suitable to other purposes; particularly religious, to which by their nature they might be supposed to give additional solemnity. According to Toland, fires were kindled on the tops of flat stones, at certain times of the year, particularly on the eves of the 1st of May and the 1st of November, for the purpose of sacrificing; at which time all the people having extinguished their domestic hearths rekindled them from the sacred fires of the cairns. In general, therefore, these accumulations appear to have been designed

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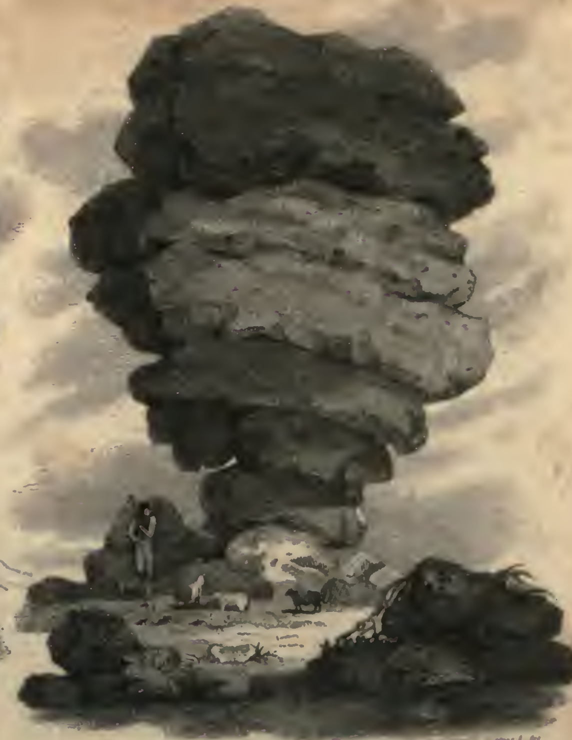
CROMLECH AT LAYON, CORNWALL.


CHEESE-WRING, CORNWALL.

for the sepulchral protection of heroes and great men. The stone chests, the repository of the urns and ashes, are lodged in the earth beneath: sometimes only one, sometimes more, are found thus deposited; and Mr. Pennant mentions an instance of 17 being discovered under the same pile.

Cairns are of different sizes, some of them very large. Mr. Pennant describes one in the island of Arran, 114 feet over, and of a vast height. They may justly be supposed to have been proportioned in size to the rank of the person, or to his popularity: the people of a whole district assembled to show their respect to the deceased; and, by an active honouring of his memory, soon accumulated heaps equal to those that astonish us at this time. But these honours were not merely those of the day, as long as the memory of the deceased endured, not a passenger went by without adding a stone to the heap: they supposed it would be an honour to the dead, and acceptable to his manes.

> Quanquam festinas, non est mora longa: licebit,
> Injecto ter pulvere, curras.

To this monument there is a proverbial expression among the highlanders allusive to the old practice; a suppliant will tell his patro, *Curri mi cloch er do charne*, "I will add a stone to your cairn;" meaning, When you are no more, I will do all possible honour to your memory.

Cairns are to be found in all parts of our islands, in Cornwall, Wales, and all parts of North Britain; they were in use among the northern nations. In Wales they are called *carneddau;* but the proverb taken from them there, is not of the complimental kind: *Karn ar dy ben*, or, "A cairn on your head," is a token of imprecation.

CROMLECHS.

This kind of ancient monument, consists, as we have already observed, of huge, broad, flat stones, raised upon other stones set upon end for that purpose.

These monuments are spoken of largely by Mr. Rowland, by Dr. Borlase, and by Wormius, under the name of *Ara* or altar. Mr. Rowland, however, is divided in his opinion; for he partly inclines to the notion of their having been altars, partly to their having been sepulchres: he supposes them to have been originally tombs, but that in after times sacrifices were performed upon them to the heroes deposited within. Mr. Keiller preserves an account of King Harold having been interred beneath a tomb of this kind in Denmark, and Mr. Wright discovered in Ireland a skeleton deposited under one of them. The great similarity of the monuments throughout the north, Mr. Pennant observes, evinces the same religion to have been spread in every part, perhaps with some slight deviations. Many of these monuments are both British and Danish; for we find them where the Danes never penetrated.

The cromlech, or cromlch, chiefly differs from the *Kist-vaen*, in not being closed up at the end and sides, that is, in not so much partaking of the chest-like figure; it is also generally of larger dimensions, and sometimes consists of a greater number of stones; the terms *cromleh* and *kist-vaen* are however indiscriminately used for the same monument. The term *cromlech* is by some derived from the Armoric word *crum*, "crooked or bowing," and *leh* "stone," alluding to the reverence which persons paid to them by bowing. Rowland derives it from the Hebrew words *caremluach*, signifying a "devoted or consecrated stone." They are called by the vulgar *coetne Arthor*, or *Arthur's quoits*, it being a custom in Wales as well as Cornwall to ascribe all great or wonderful objects to Prince Arthur, the hero of those countries.

ROCKING STONES—LOGAN ROCKS.

Of these stones the ancients give us some account. Pliny says, that at Harpasa, a town of Asia, there was a rock of such a wonderful nature, that if touched with the finger it would shake, but could not be moved from its place with the whole force of the body. Ptolemy Hephestion mentions a gygonian stone near the ocean, which was agitated when struck by the stalk of an asphodel, but could not be removed by a great exertion of force. The word *gygonius* seems to be Celtic; for *gwingog* signifies *motitans*, the rocking-stone.

Many rocking stones are to be found in different parts of this island; some natural, others artificial, or placed in their position by human art. In the parish of St. Leven, Cornwall, there is a promontory called *Castle Treryn*. On the western side of the middle group, near the top, lies a very large stone, so evenly poised that any hand may move it from one side to another; yet it is so fixed on its base, that no lever nor any mechanical force can remove it from its present situation. It is called the *Logan stone*, and it is such a height from the ground that no person can believe that it was raised to its present position by art. But there are other rocking stones, which are so shaped and so situated, that there can be no doubt but that they were erected by human strength. Of this kind Borlase thinks the great *Quoit* or *Karn-lehau*, in the parish of Tywidnek, to be. It is 39 feet in circumference, and four feet thick at a medium, and stands on a single pedestal. There is also a remarkable stone of the same kind in the island of St. Agnes in Scilly. The under rock is 10 feet six inches high, 47 feet round the middle, and touches the ground with no more than half its base. The upper rock rests on one point only, and is so nicely balanced, that two or three men with a pole can move it. It is eight feet six inches high, and 47 in circumference. On the top there is a bason hollowed out, three feet eleven inches in diameter at a medium, but wider at the brim, and three feet deep. From the globular shape of this upper stone, it is highly probable that it was rounded by human art, and perhaps even placed on its pedestal by human strength. In Sithney parish, near Helston, in Cornwall, stood the famous logan, or rocking stone, commonly called *Men Amber*, q. d. *Men an Bar*, or the *top-stone*. It was eleven feet by six, and four high, and so nicely poised on another stone that a little child could move it, and all travellers who came this way desired to see it. But Shrubsall, Cromwell's governor of Pendennis, with much ado caused it to be undermined, to the great grief of the country. There are some marks of the tool on it, and by its quadrangular shape, it was probably dedicated to Mercury.

That the rocking stones are monuments erected by the Druids cannot be doubted; but tradition has not informed us for what purpose they were intended. Mr. Toland thinks that the Druids made the people believe that they alone could move them, and that by a miracle; and that by this pretended miracle they condemned or acquitted the accused, and brought criminals to confess what could not otherwise be extorted from them. How far this conjecture is right we shall leave to those who are deeply versed in the knowledge of antiquities to determine.

[*Encyclopedia Britannica.*

CHAP. VI.

NAVAL ARCHITECTURE.

SECTION I.

Ark of Noah.

The formation of this wonderful structure is undoubted in the Jewish, Christian, and Mahommedan world: yet its dimensions far exceed any vessel of modern date of the most extensive range, and appear to have been equally unrivalled in ancient times.

There are nevertheless various difficulties which have been proposed in regard to it among those by whom its existence has been admitted. One question is as to the time employed by Noah in building it. Interpreters generally believe, that he was an hundred and twenty years; but some allow him only fifty-two years; some no more than seven or eight, and others still much less. The Mahommedans say he had but two years allowed him for this work. Another question is, what kind of wood is meant by gopher wood? Some think cedar, or box, others cypress, the pine, fir-tree, and the turpentine tree. Pelletier prefers the opinion of those who hold the ark made of cedar: the reasons are, the incorruptibility of that wood; the great plenty thereof in Asia, whence Herodotus and Theophrastus relate, that the kings of Egypt and Syria built whole fleets of it in lieu of deal: and the common tradition throughout the East imports, that the ark is preserved entire to this day on mount Ararat.

The dimensions of the ark, as delivered by Moses, are three hundred cubits in length, fifty in breadth, and thirty in height; which, compared with the great number of things it was to contain, seem to many to have been too scanty. And hence an argument has been drawn against the authority of the relation. Celsus long ago laughed at it, calling it κεϐωτον αλλοκοτον, *the absurd ark.* This difficulty is solved by Buteo and Kircher, who, supposing the common cubit of a foot and a half, prove geometrically, that the ark was abundantly sufficient for all the animals supposed to be lodged therein. The capacity of the ark will be doubled, if we admit, with Cumberland, &c. that the Jewish cubit was 21.888 inches.—Snellius computes the ark to have been above half an acre in area. Cuneus, and others, have also calculated the capacity of the ark.—Dr. Arbuthnot computes it to have been 81062 tuns.—Father

Lamy says, that it was an hundred and ten feet longer than the church of St. Mary at Paris, and sixty-four feet narrower; to which his English translator adds, that it must have been longer than St. Paul's church in London, from west to east, broader than that church is high in the inside, and about fifty-four feet in height of our measure.

The things contained in the ark were, besides eight persons of Noah's family, one pair of every species of unclean animals, and seven pair of every species of clean animals, with provisons for them all, during the whole year.—The former appears, at first view, almost infinite: but if come to a calculus, the number of species of animals will be found much smaller than is generally imagined; out of which, in this case, are to be excepted such animals as can live in the water; and Bishop Wilkins imagines, that only seventy-two of the quadruped kind needed a place in the ark.

It appears to have been divided into three stories; and it is agreed on, as most probable, that the lowest story was destined for the beasts, the middle for the food, and the upper for the birds, with Noah and his family; each story being subdivided into different apartments, stalls, &c. Though Josephus, Philo, and other commentators, add a kind of fourth story, under all the rest; being, as it were, the hold of the vessel, to contain the ballast, and receive the filth and fæces of so many animals.

Drexelius makes three hundred apartments; father Fournier, three hundred and three; the anonymous author of the Questions on Genesis, four hundred; Buteo, Temporarius, Arias Montanus, Wilkins, Lamy, and others, suppose as many partitions as there were different sorts of animals.—Pelletier only makes seventy-two, viz. thirty-six for the birds, and as many for the beasts: his reason is, that if we suppose a greater number, as three hundred and thirty-three, or four hundred, each of the eight persons in the ark must have had thirty-seven, forty-one, or fifty stalls to attend and cleanse daily, which he thinks impossible. But there is not much in this; to diminish the number of stalls, without a diminution of the animals, is vain; it being, perhaps, more difficult to take care of three hundred animals in seventy-two stalls, than in three hundred.

Buteo computes, that all the animals contained in the ark could not be equal to five hundred horses; he even reduces the whole to the dimensions of fifty-six pair of oxen. Father Lamy enlarges it to sixty-four pair, or an hundred and twenty-eight oxen; so that supposing one ox equal to two horses, if the ark had room for two hundred and fifty-six horses, there must have been room for all the animals. And the same author demonstrates, that one floor of it would suffice for five hundred horses, allowing nine square feet to an horse.

As to the food in the second story, it is observed by Buteo from Columella, that thirty or forty pounds of hay ordinarily suffices an ox for a day; and that a solid cubit of hay, as usually pressed down in our hay-ricks, weighs about forty pounds; so that a square cubit of hay is more than enough for one ox one day.—Now it appears that the second story contained 150,000 solid cubits; which, divided between two hundred and six oxen, will afford each more hay by two thirds than he can eat in a year.

Bishop Wilkins computes all the carnivorous animals equivalent, as to the bulk of their bodies, and their food, to twenty-seven wolves; and all the rest to two hundred and eighty beeves. For the former he allows the sustenance of 1825 sheep, and for the latter 109,500 cubits of hay: all which will be easily contained in the two first stories, and much room to spare.—As to the third story, nobody doubts of its being sufficient for the fowls, with Noah, his sons and daughters.

Upon the whole, the learned bishop remarks, that of the two, it appears much more difficult to assign a number and bulk of necessary things to answer the capacity of the ark, than to find sufficient room for the several species of animals already known to have been there.—This he attributes to the imperfection of our lists of animals, especially those of the unknown parts of the earth; adding, that the most expert mathematician, at this day, could not assign the proportions of a vessel better accommodated to the purpose, than is here done; and hence finally concludes, that "the capacity of the ark, which had been made an objection against scripture, ought to be esteemed a confirmation of its divine authority; since, in those ruder ages, men, being less versed in arts and philosophy, were more obnoxious to vulgar prejudices than now; so that, had it been an human invention, it would have been contrived according to those wild apprehensions which arise from a confused and general view of things; as much too big, as it has been represented too little."

[*Wilkins. Le Pelletier. Calmet.*

SECTION II.

Galley of Hiero.

It is to Hiero that Syracuse was indebted for those amazing machines of war, which the Syracusians made use of when besieged by the Romans. The public buildings, such as palaces, temples, arsenals, &c. which were erected in Syracuse by his order, and under the direction of Archimedes, were the greatest ornaments of that stately metropolis. He caused also an infinite number of ships to be built for the exportation of corn, in which the whole riches of the island consisted. We are told of a galley built by his order, which was looked upon as one of the wonders of that age. Archimedes, who was overseer of the work, spent a whole year in finishing it, Hiero daily animating the workmen with his presence. This ship had twenty benches of oars, three spacious apartments, and all the conveniencies of a large palace. The floors of the middle apartment were all inlaid, and represented in various colours the stories of Homer's Iliad. The cielings, windows, and all other parts, were finished with wonderful art, and embellished with all kinds of ornaments. In the uppermost apartment there was a spacious gymnasium, or place of exercise, and walks, with gardens and plants of all kinds, disposed in wonderful order. Pipes, some of hardened clay, aud others of lead, conveyed water all around to refresh them. But the finest of the apartments was that of Venus, the floors being inlaid with agats, and other precious stones, the inside lined with cypress-wood, the windows adorned with ivory, paintings, and small statues. In this apartment there was a library, and a bath with three great coppers, and a bathing vessel made of one single stone of various colours, and containing two hundred and fifty quarts. It was supplied with water from a great reservoir at the head of the ship, which held an hundred thousand quarts. The vessel was adorned on all sides with fine paintings, and had eight towers of equal dimensions, two at the head, two at the stern, and four in the middle. Round these towers were parapets, whence stones might be discharged against the enemy's vessels when they approached. Each tower was constantly guarded by four young men completely armed, and two archers. To the side of the vessel was fastened an engine made by Archimedes, which threw a stone of three hundred weight, and an arrow of eighteen feet, the distance of a stadium, or an hundred and twenty-five feet. Though the hold of this vessel was exceeding deep, a single man could soon clear it of water with a machine invented for that purpose by Archimedes. An Athenian poet having composed some verses on this magnificent vessel, Hiero, who understood the value of verse, rewarded him with a thousand medimni, that is, six thousand bushels of wheat, which he caused to be carried to the Pyreæus, or port of Athens. Hiero made afterwards a present of this great vessel to Ptolemy, probably Philadelphus, king of Egypt, and sent it to Alexandria. As there was at that time a great famine in Egypt, good king Hiero sent along with it several other ships of less burden with three hundred thousand quarters of corn, ten thousand great earthen jars of salt fish, twenty thousand quintals of salt meat, and an immense quantity of other provisions. [*Anc. Univ. Hist.*

SECTION III.

Xerxes's Bridge of Boats over the Hellespont.

Xerxes, having resolved to attack Greece, that he might omit nothing which could contribute to the success of his undertaking, entered into an alliance with the Carthagenians, who were, at that time, the most powerful people of the west; whereby it was agreed, that, while the Persians invaded Greece, the Carthaginians should fall upon the Greek colonies in Sicily and Italy, and thereby they might be diverted from helping each other. The Carthaginians appointed Hamilcar their general, who not only raised what forces he could in Afric, but, with the money sent him by Xerxes, hired a great many mercenaries in Spain, Gaul, and Italy; so that his army consisted of three hundred thousand men, besides a proportionable number of ships for transporting his forces, and the necessary provisions. And thus Xerxes, agreeable to the prophecy of Daniel, having, by his strength through his riches, stirred up all the nations of the then known world against the realm of Greece, that is, all the west under the command of Hamilcar, and all the east under his own banners, set out from Susa, to enter upon this war, in the fifth year of his reign, after having spent three years in making vast preparations throughout all the provinces of his wide, spreading empire. From Susa he marched to Sardis, which was the place appointed for the general rendezvous of all his land forces, while his navy advanced along the coasts of Asia Minor towards the Hellespont.

Two things Xerxes commanded to be done before he came to the sea side; the one was a passage to be cut through mount Athos. This mountain reaches a great way into the sea, in the form of a peninsula, and is joined to the land by an isthmus twelve furlongs over. The sea, in this place, is very tempestuous, and the Persian fleet had formerly suffered shipwreck in doubling this promontory. To prevent the like disaster, Xerxes caused a passage to be cut through the mountain, broad enough to let two galleys, with three banks of oars each, pass in front. By this means he severed from the continent the cities of Dion, Olophyxus, Acrothoon, Thysus, and Cleone. It is said however, that Xerxes undertook this enterprize only out of ostentation, and to perpetuate the memory of his name, since he might, with far less trouble, have caused his fleet to be conveyed over the isthmus, as was the practice in those days.

He likewise commanded a bridge of boats to be laid over the Hellespont, for the passing of his forces from Asia into Europe. The sea which separates Sestos and Abydus, where the bridge was built, is seven furlongs over. The work was carried on with great expedition by the Phœnicians and Egyptians, who had no sooner finished it, but a violent storm arising, broke it in pieces, and dispersed or dashed against the shore the vessels of which it was composed: which when Xerxes heard, he fell into such a violent transport of anger, that he commanded three hundred stripes to be inflicted on the sea, and a pair of fetters to be thrown into it, injoining those who were trusted with the execution of his orders, to pronounce these words: "Thou salt and bitter element, thy master has condemned thee to this punishment, for offending him without cause; and is resolved to pass over thee, in spite of thy billows, and insolent resistance." The extravagant folly and madness of this prince did not stop here; he commanded the heads of those who had the direction of the work to be struck off.

In their room he appointed more experienced architects to build two other bridges, one for the army, the other for the beasts of burden, and the baggage. When the whole work was completed, and the vessels which formed the bridges secure against the violence of the winds, and the current of the water, Xerxes departed from Sardis, where the army had wintered, and directed his march to Abydus. When he arrived at that city, he desired to see all his forces together; and, to that end, ascending a stately edifice of white stone, which the Abydenians had built, on purpose to receive him in a manner suitable to his greatness, he had a free prospect to the coast, seeing at one view both his fleet and land forces. The sea was covered with his ships, and the large plains of Abydus with his troops, quite down to the shore. While he was surveying the vast extent of his power, and deeming himself the most happy of mortals, his joy being all on a sudden turned into grief, he burst out into a flood of tears; which Artabanus perceiving, asked him, what had made him, in a few moments, pass from an excess of joy to so great a grief. The king replied, that, considering the shortness of human life, he could not restrain his tears; for, of all these numbers of men, not one, said he, will be alive an hundred years hence. Artabanus, who neglected no opportunity of instilling into the young prince's mind sentiments of kindness towards his people, finding him touched with a sense of tenderness and humanity, endeavoured to make him sensible of the obligation that is incumbent upon princes, to alleviate the sorrows, and sweeten the bitterness, which the lives of their subjects are liable to, since it is not in their power to prolong them. In the same conversation, Xerxes asked his uncle, whether, if he had not seen the vision which made him change his mind, he would still persist in the same opinion, and dissuade him from making war upon Greece. Artabanus sincerely owned, that he still had his fears, and was very uneasy concerning two things, the sea and the land; the sea, because there were no port capable of receiving and sheltering such a fleet, if a storm should arise; the land, because no country could maintain so numerous an army. The king was very sensible of the strength of his reasoning; but as it was now too late to go back, he made answer, that, in great enterprizes, men ought not to enter into so nice a discussion of all the inconveniencies that may attend them: that bold and daring undertakings, though subject to many evils and dangers, are preferable to inaction, however safe: that great successes are no otherwise to be obtained than by venturing boldly; and that, if his predecessors had observed such scrupulous and timorous rules of politics, the Persian empire would never have attained to so high a degree of glory and grandeur.

All things being now in readiness, and a day appointed for the passing over of the army, as soon as the first rays of the sun began to appear, all sorts of perfumes were burnt upon the bridge, and the way strewed with myrtle. At the same time, Xerxes, pouring a libation into the sea out of a golden cup, and addressing the sun, implored the assistance of that deity, begging that he might meet with no impediment so great as to hinder him from carrying his conquering arms to the utmost limits of Europe. This done he threw the cup into the Hellespont, with a golden bowl, and a Persian scymitar; and the foot and horse began to pass over that bridge, which was next to the Euxine, while the carriages and beasts of burden passed over the other, which was placed nearer the Ægean sea. The bridges were boarded, and covered over with earth, having rails on each side, that the horses and cattle might not be frightened at the sight of the sea. The army spent seven days and nights in passing over, though they marched day and night, without intermission, and were, by frequent blows, obliged to quicken their pace. At the same time, the fleet made to the coasts of Europe. After the whole army was passed, Xerxes advanced with his land forces, through the Thracian Chersonesus to Doriscus, a city at the mouth of the river Hebrus, in Thrace: but the fleet steered a quite different course, standing to the westward for the promontory of Sarpedon, where they were commanded to attend farther orders. Xerxes, having encamped in the large plains of Doriscus, and judging them convenient for reviewing and numbering his troops, dispatched orders to his admirals to bring the fleet to the adjacent shore, that he might take an account both of his sea and land forces. His land army, upon the muster, was found to consist of one million seven hundred thousand foot, and fourscore thousand horse; which, together with twenty thousand men that conducted the camels, and took care of the baggage, amounted to one million eight hundred thousand men. His fleet consisted of twelve hundred and seven large ships, and three thousand gallies and transports: on board all these vessels, there were found to be five hundred and seventeen thousand six hundred and ten men. So that the whole number of sea and land forces, which Xerxes led out of Asia to invade Greece, amounted to two millions three hundred and seventeen thousand six hundred and ten men. We are told, that, on his passing the Hellespont, to enter Europe, an inhabitant of that country cried out: "O Jupiter, why art thou come to destroy Greece, in the shape of a Persian, and under the name of Xerxes, with all mankind following thee; whereas thy own power is sufficient to do this, without their assistance?" After he had entered Europe, the nations on this side the Hellespont that submitted to him, added to his land forces three hundred thousand more, and two hundred and twenty ships to his fleet, on board of which were twenty-four thousand men. So that the whole number of his forces, when he arrived at Thermopylæ, was two millions six hundred and forty-one thousand six hundred and ten men, without including servants, eunuchs, women, sutlers, and other people of that sort, who were computed to equal the number of the forces: so that the whole multitude of persons that followed Xerxes in this expedition, amounted to five millions two hundred and eighty-three thousand two hundred and twenty. Among these millions of men, there was not one that could vie with Xerxes, either in comeliness or stature, or that seemed more worthy of that great empire. But this is a poor commendation, when it is not accompanied with other qualifications. Accordingly, Justin, after he has mentioned the number of his troops, emphatically concludes, "but this vast body wanted a head." Besides the subordinate generals of each nation, who commanded the troops of their respective countries, the whole army was under the command of six Persian generals; viz. Mardonius, the son of Gobryus; Triatatœchmes, the son of Artabanus; Smerdones, the son of Otanes (the two latter were cousins to Xerxes); Masistus, the son of Darius by Atossa; Gerges, the son of Ariazus; and Megabyzus, the son of the celebrated Zopyrus. The ten thousand Persians, who were called the Immortal Band, obeyed no other commander but Hydarnes. The fleet was commanded by four Persian admirals: and likewise the cavalry had their particular generals and commanders. [*Anc. Univ. Hist.*

SECTION IV.

Spectacle of a Sea-fight at Rome.

Augustus, to divert his mind from fixing on his domestic misfortunes, exhibited the most magnificent and expensive shews that had ever been seen at Rome. Chariot races in the Circus, representations on the stage, combats by gladiators, &c. were now become common. Augustus, therefore, the better to divert both himself and the people, revived these sports, which had been for a considerable time laid aside, on account of the extraordinary charges that attended them. He caused a canal to be dug eighteen hundred paces in length, and two hundred in breadth, conveying into it the Flaminian water, and building scaffolds quite round it, capable of holding numberless multitudes of spectators. And indeed the concourse of people was so great, that the emperor was obliged to place guards in all quarters of the city, lest the thieves should lay hold of that opportunity to plunder the empty and abandoned houses. Augustus had frequently entertained the people with fights of lions, tygers, elephants, rhinoceroses, &c. but now the new canal appeared all on a sudden covered with crocodiles, of which thirty-six were killed by Egyptians brought from the banks of the Nile for that purpose. The multitude were highly delighted by this sight, which was quite new; but the sea-fight, which ensued, afforded them still greater diversion. For, at the opposite ends of the lake or canal, two fleets appeared, the gallies one being built after the Greek, and those of the other after the Persian, manner. Both fleets engaged; and, as they fought in good earnest, most of the combatants being persons sentenced to death, the battle proved very bloody. [*Anc. Univ. Hist.*

CHAP. VII.

BRIDGES AND LIGHT-HOUSES.

SECTION I.

Bridges most curious or interesting.

A BRIDGE is the work of carpentry or masonry, built on a river, canal, or the lake. for the convenience of passing from one side to the other; and may be considered as a road over water, supported by one or more arches, and these again supported by proper piers or buttments. Besides these essential parts, may be added the paving at top, the banquet, or raised footway, on each side, leaving a sufficient breadth in the middle for horses and carriages, also the parapet wall either with or without a balustrade, or other ornamental and useful parts. The breadth of a bridge for a great city should be such, as to allow an easy passage for three carriages and two horsemen abreast in the middle way, and for three foot passengers in the same manner on each banquet: but for other smaller bridges a less breadth.

The conditions required in a bridge are, that it be well designed, commodious, durable, and suitably decorated. It should be of such a height as to be quite convenient for the passage over it, and yet easily admitting through its arches the vessels that navigate upon it, and all the water, even at high tides and floods: the neglect of this precept has been the ruin of many bridges. Bridges are commonly continued in a straight direction perpendicular to the stream; though some think they should be made convex towards the stream, the better to resist floods, &c. And bridges of this sort have been executed in some places, as Pont St. Esprit, near Lyons. Again, a bridge should not be made in too narrow a part of a navigable river, or one subject to tides or floods; because, the breadth being still more contracted by the piers, this will increase the depth, velocity, and fall of the water under the arches, and endanger the whole bridge and navigation. There ought to be an uneven number of arches, or an even number of piers; both that the middle of the stream or chief current may flow freely without the interruption of a pier; and that the two halves of the bridge, by gradually rising from the ends to the middle, may there meet in the highest and largest arch; and also, that by being open in the middle, the eye in viewing it, may look directly through there. When the middle and ends are of different heights, their difference however ought not to be great in proportion to the length, that the ascent and descent may be easy; and in that case also it is more beautiful to make the top in one continued curve, than two straight lines forming an angle in the middle. Bridges should rather be of few and large arches than of many smaller ones, if the height and situation will possibly allow of it; for this will leave more free passage for the water and navigation, and be a great saving in materials and labour, as there will be fewer piers and centres, and the arches, &c. will require less materials; a remarkable instance of which appears in the difference between the bridges of Westminster and Blackfriars, the expence of the former being more than double the latter.

For the proper execution of a bridge, and making an estimate of the expence, &c., it is necessary to have three plans, three sections, and an elevation. The three plans are so many horizontal sections, viz. first a plan of the foundation under the piers, with the particular circumstances attending it, whether of gratings, planks, piles, &c.; the second is the plan of the piers and arches; and the third is the plan of the superstructure, with the paved road and banquet. The three sections are vertical ones, the first of them a longitudinal section from end to end of the bridge, and through the middle of the breadth; the second a transverse one, or across it, and through the summit of an arch; and the third also across, but taken upon a pier. The elevation is an orthographic projection of one side or face of the bridge, or its appearance as viewed at a distance, shewing the exterior aspect of the materials, with the manner in which they are disposed, &c.

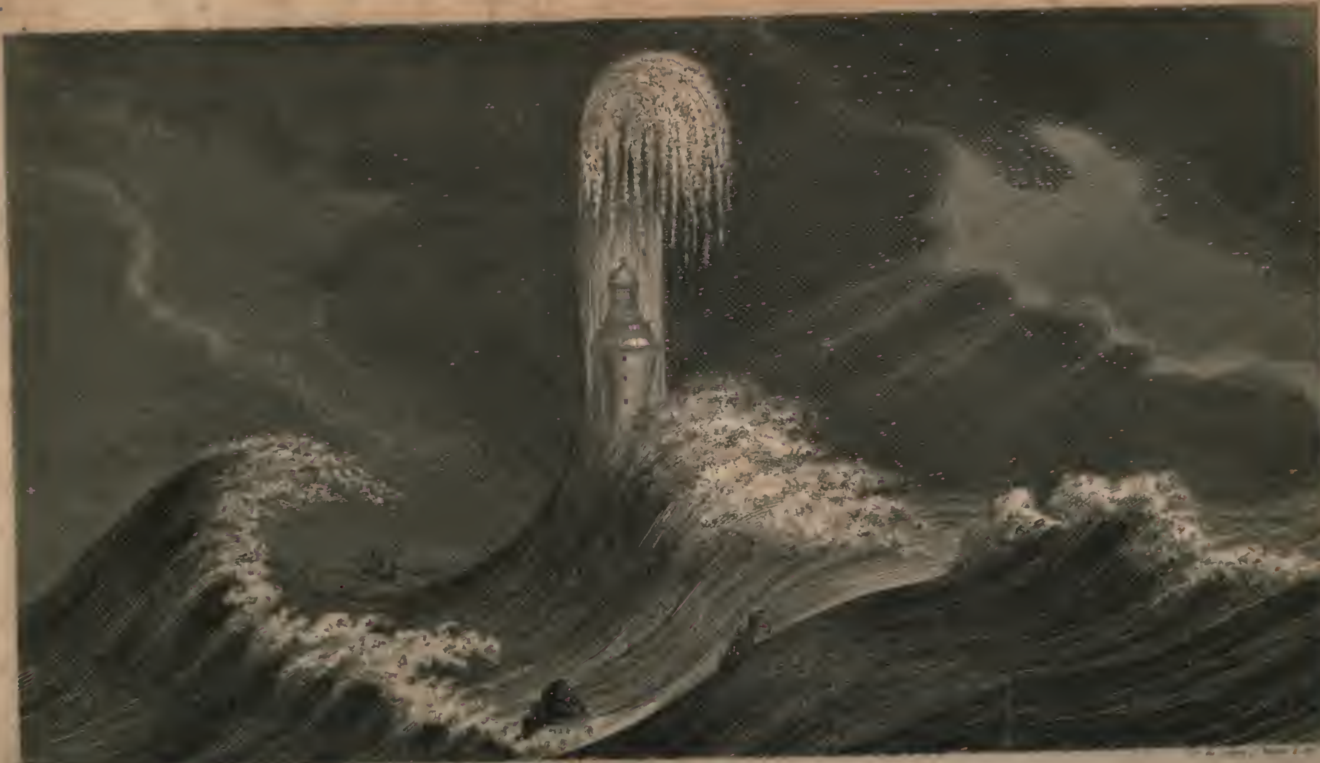
In the construction of stone bridges many difficulties must be encountered, particularly those of laying foundations and walling under water; these are best overcome by means of the coffer-dam. A due regard must be paid to the size and shape of the arch, and the magnitude of the pier. Much information on these subjects may be obtained from the works of Alberti, Gautier, Blonde Rio, Palladio, Labelye, Perronet, and the ingenious and useful treatises of Dr. Hutton and M. Bassuet.

The chief foreign bridges are, the bridge of Trajan, over the Danube, the bridge of Avignon, the Pont de Garde, in France, the bridge at Munster, in Bothnia, the aqueduct bridge of Alcantara, near Lisbon, and the Rialto of Venice. There are nearly 500 bridges of different sizes over the canals at Venice. The Rialto, the principal of these, is esteemed a master-piece of art: it consists of one flat and bold arch, nearly 100 feet span, and only 23 feet high above the water, and was built in 1588,—1591, after a design by Michael Angelo. The breadth of the bridge, which is 43 feet, is divided by two rows of shops, into three narrow streets, that in the middle being the widest; and there is in the centre an open archway, by which the three streets communicate with one another. At each end of the Rialto, is an ascent of 56 steps: the view from its summit is very lively and magnificent. The whole exterior of the shops and of the bridge is of marble. The foundation extends 90 feet, and rests upon 12,000 elm piles. This structure cost the republic 250,000 ducats.

We have many bridges of considerable note in our own country: such is the bridge at York, whose master arch in the middle, is 82 feet and a half in the clear wide, and 27 feet high. Rochester bridge is built in the same style with that of London; it is 550 feet long, and consists of 11 arches, the biggest of which is more than 50 feet. The two middle arches of this fine old bridge have been recently thrown into one by that skilful and scientific architect Mr. Daniel Alexander. The bridge of Blenheim consists of three arches, the chief of which spans $101\frac{1}{2}$ feet. There is a bridge over the river Don, near Old Aberdeen, very much celebrated, in the taste and on the plan of the Rialto, at Venice. There is also in the same style, a very remarkable bridge in Wales, built by William Edwards, a country mason, over the River Taaf, near Caerphilly in Glamorganshire. It is no more than eight feet broad, but consists of a single arch no less than 140 feet wide, part of a circle of 175 feet diameter, so as to make the altitude 35 feet. The arch of this bridge is between 40 and 50 feet wider than the celebrated Rialto of Venice, In order to lessen the quantity of matter in the abutments pressing upon the arch, and thereby to bring it to an equipoise with that in the crown, Edwards contrived three circular arches in the abutments; which pass through from side to side like round windows, and gradually decrease in the ascent.

The longest bridge in England is that over the Trent, at Burton, built by Bernard, abbot of Burton, in the twelfth century; it is all of squared free-stone, strong and lofty, 1545 feet in length, and consisting of 34 arches. Yet this comes far short of the wooden bridge over the Drave, which, according to Dr. Brown, is at least five miles long.

The triangular bridge at Croyland, in Lincolnshire, which was erected about the year 860, is said to be the most ancient gothic structure remaining entire in the kingdom. There are two circumstances, in the construction of this bridge which render it an object of great curiosity. First, it is formed by three semi-arches, whose bases stand in the circumference of a circle, at equal distances from each other: these unite at the top, and the *tri une* nature of the structure has led some to imagine it was intended as an emblem of the Trinity. Secondly, the ascent on each of the semi-arches is by steps paved with small stones, and is so steep that none but foot passengers can go over the bridge: horsemen and carriages frequently pass under it, as the river in that place is but shallow. For what purpose this bridge was really designed, it is difficult, if not impossible to determine. Utility, it is obvious, was one of the least motives to its erection. To boldness of design, and singularity of construction, it has more powerful claims; and these qualities it must be allowed to possess in as great a degree as any bridge in Europe. London bridge consists of 20 locks or arches, whereof 19 are open, and one filled up or obscured; it is 900 feet long, 60 high, and 74 broad, and almost 20 feet aperture in each arch. It is supported by 18 piers or solids, from 34 to 25 feet thick; so that the greatest water-way, when the tide is



EDYSTONE LIGHT HOUSE
after a Storm

above the sterlings, is 450 feet, scarce half the width of the river; and below the sterlings, the water-way is reduced to 194 feet. Thus a river 900 feet wide, is here forced through a channel of 194 feet. This bridge, it is expected, will be taken down ere long, and one of cast iron has been proposed to be erected in lieu of it. Opinions are much divided, however, as to the propriety of such an erection, but, as to the necessity of a new bridge there can be no doubt; the piling of the old one being in such a condition as to place the whole structure in a veryprecarious state.

Of modern bridges there are few, if any, which excel the Westminster and Blackfriars' bridges over the river Thames. The former is 1220 feet long, and 44 feet wide, having a commodious foot-path on each side for passengers. It consists of 15 arches; was finished in 1750, and cost 389,500*l.* The latter, nearly opposite the centre of the city of London, was finished in 1770: it consists of 9 large and elegant arches, nearly eliptical, of which the centre arch is 100 feet wide: the breadth of the bridge is 42 feet, and its length from wharf to wharf 995. It cost 150,840*l.*

[*Hutton. Perronet. Pantolog.*

SECTION II.

Light-houses, exemplified by those of Phaselus, Pharos, and the Eddystone Rocks.

A LIGHT-HOUSE is a building erected upon a cape or promontory on the sea-coast, or upon some rock in the sea, and having on its top in the night-time a great fire, or light formed by candles; which is constantly attended by some careful person, so as to be seen at a great distance from the land. It is used to direct the shipping on the coast, that might otherwise run ashore, or steer an improper course when the darkness of the night and the uncertainty of currents, &c. might render their situation with regard to the shore extremely doubtful. Lamp-lights are, on many accounts, preferable to coal-fires or candles; and the effect of these may be increased by placing them either behind glass-hemispheres, or before properly disposed glass or metal reflectors, which last method is now very generally adopted.

In the supplement to the Encyclopedia Britannica, under the word Reflector, it is stated that " Mr. Thomas Smith, tin-plate worker, Edinburgh, seems to have conceived the idea of illuminating light-houses by means of lamps and reflectors, instead of coal-fires, without knowing that something of the same kind had been long used in France; he has therefore all the merit of an inventor, and what he invented, he has carried to a high degree of perfection."

The writer of this article has certainly been misinformed, for reflectors, such as he describes, were invented by Mr. Ezekiel Walker, of Lynn Regis, they were also made, and fixed up, under his direction, in a light-house on the coast of Norfolk, in the year 1782. and in the year 1787, at the request of the trustees appointed by act of parliament for erecting four light-houses on the northern parts of Great Britain, he instructed the above-mentioned Mr. Thomas Smith, in this method of constructing light-houses.

The parabolic moulds used by Mr. Walker and Mr. Smith, are from three to five or six feet in diameter; and in the centre or apex of each is placed a long shallow lamp of tin-plate, filled with white oil. In each lamp are six cotton wicks, almost contiguous to each other, which are so disposed as to burn without trimming for about six hours. The light of these is reflected from each mirror spread over the concave surface, and is thus multiplied, as it were, by the number of mirrors. The stucco moulding is covered on the back with tin plate, from which a tube, immediately over the lamp proceeds to the roof of the light room, and serves as a funnel, through which the smoke escapes without sullying the faces of the mirrors. The light-room is a cupola or lantern of from eight to twelve sides, composed entirely of glass, fixed in cast iron frames or sashes, and roofed with copper. On circular benches passing round the inside of this lantern, at about eighteen inches from the glass frames, are placed the reflector with their lamps, so as that the concave surfaces of two or three of the reflectors front every point of the compass, and throw a blaze of light in all directions. In the roof immediately over the centre of the room is a hole, through which pass all the funnels already mentioned, and which serves likewise to admit fresh air to the lamps. This light-room is firmly fixed on the top of a round tower, so as to be immoveable by the weather; and the number of the reflectors, and the height of the tower, are less or greater according as it is the intention that the light should be seen at a less or a greater distance.

A man judging from mere theory would be very apt to condemn light-houses of this kind; because the firmest building shakes in a violent storm, and because such shaking, he may think, would sometimes throw the whole rays of light into the air, and thus mislead the bewildered seamen. This opinion, we know, was actually entertained of them by one of the profoundest philosophers and most scientific mechanicians of the age. Experience, however, convinced him, as well as the public at large, that such apprehensions are groundless, and that light-houses with lamps and reflectors are, in every point of view, preferable to those with fires burning in the open air. They are supported at much less expence; their light is more brilliant, and seen at a greater distance, whilst it can never be obscured by smoke, or beaten down on the lee side by a violent gust of wind; and what is perhaps of still greater importance, the reflectors with their lamps may be so variously placed, that one light-house cannot be mistaken for another. If we add to all this, that the lamps do not stand in need of trimming so often as open fires require fuel, and that the light-man is never exposed either to cold or to wet by attending to his duty, we must be convinced that light-houses with reflectors are much less liable to be neglected in stormy weather than those with open fires, and that this circumstance alone would be enough to give the former a preference, almost incalculable, over the latter.

According to Josephus one or two, and perhaps more, of the watch-towers of Jerusalem were of this kind. He particularly speaks of the Phaselus, which he describes as resembling the Pharos near Alexandria, but much larger, and calculates it as a square building of forty cubits or sixty feet on each side, and ninety cubits or a hundred and thirty feet high.

But the light-house of Pharos acquired a much higher celebrity. It was commenced by Ptolemy Soter, and finished some years afterwards in the joint reign of himself and his son Ptolemy Philadelphus. It is commonly called the Tower of Pharos, and was counted by the ancients among the wonders of the world. It was a large square structure of white marble, on the top of which fires were kept constantly burning for the direction of sailors. It cost eight hundred talents, which, if they were Attic talents, amounts to one hundred and sixty-five thousand pounds sterling and upwards; if Alexandrian, to twice that sum. The architect employed by Ptolemy in this wonderful structure, was Sostratus of Cnidus, who by the following crafty device, attempted to usurp the whole glory of it to himself. He was ordered to engrave on it the following inscription; "King Ptolemy to the gods the saviours for the benefit of sailors;" but instead of Ptolemy's name, he cut out his own in the solid marble, and then filling up the hollow of the letters with mortar, wrote on it the above-mentioned inscription. In process of time the mortar with Ptolemy's name being wore off, the following inscription appeared; "Sostratus the Cnidian, the son of Dexiphanes, to the gods the saviours for the benefit of sailors." This, as it was engraved on the solid marble, lasted as long as the tower itself. This wonderful work has been demolished some ages since; and now in its place stands a castle, as our modern travellers informs us, called Farillon, where a garrison is kept to defend the harbour. Pharos was originally an island about seven furlongs distant from the continent, to which it was afterwards joined by a causey, it being seven furlongs in length. This was the work of Dexiphanes, the father of Sostratus, who compleated it at the same time that his son put the last hand to the tower. As they were both celebrated architects, Ptolemy employed them in these and many other works, which he undertook for the adorning and strengthening Alexandria, the metropolis of his kingdom. Amianus Marcellinus ascribes the heptastadium to queen Cleopatra; but as he contradicts therein Cæsar in his Commentaries, and all the ancients who speak of that great work, his authority is of no great weight with us.

Nicholas Lloyd tells us out of a manuscript copy of the Greek scholiast on Lucian, whose very words he quotes, that this tower was a square structure of a furlong, or six hundred foot on each side, and so high, that it was seen at the distance of an hundred miles. Eben Adris, an Arabic writer, in his book, which the Latin translator styles Geographia Nubiensis, says, that this tower was three hundred cubits, or four hundred and fifty foot high.

In our own day the most celebrated light house is that built on the Eddystone-rocks. These are situate nearly S.S.W. from the middle of Plymouth sound, according to the true meridian. The distance from the port of Plymouth is nearly fourteen miles, and from the promontory called Ramhead about ten 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 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 Eddystone are from eighty fathoms to forty, and everywhere till you come near the Eddystone the sea is full thirty fathoms in depth; so that all the heavy seas from the south-west come uncontrouled upon the Eddystone 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 a hundred fathoms, and by their lying in a sloping manner toward the south-west quarter. This striving of the rocks, as it is technically called, does not cease at low water, but still goes on progressively; so that, at fifty fathoms westward, there are twelve 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 comes swelling to this part, meet so sudden a check, that they frequently fly to the height of thirty or forty feet.

Notwithstanding these difficulties, it is not surprising that the dangers to which navigators were exposed by the Eddystone 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. He entered upon his undertaking in 1696, and completed it in four years. This gentleman was so certain of the stability of his structure, that he declared it to be his wish to be in it "during the greatest storm that ever blew under the face of the heavens." Mr. Winstanley was but too amply gratified in his 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.

In 1709, another light-house was built of wood, on a very different construction, by Mr. John Rudyerd, then a silk-mercer on Ludgate-hill. This was a very ingenious structure: after it had braved the elements for forty-six years, it was burnt to the ground in 1755. On the destruction of this light-house, that excellent mechanic and engineer Mr. Smeaton was chosen as the fittest person 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, whichlie 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."

With these views as to the proper form of the superstructure, Mr. Smeaton began the work on the 2d of April, 1757, and finished it in August 4, 1759. The rock, which slopes towards the S.W. is cut into horizontal steps, into which are dovetailed, and united by a strong cement, Portland stone and granite. The whole, to the height of thirty-five feet from the foundation, is a solid of stones, engrafted into each other, and united by every means of additional strength. The building has four rooms, one over the other, and at the top a gallery and lantern. The stone floors are flat above, but concave beneath, and are kept from pressing against the sides of the building by a chain let into the walls. It is nearly eighty feet high, and since its completion has been assaulted by the fury of the elements, without suffering the smallest injury.

We regret that we cannot with propriety trace out the progress of this great work, and shew with what skill and judgment this unparalleled engineer overcame the greatest difficulties: we, however, beg to recommend to our curious readers Mr. Smeaton's own Account of the Eddystone Light-house, not doubting that they will be highly gratified by the perusal. According to the Requisite Tables, this light-house is situated in lat. 50. 8 N. Lon. 4. 24 W. of Greenwich, or 4. 18. 23 W. of London.

CHAP. VIII.

CHRONOLGICAL TABLE OF MECHANICAL INVENTIONS.

Scipio Nasica's clepsydra* . .	B. C. 159
Scissors invented in Africa	
Diophantus employed some algebraic symbols. Montucla.	
Pens made from quills . .	A. D. 635
Glass introduced into England . . .	674
Silk worked in Greece about . . .	700
The Chinese canal 806 miles long, finished by 30,000 men in 43 years	980
Paper of linen introduced about . . .	1100
The first canal in England, from the Trent to the Witham	1134
Glass commonly used in England . . .	1180
Some Greek weavers settled at Venice . .	1207
Linen first made in England . . .	1253
A clock at Westminster Hall about . .	1288
A clock at Canterbury . . .	1292
Faenza's earthen ware invented . . .	1299
Windmills invented	1299
Cannons invented	1330
Two weaver's from Brabant settled at York . .	1331
Wire invented at Nuremberg . . .	1351
Gunpowder used according to Langlais . .	1338
Battle of Cressy	1346
Gunpowder used at Lyons in Brabant Wiegleb .	1356
Muskets used at the siege of Arras . .	1414
Engraving on metal and rolling-press printing invented	1423
Printing invented by Faust . . .	1441
Delft ware invented at Florence . .	1450
Printing made public by Gutenberg . .	1458
Wood cuts invented . . .	1460
Casts in plaster, by Verocchio . . .	1470
Watches made at Nuremberg . . .	1477
Diamonds polished at Bruges . . .	1489
Shipping improved, and port holes invented by Decharges	1500
Hats made at Paris	1504
Etching on copper invented . . .	1512

* An instrument to measure time by the fall of water.

Proportional compasses invented by L. da Vinci, before	1519
Spinning-wheel invented by Jürgen of Brunswick .	1530
Pins brought from France . . .	1543
Needles made in England . . .	1545
Air guns made at Nuremberg . . .	1560
Stockings first knit in Spain about . .	1550
Many Flemish weavers were driven to England by the Duke of Alva's persecution . . .	1567
Three clockmakers came to England from Delft .	1568
Log line used	1570
Coaches used in England . . .	1580
Bombs invented at Venloo . . .	1688
Stocking weaving invented by Lee of Cambridge .	1589
A slitting mill erected at Dartford . .	1590
New River brought to London . . .	1614
The dimensions of bricks regulated . .	1625
Vernier's index made known . . .	1631
Clocks and watches generally used about . .	1631
Bows and arrows still used in England, and artillery with stone bullets	1640
Newton born	1642
Guericke invented the air pump . . .	1654
Fromantil is said to have applied pendulums to clocks in	1656
Hook's watch with a balance spring . .	1658
Hooke finished his air pump . . .	1658
Savery had erected steam engines . . .	1696
Chain shot invented by Dewit . . .	1666
Threshing machines with flails invented . .	1700
China made at Dresden	1702
China made at Chelsea	1753
Wedgwood's improvements in pottery . .	1763
Muslins made in England . . .	1781
Balloons invented by Montgolfier . . .	1783
Lunardi ascended in Moorfields . . .	1784

In 1787 about twenty-three million pounds of cotton were manufactured in Britain; about six were imported from the British colonies, six from the Levant, and ten from the settlements of other European nations. Half the quantity was employed in white goods, one-fourth in fustians, one fourth in hosiery, mixtures, and candle wicks; giving employment to 60,000 spinners, and

360,000 other manufacturers. In 1791, the quantity was increased from twenty-three millions to thirty-two.

The value of the wool annually manufactured in England is about three millions sterling; it employs above a million persons, who receive for their work about nine millions.

Thread has been spun so fine as to be sold for £4 an ounce; lace for £40.

The premiums annually proposed by the Society for the Encouragement of Arts, enable us to form some opinion of the present state of our machinery and manufactures. Some of their objects are, a substitute for white lead paint, a red pigment, a machine for carding silk, cloth made from hop stalks, paper made from raw vegetables, transparent paper, the prevention of accidents from horses falling, cleaning turnpike roads, machines for raising coals, and for making bricks, instruments for harpooning whales; machines for reaping or mowing corn, for dibbling wheat, for threshing; a family mill, a gunpowder mill, a quarry of millstones; and a mode of boring and blasting rocks 1802.

[*Luckombe's Tablet of Memory. Young's Nat. Phil. Edit.*

CHAP. IX.

TABLE OF ANCIENT MEASURES AND WEIGHTS.

SECTION I.

Ancient Measures.

Arabian foot	1.095 Engl. Hutton
Babylonian, foot	1.144 Hutton 1.135 Hutton
Drusian, foot	1.090 Hutton
Egyptian, foot	1.421 Hutton
Egyptian, stadium	730.8
Greek, foot	1.009 Hutton
	1.006 1.007 Folkes, $1\frac{1}{2}$ Roman f.
	1.007 Cavallo

Greek, phyleterian foot	1.167 Hutton
Hebrew, foot . .	1.212 Hutton
Hebrew, cubit .	1.817 Hutton
Hebrew, sacred cubit	2.002 Hutton
Hebrew, great cubit=6 common cubits. Hutton	
Macedonian, foot .	1.160 Hutton
Natural foot .	.814 Hutton
Ptolemaic=Greek foot	Hutton
Roman, foot . .	.970 Bernard
	.967 Picard and Greaves
	.966 } Folkes
	.967 } Folkes
	.970 before Titus. Raper
	.965 after Titus. Raper.
	.9672 from rules. Shuckburgh
	.9681 from buildings. Shuckburgh
	.9696 from a stone. Shuckburgh.
	.967 Hutton
Roman mile of Pliny 4840.5 Cavallo	
Roman mile of Strabo 4903.	
Sicilian foot of Archimedes .	.730 Hutton

SECTION II.

Ancient Weights.

1. *Greek Weights, in English Grains.*

Attic obolus .	8.2 Christiana
	9.1 Arbuthnot
Attic drachma .	51.9 Christiani
	54.6 Arbuthnot
Attic lesser mina	3892. =75 drachms. Christiani
Attic greater mina	5189. =100 drachms. Christiani
	5464. Arbuthnot
Attic medical mina	6994. Arbuthnot
Attic and other talents=60 minae	
Old Greek drachm	146.5 Arbuthnot
Another Greek drachm	62.5=Roman denarius. Arbuthnot

Old Greek mina	6425.	Arbuthnot
Egyptian mina	8326.	
Ptolemaic mina of Cleopatra .	8985.	
Alexandrian mina of Dioscorides .	9992.	

Roman Weights.

Denarius .	51.9	Christiani $\frac{1}{8}$ oz.
	62.5	Arbuthnot $\frac{1}{7}$ oz.
Ounce .	415.1	Christiani
	437.2	Arbuthnot
Pound of 10 ounces	4151.	Christiani
Pound of 12 ounces	4981.	Christiani
	5246.	Arbuthnot

END OF VOLUME VI.