A

BRIEF RETROSPECT

OF THE

EIGHTEENTH CENTURY.

Saml. Miller

PART THE FIRST;

IN THREE VOLUMES:

CONTAINING

A SKETCH

OF THE REVOLUTIONS AND IMPROVEMENTS

IN

SCIENCE, ARTS, AND LITERATURE,

DURING THAT PERIOD.

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TO

JOHN DICKINSON, ESQ. LL. D.

LATE PRESIDENT OF THE STATE OF DELAWARE,

AND

PRESIDENT OF THE SUPREME EXECUTIVE COUNCIL

OF THE

COMMONWEALTH OF PENNSYLVANIA.

DEAR SIR,

IN finding your name prefixed to the following pages, without permission, I trust you will feel no emotion more unfavourable than that of surprise. I know not, indeed, to whom I could dedicate such a work as this with more propriety than to an elegant scholar, a comprehensive observer of a large portion of the century attempted to be reviewed, a master of so many of its literary and scientific improvements, a conspicuous actor in some of its most memorable and important transactions, an able and eloquent defender of his country's rights, a munificent patron of American literature, and (if personal or local feelings may be allowed to intrude) a uniform and affectionate friend of my honoured parents, and one of the most illustrious of those who owe their birth to my native state.

Among the numerous opinions expressed in these volumes, you will, no doubt, find some which totally differ from your own; and others which more attentive and enlarged views would have taught me considerably to modify or amend. Of the former you will not consider this public address as implying or soliciting your approbation. Of the latter I am confident you will be disposed to form a candid and even an indulgent estimate.

But with respect to some of the leading opinions delivered in the following sheets, I am happy in the assurance that you perfectly coincide with me. To all that is said of the perfect harmony between the RELIGION OF CHRIST and genuine Philosophy, and of the illustration and support which the former has received at every successive step of the latter in the last age; to every unfavourable judgment pronounced on those theories, falsely called philosophy, which pervert reason, contradict Revelation, and blaspheme its divine Author; and to every expression of satisfaction at the progress of elegant letters and substantial science, as tending to promote the dignity and happiness of man—to opinions and sentiments like these, I know too much of your character to doubt of receiving your sanction.

Those who, like yourself, contemplate every department of human affairs through the medium of Christian principles, while they see much to deplore, see also much to approve and admire in the history of science for the last age. What effect the knowledge bequeathed by that age may have on the harmony, virtue and happiness of mankind in the one on which we have entered, is known only to infinite Wisdom. Let us, however, indulge in favourable anticipations as long as we can. In all events we are assured, that this, as well as all the other fruits of human genius and activity, will be made conducive to the welfare of the good, in a more enlightened and a more happy world.

I am, dear sir,

With much respect,

Your obliged and obedient servant,

SAMUEL MILLER.

New York, Nov. 25, 1803.

PREFACE.

A SIMPLE history of this publication will best unfold its design, and will form the best apology for its numerous imperfections. On the first day of January, in the year 1801, the author being called, in the course of his pastoral duty, to deliver a sermon, instead of choosing the topics of address most usual at the commencement of a *new year*, it occurred to him as more proper, in entering on a *new century*, to attempt a review of the preceding age, and to deduce from the prominent features of that period such moral and religious reflexions as might be suited to the occasion. A discourse, formed on this plan, was accordingly delivered. Some who heard it were pleased to express a wish that it might be published. After determining to comply with this wish, it was at first intended to publish the original discourse, with some amplification; to add a large body of notes for the illustration of its several parts; and to comprise the whole in a single volume. Proposals were issued for the publication in this form, and a number of subscribers gave their names for its encouragement.

Little progress had been made in preparing the work, on this plan, for the press, before the objections to such a mode of arranging the materials appeared so many and cogent, that it was at length thought best to lay aside the form of a sermon, and to adopt a plan that would admit of more minuteness of detail, and of greater freedom in the choice and exhibition of facts. This alteration in the structure of the work led to an extension of its limits; materials insensibly accumulated; and that portion which was originally intended to be comprised in a third or fourth part of a single volume gradually swelled into two volumes*.

It is probable that one of the first reflexions made by most readers of the following pages will be, that the plan is too extensive to be well executed by *any* individual; and that it was peculiarly presumptuous, in one of comparatively small reading, and who could not obtain access to ample libraries, to undertake such a work. The author feels the justness and weight of this reflexion; and is sensible that to present a full and satisfactory view of any one of the departments embraced by this Retrospect, would be a task beyond his powers, would afford abundant employment, for many years, to a mind much more mature, active, and enlightened than his. Why, then, it will be asked, did he adventure on so arduous an enterprise? In answer to this question, he must ingenuously confess, that he engaged without any due consideration, and did not begin suitably to estimate the extent and difficulty of the task till he had proceeded too far to retract. He is also bound in candour to declare, that his own instruction and improvement were among his principal motives in undertaking and prosecuting this work. Being per-

* The original edition is in two volumes.

suaded that writing on a subject is one of the best means of methodising and correcting one's own views of it; and hoping that, while he informed himself, he might amuse, if not instruct, others, he submitted to the toils of collecting and arranging the materials which are here presented. If none of his readers should be able to derive either entertainment or information from the following sheets, he has the satisfaction of reflecting, that he himself derived both from the labour of preparing them for the press.

Though the greater part of this work consists of compilations, yet the writer claims to be something more than a mere compiler. He has offered, where he thought proper, opinions, reflexions, and reasonings of his own; and though many of these are adopted, perhaps too hastily, from others, there are some of which all the praise and all the blame belong to himself. He is not, however, solicitous to discriminate, even if it were possible, between these several parts of the work. If the exhibition of facts and opinions, so far as it goes, be tolerably just, the question whence they originated is of little consequence to the reader.

With respect to the division and arrangement of the subjects, it was judged advisable to adopt rather a *popular* than a *scientific* plan. This plan is, no doubt, liable to some objections; but it appeared better suited to the purpose in view than any other that presented itself. The reader will observe that the sciences of *Theology*, *Morals*, and *Politics*, are not noticed in this First Part. The reason of the omission is, that it appeared most proper to leave what may be said concerning the revolutions and improvements in these three interesting departments of science, respectively, to stand as preliminaries to the three remaining divisions of the work, in which some account will be attempted of the great events in the Christian Church, in the Moral World, and in Political Principles and Establishments, during the last century. It was supposed that, in this connexion, the rise, progress, and influence of new systems, and modes of thinking, might be exhibited with greater advantage, and perused with more satisfaction.

As the author aimed at nothing more than a *brief retrospect* of the period to which this work is devoted, it was impossible for him to do more, consistently with his plan, than to mention the *principal* discoveries, inventions, improvements, and writers, under each head; and even these could only be noticed with great brevity, and in very general terms. To have attempted minute details, and particular explanations, would have extended the work to many volumes. With respect to the choice which has been made of facts and names, the degrees of importance ascribed to them, and the proportion of room and attention allotted to each, different readers will, no doubt, entertain different opinions. Every one will be apt to suppose that the particular names and studies to which he is most attached, are not noticed with sufficient respect, or dwelt upon at sufficient length. The author can only say, that, in general, he indulged in more or less prolixity, according to his ideas of the importance of the several subjects, the extent of his acquaintance with them, or the degree in which they interested his own mind. That, from such a multiplicity of objects, he often selected injudiciously, and made an erroneous estimate of their comparative value, is altogether probable.

Although the very nature of the work required that all the subjects brought into view should be treated superficially, and that nothing more than rapid outlines should be attempted, yet the intelligent reader will, doubtless, discern, that the mode of treating some of the subjects manifests a very small and partial acquaintance with them. For the want of more just and enlarged views, the author fears he has often written in a crude and unsatisfactory manner on topics which might, in the same compass, have been better discussed. In some instances, however, he has failed of giving a more satisfactory account of the additions made to science, by distinguished individuals, from another cause: where it would have been impossible to state the precise limits of what each has done to advance our knowledge of a particular subject, without going into a discussion of many pages, little more is frequently attempted than to give a list of the names of those individuals, on the presumption that the inquisitive reader will seek for a more full account of their respective claims elsewhere.

In enumerating the principal writers on the various subjects reviewed, it will be observed, that those who have written in the English language engage the largest share of the author's attention. The reason of this is obvious; he is best acquainted with such writers; and, from his ignorance of most of the languages of the continent of Europe, he has probably failed of mentioning many works quite as worthy of respectful notice as others on which he has bestowed high praise. Perhaps a still more formal apology will be deemed necessary for the disposition to introduce American writers and publications, even of moderate character, which he has so frequently discovered. But, beside indulging a natural partiality for his own country, which is at least pardonable, he was desirous of collecting and exhibiting as much information on the subject of American literature as the nature of his undertaking admitted. And as no attempt to give a general historical view of this subject has ever been before made; as a considerable portion even of the humble and meagre records from which he has drawn his materials, are daily perishing; and as peculiar circumstances sometimes give to literary characters and events a relative importance, beyond their absolute value, he thought it advisable to take notice of more obscure names, and of smaller publications, than could with propriety have been mentioned in countries of a more mature literary character. Perhaps, however, in his zeal to collect every thing he could find on this subject, he has sometimes descended too low.

Should any reader be offended by the language of panegyric, which is frequently bestowed on the intellectual and scientific endowments of some distinguished abettors of heresy or of infidelity, he is entreated to remember that justice is due to all men. A man who is a bad Christian may be a very excellent mathematician, astronomer, or chemist; and one who denies or blasphemes the Saviour, may write profoundly and instructively on some branches of science highly interesting to mankind. It is proper to commiserate the mistakes of such persons, to abhor their blasphemy, and to warn men against their fatal delusions; but it is surely difficult to see either the justice or utility of withholding from them that praise of genius or of learning to which they are fairly entitled.

It will probably be remarked, by the intelligent reader, that a due *proportion* between the parts of this work, according to the relative importance and extent of each subject, is not always preserved. Had the manuscript been completed before any part of it was sent to the press, faults of this kind would, no doubt, have been, in some degree, avoided; but the truth is, that the first pages of the manuscript were put into the hands of the printer before a single chapter of the work had been fully written; and each successive sheet was prepared, from the materials previously collected, at the call of the printer, and amidst the hurry of incessant professional labours. It is scarcely necessary to add, that this race with the press frequently rendered impossible that laborious investigation, and that careful correction which were highly desirable: nor could the author excuse himself for conduct so manifestly indiscreet, had he duly considered beforehand the nature and magnitude of the engagement. But it must be acknowledged, that as he entered on the work without duly appreciating the arduousness of his undertaking, so every step in the pursuit convinced him more and more of its extent and difficulty; that in the prosecution of his task he wished a hundred times he had never undertaken it; and that now it is brought to a close, few readers can be more sensible than he is himself of its numerous and great defects.

It will be observed, that *three* parts of the original plan yet remain to be executed. Whether the execution of the whole will be attempted depends, in some measure, on the reception which shall be given to this *First Part*. The author is particularly desirous of completing the fourth and last division; *viz.* that which relates to the Literature, Science, Revolutions, and principal Events of the Christian Church during the last age; and even if he should be compelled to abandon the two intermediate divisions, he cherishes the hope of being able, if his life should be spared, to lay something before the public on this favourite subject.

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OF

THE FIRST VOLUME.

A

BRIEF RETROSPECT

OF THE

EIGHTEENTH CENTURY.

INTRODUCTION.

THE oldest historian in the world, and the only one in whose information and faithfulness we can place unlimited confidence, tells us, that, in the beginning, when God created the heavens and the earth, he said, *Let there be lights in the firmament of the heaven, to divide the day from the night; and let them be for signs, and for seasons, and for days, and for years.* Without recurring to the regular motions of these celestial orbs, time would pass unnoticed and unmeasured. Its flight, in itself, is not an object of sense; we neither see nor hear it. But by observing the diurnal revolutions of the heavenly bodies, we acquire the conception of days; by dividing these days, we form hours and minutes; and, by multiplying them, we gain the ideas of months, years, and ages. Like all the rest of the works and ways of God, these means of marking the progress of time, and ascertaining its portions, are adapted to promote both physical and moral advantage. To the philosopher they furnish inestimable rules and principles of calculation; to the man of business they present measures and stimulants to industry; and, above all, to the christian they offer continual memorials of the end of life, and unceasing excitements to moral exertion.

Hence the close of one year, and the commencement of another, are generally marked by mutual congratulations, by a peculiar train of reflexions, by new plans and undertakings, and by characteristic changes in domestic, social, and political affairs. They form a period which interests the feelings, and constitutes a prominent point in the life of almost every man.

But, on reaching the termination of an active and eventful CENTURY, and entering upon a new one, the emotions of the reflecting mind are still more strong, and the impressions made more various and interesting. This is a transition, which few individuals at present on earth have before witnessed, and which few now living will ever again behold. At such a period it is natural, and it is useful, to pause; to review the extensive scene; to estimate what has been done; to inquire whether we have grown wiser and better, or the reverse; and to derive those lessons of wisdom from the whole, which rational beings ought ever to draw from experience. While the student of chronology is disputing about the time when the old century terminated, and the new one began *; and while

* It would be neither convenient nor seasonable to attempt, in this place, a discussion of the question, when the nineteenth century commenced. The author takes for granted, that it com-

the astronomer sees nothing in this period but the completion of a certain number of planetary revolutions, and the commencement of another series; the man of true wisdom is employed in attending to other objects, and in pursuing different inquiries. Rich were the stores of instruction, and great the improvement, which an ancient king received from *returning, after a long course of action, and looking upon all the works which his hands had wrought, and the labour which he had laboured to do.* It was upon this calm retracing of his steps, that he discovered, more fully than ever before, wherein he had been profitably employed; and in what respects his unwearied exertions had been but *vanity and vexation of spirit.*

Standing, therefore, as we do, upon the threshold of a NEW CENTURY, it may prove both amusing and instructive to take a hasty retrospect of that to which we have just bidden adieu. In this retrospect, the scene which lies before us is large and various. On whatever part we cast the eye, important objects, and interesting lessons, present themselves to view. Out of these it will only be possible to select a few of the most conspicuous and striking, and to display each with the utmost brevity.

menced on the first day of January, 1801. In this opinion he is supported by the decision of many of those who are best qualified to judge on the subject. De Lalande, the great French astronomer, tells us that the same question was discussed with great warmth at the close of the seventeenth century; and that many pamphlets were written with a view to settle it, of several of which he is possessed. He decides, without hesitation, that the century commenced on the day above-mentioned.—*See De Lalande's History of Astronomy for* 1799.

He who attempts to take a view, even the most superficial, of human nature, and of human affairs, within any given period, will soon find that the object which he undertakes to survey, is complex and multiform. Man, always variable, and never consistent, imparts this character to every thing that he touches. To give the history of a single mind for a single day; to mark with justice its revolutions, its progress, its acquirements, and its retrocessions; to form an estimate of the good, or of the evil, which, within this time, it may have produced; and to trace, in accurate lines, wherein its character on that day differed from its character on the preceding; is a task which can appear easy only to ignorance and inexperience. And in proportion as the number of minds to be contemplated increases, or the length of the time in question is extended, the difficulties of the undertaking multiply, and it becomes, in every respect, more arduous. How numerous the difficulties, then, of estimating the operations and the progress of the human race for a hundred years!

Another source of doubt and mistake also arises here, beside that which is occasioned by the complexness and confusion of the scene. Who can distinguish between *revolution* and *improvement* in human affairs? Who can undertake to say in what cases they are synonymous terms, and when they are directly opposite? If every change were to be considered an advantage, it would follow, of course, that the strides of civilised man, in every species of improvement, during the last century, have been prodigious. But, alas! this principle cannot be admitted by the cautious inquirer, or the friend of human happiness. The passion for novelty and change, so universal and unceasing, has doubtless often indulged itself at the expense of real good, and substantial enjoyment.

A wise man, and an inspired writer, has told us, that *there is no new thing under the sun. Is there any thing whereof it may be said, See, this is new? It hath been already of old time, which was before us.* This passage, like many others of a similar kind, is doubtless not to be interpreted as declaring literally, that there never have been, nor ever can be, any schemes, events, or discoveries, entitled to the appellation of *new;* but as teaching us, in a strong and figurative manner, that the projects and improvements of human genius are frequently sinking into forgetfulness, and rising again; that old systems are daily revived, clothed in new dresses, decorated with new names, and palmed on the world as creatures of modern birth; and that very few of the boasted efforts of genius, either in Solomon's days, or at any subsequent period, could be called entirely original. The smallest acquaintance with history is sufficient to convince any one, that this is a just representation. That there are some things peculiar to certain periods and countries, will not be disputed; but that these are fewer in number, and the peculiarity much smaller in degree, than transient observers imagine, is certainly also true. Hence arises a further difficulty in deciding wherein one age differs from another. History is not an instructress sufficiently minute and patient, to enable us always to judge promptly and accurately on this subject.

"It affords some astonishment," says a late writer, "and much curious speculation to the reflecting mind, that, probably, not a system of philosophy exists among the moderns, which had not its foundation laid upon some one opinion or another of the ancient theorists, and the outlines of which may not be found in such of their writings as have come down to our time. Even the Newtonian doctrine of gravitation was not unknown to *Lucretius;* for that poet, in his first book, attempts to refute the idea that the universe had a centre, to which all things tend by their natural gravity. That the central point had the strongest power of attraction, was equally an hypothesis of Sir Isaac Newton and the ancient stoics *." The ingenious writer might have extended his remark much farther, and have gone into a very amusing detail on this subject. Some facts, tending to confirm his position, will appear in the following pages †. Let us beware, however, of carrying the principle beyond due bounds.

A difficulty also arises, in attempting to make the proposed estimate, from the disposition of man to magnify present objects. It is an old remark, that important persons and scenes acquire an additional magnitude in our eyes when viewed from a distance. But it is as true, that the same error of

* *Drake's Literary Hours,* vol. i. p. 12, 13.

† Those who wish to see this subject farther elucidated, may consult a very amusing work of M. Dutens, entitled *Origine des Découvertes attribuées aux Modernes, &c.* 2 vols. 8vo. Paris, 1766. And although the impartial reader will frequently perceive, that the author carries his determination to withhold from the moderns the credit due to them, for many discoveries, to an extravagant and ridiculous length, yet the work undoubtedly contains much instructive and valuable matter.

intellectual vision occurs daily with respect to objects seen near at hand. Men have always been unduly disposed to consider their own times as distinguished, above all others, by remarkable events. The virtue or the vice, the knowledge or the ignorance, the discoveries or the destructions, which we personally witness, or of which we have recently heard, are apt to impress us more deeply, and to be estimated more highly in the history of man, than their real importance deserves. Hence nothing is more common than to hear men express an opinion, that the country and the period in which their lot is cast are more awfully *degenerate*, or more extensively *enlightened*, according to the occurrence or the object which happens to occupy their minds, than the world ever before witnessed. No doubt, a portion of this prejudice and partiality cleaves to every mind, and must always interpose an obstacle in the way of him who would accurately calculate the magnitude, and justly exhibit the features, of recent events.

But, after making every allowance for errors in calculation which may arise from these several sources, it will probably be acknowledged, that the century of which we have just taken leave has produced an unusual number of revolutions, and at least some improvements,—In LITERATURE and SCIENCE—in POLITICAL PRINCIPLES and ESTABLISHMENTS—in the MORAL WORLD—and in the CHRISTIAN CHURCH.

To think of surveying each of these wide fields, throughout its whole extent; and especially to think of conducting the survey with the minuteness of observation, and the profundity of research, which would become a philosophic inquirer; are, at present, out of the question. Had the writer temerity enough to engage in such a plan, or the presumption to assume so high a character, the variety and immensity of the task would soon convince him of his error. The most brief and rapid sketches only will, therefore, be attempted, on each of the above heads of inquiry.

PART FIRST.

ON THE REVOLUTIONS AND IMPROVEMENTS IN SCIENCE, ARTS, AND LITERATURE, DURING THE EIGHTEENTH CENTURY.

IT is justly remarked, by an acute modern writer *, that the history of learning and science is much less uniform than that of civil affairs; that the wars, negotiations, and politics of one age more resemble those of another, than the literary and scientific taste. He explains this obvious fact by observing, that, in public and political transactions, ambition, honour, malice, revenge, and the various turbulent passions of man, are the prime movers; and that these passions are not only the same in every age, but are also stubborn, intractable, and by no means susceptible of the same variety of modification, which frequently takes place in the literary taste and habits of different times. The former we can scarcely expect any thing human to control; but the latter may be and are every day affected by education, by example, and by a thousand circumstances which it would be difficult to enumerate.

It has often been made a question, whether mankind have effected any real progress in knowledge during the eighteenth century. There are not a few who maintain the negative; who con-

* HUME's *Essays*, vol. i. p. 110.

tend, that although this period has been abundantly productive of new theories, specious plans, and *oppositions of science falsely so called;* yet that little, if any thing, has been done toward the cultivation of solid learning and real science, since our fathers of the seventeenth century fell asleep. In the opinion, and in the language of such, the present race of men are " a generation of triflers and profligates, sciolists in learning, hypocrites in virtue, and formalists in good breeding; wise only when they follow their predecessors, and visionary fools whenever they attempt to deviate from, or go beyond, them." With these cynical critics novelty is degeneracy; and every thing which bears the name of invention, discovery, or improvement, is useless, if not dangerous innovation. But this indiscriminate opposition to the claims of modern times is evidently dictated rather by prejudice, than by enlightened views and impartial observation. Though a change of circumstances may produce different degrees or kinds of excellence in the efforts of intellect; yet the native powers of man are doubtless the same in all ages. It must be admitted, indeed, that in some of the branches of human knowledge the last age has added but little to the attainments of the preceding; and that many things which superficial readers consider as new, were long since familiarly known, and as well practised as at the present day. In works of genius, there seems no good ground to represent the present generation as possessing any peculiar or transcendent excellence. Perhaps a candid inquirer would even say, that in this respect we rather fall below than rise above the standards of former times; and for this fact plausible if not satisfactory reasons may be assigned. But still, amidst multiplied false theories, and much pompous jargon, which have been too prevalent in the world during the last century; though the field of enterprise, in this department of human exertion, has been more remarkable for the number of labourers employed in it, than for the success of their labours; though luxuriant foliage, more than substantial fruit, has abounded; yet much, within this period, has been done. New and important truth has been elicited: discoveries of a highly interesting nature have been made: systems of philosophy have assumed a more regular, consistent, and dignified form: and various departments of learning have been purged of the dregs, and rescued from the rubbish, with which the ignorance and the inexperience of former times had encumbered them.

At the close of the seventeenth century the stupendous mind of Newton, and the penetrating genius of Locke, had laid their systems of *matter* and of *mind* before the world. Like pioneers in an arduous siege, they had many formidable obstacles to remove—many labyrinths to explore—and the power of numberless enemies to overcome. But they accomplished the mighty enterprise. With cautious, but firm and dauntless step, they made their way to the intrenchments of fortified error; they scaled her walls; forced her confident and blustering champions to retreat; and planted the standard of truth, where the banner of ignorance and of falsehood had so long waved.

It can scarcely be supposed, indeed, that these great men taught *nothing but the truth*, and far less that they taught the *whole truth*. They were fallible mortals. They were liable to err. They did err. But their achievements in the respective regions of knowledge which they explored and cultivated, were so splendid, as to command the admiration not only of their countrymen and contemporaries, but of the civilised world, and of posterity. Beside all the light they individually threw on the departments of science which they undertook to investigate, each commenced, or rendered popular, a mode of philosophising in his particular sphere, equally new, grand, and interesting; and they may be said to have laid the foundation of all the magnificent structures that have been since erected.

To NEWTON no successor has hitherto appeared. The chair which he left has never since been filled. It is probable no effort of the human mind, to rear a rational and permanent system of philosophy, was ever attended with such a degree of success as that which he made. Certainly no other system ever attained such extensive and undisputed empire in science. It is founded on principles so precise, connected, and firm; it explains, with such luminous clearness, most of the phenomena of the heavens which had been observed before his time, as well as of those which the persevering industry, and the more perfect instruments, of later astronomers have made known; and instead of being undermined or discredited, has been so remarkably illustrated and confirmed, by the labours of subsequent inquirers; that every thing like efficient opposition seems to have been long since given up; and the admiring world appears no longer to hesitate in placing the discoveries of this wonderful genius among the most important that were ever made by man, and among the very few which may justly lay claim to immortality.

And if the intellectual system of Locke have gained a sway less general and potent, than the physical doctrines of his great contemporary; still, perhaps, his genius ought to be considered as but little inferior. What though a few respectable metaphysicians, since his day, have pointed out some errours in his principles, and suggested some valuable improvements in his philosophy of mind? They were taught by him to think and to reason. They stood on ground which his wisdom and diligence had gained. As long as the human faculties continue to be objects of study, this illustrious man must be considered one of the greatest fathers of knowledge, and his writings as forming a distinguished æra in the history of science.

But though no builders in the temple of science have risen to the same rank with those master workmen, whose names have been mentioned; yet many distinguished men, within the period of which we are speaking, have contributed their labours to enlarge, to simplify, to strengthen, and to adorn the edifice, with honourable success. Of these, time would fail us to recount even the principal names. The most general and superficial views only of their laudable achievements can be here given.

CHAPTER I.

MECHANICAL PHILOSOPHY.

UNDER this general head is included the whole of that extensive branch of science, " which explains the sensible motions of the bodies of the universe, with the view to discover their causes, to account for subordinate phenomena, and to improve art." In this department of science, the progress of the last century has been astonishingly great. New fields of inquiry have been opened; splendid discoveries have been made; and facts, apparently discordant, have been connected and systematised, to an extent which does signal honour to human capacity, and which far surpasses what the most sanguine projectors of former times had reason to anticipate. And the paths to yet farther improvements in this science are so clearly marked out, that nothing seems requisite but honest industry, patience, and persevering attention, to enable future adventurers to penetrate into regions of knowledge, at present far removed from the sight of man.

Though the Newtonian Philosophy is, perhaps, one of the noblest products of human genius ever given to the world; yet that great interpreter of nature was by no means free from mistake, which besets and characterises all human labours.—His errours, which probably, all things considered, were as few as ever mingled themselves with so extensive and important a system, were, some of them, corrected by his successors; who, while they could distinguish spots in this luminary of science, yet were not backward to pay due homage to his general and splendid excellence.— But, though he had many philosophical adversaries, who called in question his right to the honour of certain discoveries, and who opposed particular doctrines, there were few who ventured to declare war against the leading principles of his system. This however was done by some, respectable both for their learning and talents.

Among these, perhaps none are more worthy of notice than the celebrated John Hutchinson *, of Great Britain, and his followers, who occupy a considerable space in the scientific history of the eighteenth century. Mr. Hutchinson, dissatisfied with the prevalence of Newton's opinions, and, perhaps, feeling some envy at his extended fame, undertook to disprove the doctrines displayed in his *Principia*, as hostile to revelation, and, of consequence, false. To effect this, he published, in 1724, the first part of a large and learned work, which he called *Moses's Principia*, in which he ridiculed the doctrine of gravitation as impious and absurd; and in 1727, the second part, in which he delivered what he supposed to be the true principles of scripture philosophy. This singular philosopher taught, that the sacred writings are in-

* Born in Yorkshire, in 1674, and died in 1737. He was, undoubtedly, a man of respectable talents, and great learning.

tended to instruct us in all physical as well as moral and spiritual truth: that the Hebrew text of the Bible is not only, in every respect, entire, as it came from God; but also that every word of it is pregnant with philosophical, as well as theological, meaning. Hence his hypothesis is chiefly founded on arbitrary and fanciful interpretations of Hebrew words, from the hidden meaning of which he and his followers supposed themselves to have drawn the richest stores of various kinds of knowledge.

According to Hutchinson, " all things are contained in the substance of God, and his substance extends to infinite space. Heaven and earth, space and matter, are created things, and consist of solid atoms; those of the earth adhering in bodies or dense fluids—those of Heaven in orbs, darkness, fire, light, and clouds. The universe is *full* of these solid atoms: in other words, creation is a *plenum*. The matter of the heavens is fluid; it is also finite, and has circumferential limits or extremities, though it extends through all created space, from the sun, its centre, beyond the remotest fixed stars. This matter of the heavens consists of *spirit*, or *air*, *light* and *fire*, as three of its principal modifications. The sun is the fire-place which sets all this matter in motion, melting, expanding, and throwing it off to the most distant confines of creation, where it is cooled, consolidated, and pressed back again, to be melted anew, and sent forth a second time; and so on. The solid atoms are of different sizes and figures; so that, when one portion of them congeals, or forms into grains, there are pores among them large enough to permit atoms of a smaller size to pass freely through. The condition of the matter of the heavens, under the action of fire at the sun, was *chamah;* the streams of light from the sun, moon, and stars, were *ashteroth;* and the grains of air returning from the circumference of the heavens to the sun, were *baalim.* Concrete matter, however, is often so constituted as not to be permeable very easily, but to resist. The several sorts of atoms composing the fluid matter which occupies immeasurable space, are the moving powers by which God acts upon and regulates the machinery of the universe. The more compact or unyielding modifications of it constitute the great orbs, or machines, to be urged along by their impulse. The latter are the *chariots,* and the former the *drivers.* When, therefore, light, impelled by the sun, strikes the side of such a body as the earth we inhabit, it excites heat in that part, and the spirit, or air, being rarefied, or made to recede thereby, motion is communicated to the whole orb. The motion thus begun, is promoted and continued by the vast and incessant pressure of the dark, cold, and dense matter on the opposite side. And thus the globe being started by the lessening of pressure on one side, and the augmentation of it on the other, its diurnal and annual revolutions were soon impressed upon it by a little variation of the forces. The like reasoning he applied to the moon, and to all the other planets and their satellites. By the operation of light, thus sent out from the sun, and acting upon the other fluid matter of the heavens, and upon the celestial orbs, they become enlightened, warmed, or inflamed: spirit, or air, pushed in with irresistible compression; and motion, rotation, and progression were accounted for, without having recourse to such miserable terms as projection, gravitation, or attraction*."

These wild and fanciful opinions attracted much attention in Great Britain, and were embraced by some learned and respectable men; especially by those who entertained the groundless fear, that Newton's system of philosophy was hostile to revelation. Among these the celebrated Parkhurst, bishop Horne, and the rev. Mr. Jones of Nayland, were, perhaps, the most able and distinguished.—But, notwithstanding the weight of a few names, which appeared on the side of this hypothesis, before the close of the eighteenth century it had lost a large portion of its advocates; and both the admiration and the knowledge of Hut-

* After examining, with considerable care, Hutchinson's Works, in 12 vols 8vo, printed in 1748, I did not dare to undertake the arduous task of exhibiting the opinions scattered through his erudite but obscure pages, in a short compass, and in my own language. I have therefore taken the above abstract from the Medical Repository, vol. iv, pp. 281, 282. Those who wish to obtain a farther knowledge of the peculiar notions of this singular man, without the trouble of wading through his dull and tedious volumes, will find a tolerably distinct and comprehensive account of them, in *the State of the Republic of Letters*, &c., vol. v, for the year 1730. See also *Additional Notes—(A)*. It is curious to observe, that while the *Hutchinsonians* so liberally censure the followers of Newton for giving too much *activity* to *matter*, they fall into the same error (as they call it) in an equal degree. But, in truth, if Newton's idea of *attractive power* be examined, it will be found only another mode of expression for *a continual Divine agency*, exerted *according to a certain law*.

chinson's voluminous writings had nearly disappeared*.

Another opponent of the Newtonian system was Godfred William Leibnitz, a philosopher of Leipsic, in Germany, whose celebrated theory demands our notice. He taught that the whole universe is made up of *monads*, that is, simple substances without parts or figure, each of which is, by the Creator, in the beginning of its existence, endowed with certain active and perceptive powers, sufficient to produce all the changes which it undergoes, from the beginning to eternity; which changes, though they may seem to us to be the effects of causes operating from without, are only the gradual and successive evolutions of the monad's own internal powers, which would have produced the same motions and changes, although there had been no other being in the universe. He supposed, farther, that the universe is completely filled with monads, without any chasm or void, and thereby every body acts upon every other body, according to its vicinity or distance, and is mutually reacted upon by every other body; hence he considered every monad as a kind of living mirror, which reflects the whole universe, according to its point of view, and represents the whole more or less distinctly. The adoption of this visionary system led Leibnitz to oppose, with considerable warmth, several of the leading doctrines of Newton, and especially his great principle of gravitation. The hostility of the German philosopher toward the illustrious Briton was particularly displayed in his controversy with

* See *Additional Notes*—(*B*).

the learned and acute Dr. Samuel Clarke. The papers which gave rise to this controversy, together with the various answers, replies, and rejoinders which took place in the course of it, were transmitted from the one party to the other, through the hands of queen Caroline, consort of George I, and the patron and correspondent of Leibnitz. They were afterwards published, and hold an important place in the philosophical history of the age.

Soon after the theory of monads was published, Christian Wolfe, a philosopher of Breslau, formed, on the foundation of this theory, a new system of *Cosmology*, digested and demonstrated in a mathematical method. He was one of the most voluminous writers in philosophy which the century afforded, and is considered as the great interpreter and advocate of the Leibnitzian system.

Another *theory of matter*, which distinguished the eighteenth century, was that of Father Boscovich *, a learned Jesuit of Italy.—Newton paid little attention to the individual atoms of which matter is composed. The attraction and repulsion of which he spoke, appear to refer chiefly to the laws of motion of the larger bodies which we behold. He expressed a suspicion, indeed, that "As the great movements of the solar system are regu-

* Roger Joseph Boscovich was born at Ragusa in 1711, and died at Milan in 1787. When the order of Jesuits was suppressed, he was invited to Paris, and made director of the optical instruments of the marine; in which office he was led to improve the theory of *achromatic* glasses. He returned to Italy in 1783. His philosophical works are numerous, profound, and elegant. He published a poem, entitled, *De Solis ac Lunæ Defectibus*, which is highly esteemed.

lated by universal gravitation; so the mutual actions of the particles of matter are produced and regulated by tendencies of a similar kind, equally, but not more, inexplicable, and the principles of which are to be discovered by as careful an attention to the phenomena, and by the same patient thinking which he had employed on the planetary motions." But he seems to have willingly yielded, to some able and diligent inquirer who should come after him, both the labour and the honour of exploring this extensive field of speculation.

Such an inquirer was the illustrious Boscovich, a man equally distinguished for the purity of his moral and religious character, the depth of his erudition, and the native vigour and acuteness of his mind. A few years after the death of the great British philosopher, he published a new *theory of matter*. In this theory, the whole mass of which the bodies of the universe are composed, is supposed to consist of an exceeding great, yet finite, number of simple, indivisible, inextended atoms. These atoms are endued by the Creator with *repulsive* and *attractive* forces, which vary according to the distance. At very small distances the particles of matter repel each other; and this repulsive force increases beyond all limits, as the distances are diminished; and will, consequently, for ever prevent actual contact. When the particles of matter are removed to sensible distances, the *repulsive* is exchanged for an *attractive* force, which decreases in an inverse ratio with the squares of the distances, and extends beyond the sphere of the most remote comets. Beside these repulsive and attractive forces, the particles of matter have that *vis inertiæ* which is admitted by almost all modern philosophers. These atoms, endued with these forces and properties, form the basis of this celebrated system; a system unquestionably among the most remarkable that have been proposed to the world in modern times, and which leads to consequences in a very high degree interesting *. This system has been, in substance, adopted by many of the learned in various parts of Europe; and is supposed, by those who embrace it, to afford a very satisfactory solution of many difficulties to which former theories evidently gave rise; to explain most happily the various phenomena of matter to which its principles extend; and to receive confirmation by the experiments and discoveries of every day. If we may rely on the doctrines of the ingenious Italian, the stumbling-blocks of the *infinite divisibility* and *impenetrability* of matter will be taken out of the way; many of the most fruitful sources of perplexity and dispute respecting *extension*, *elasticity*, &c. will be cut off; a large portion of the difficulties attending the *affinities*, *attractions*, and *combinations* in chemical philosophy, hereafter to be noticed, will diminish, if not disappear; and the path to a just understanding of all the physical sciences will be simplified and smoothed in a very pleasing degree †.

* See *Additional Notes—(C)*.

† The author has never yet been able to procure a copy of the *Theoria Philosophiæ Naturalis* of Boscovich, published in 1758; but a very satisfactory abstract of the work is given in the *Supplement* to the *Encyclopædia*, lately published by Dr. Gleig. The system is, in some of its parts, so intricate, and throughout so involved in mathematical calculation, that a more full account of it could not be given in the present sketch. It is charged, by some,

But, beside these new theories and ingenious discussions, respecting the general principles and properties of matter, almost all the particular departments of mechanical philosophy have been investigated with great diligence and success, throughout the whole of the period under consideration.

SECTION I.

ELECTRICITY.

Concerning Electricity, that powerful and still mysterious agent, philosophers of the last age have made splendid discoveries. At the beginning of the eighteenth century, this branch of science could hardly be said to have a place in systems of philosophy. Its phenomena had been so little the subject of experiment, and its laws had been so little comprehended or methodised, that scarcely any thing which deserves the name of theory on the subject, was then presented to the world. It is true, a number of facts were then known, and some experiments had been made, in order to elucidate this dark recess of science. But they were known, for the most part, only as insulated facts, without any correct idea of the relation subsisting between them, or of the general principles upon which they depended. The principal of these facts had been brought to light by Dr. Gilbert, Mr. Boyle,

with having an *atheistical* foundation and tendency. Of the ground of this charge too little is known by the writer to attempt a discussion of it.

and sir Isaac Newton; but they continued to lie in uncertainty and confusion, until 1709, when Mr. Hawksbee, an English gentleman, wrote on the subject, and distinguished himself by the experiments and discoveries which he announced. He first took notice of the great electric powers of *glass*, together with a variety of phenomena relating to electrical attraction and repulsion; insomuch that his writings and experiments form a grand æra in this branch of knowledge. From the time of Mr. Hawksbee's publication, near twenty years elapsed before any farther discoveries or improvements were suggested.

In 1729, the fundamental distinction between *conductors* and *nonconductors* was first ascertained by Stephen Gray, a British philosopher, who had for some time before amused himself with electrical experiments, and who was now accidentally led to the discovery of this important principle. Soon afterwards M. du Fay, member of the Academy of Sciences at Paris, in repeating Mr. Gray's experiments, unexpectedly perceived, for the first time, that difference in the attractive powers of different bodies, which he supposed to arise from two different species of electric fluids, and which he denominated the *vitreous* and *resinous* electricities. The drawing a spark from the living body was also first observed by this gentleman, and his companion, the abbé Nollet. The next person who distinguished himself in this part of science was Dr. Desaguliers, who, though he added but little to the knowledge before possessed, yet made some valuable experiments, and invented some *technical terms*, such as *conductor, electric per se, &c.*,

which have proved highly convenient, and are still in use. About 1742 electricity began to excite attention, and became the subject of much inquiry in Germany. Professor Boze, of Wittemburgh, and professor Winckler, of Leipsic, invented several improvements in the apparatus for conducting experiments. Dr. Ludolf, of Berlin, first succeeded in setting fire to inflammable substances by the electric fluid; and Mr. Waitz, Mr. Allamand, and others, made some new observations, though chiefly of the smaller kind. To the experiments in Germany succeeded those of Dr. William Watson, in Great Britain. He first ascertained that the friction of an electric did not *produce*, but only *collected*, the mysterious matter which wrought such powerful effects; and also made a number of other interesting additions to the knowledge before existing on the subject. The year 1745 was distinguished by a discovery still more remarkable and important than any that preceded it—viz. the method of giving a shock, by accumulating the electric fluid in a jar, and discharging it by means of a conductor. This discovery was made by Mr. von Kleist, dean of the cathedral in Camin; and the next year the experiment being repeated in a different manner, and with better success, by Mr. Cunæus, of Leyden, the jar so filled became generally known by the name of the *Leyden phial*, which it has retained to the present day. Soon afterwards, Mr. Gralath, a German, first contrived to increase the shock by charging several phials at the same time, and making what is now called a *battery*.

About the same time experiments began to be made of the effects produced by electricity on *animal* bodies. In these inquiries the abbé Nollet greatly distinguished himself. He pursued his investigations with singular ingenuity, labour, and expense; and opened a new and noble field of electrical discoveries. The application of electricity to growing *vegetables* was first made by Mr. Maimbray, of Edinburgh, who found that, in certain cases, it expedited the progress of vegetation. In these experiments he was followed by the abbé Nollet, M. Jallabert of Geneva, Mr. Boze before-mentioned, and a number of others on the continent of Europe, who all drew the same conclusions*.

In the midst of the general attention, and the deep interest which this subject now began to excite throughout the philosophic world, Dr. Franklin, in 1752, after having been for some time engaged in making new and interesting experiments, discovered the *identity of the electric fluid and lightning* †; a discovery of the greatest practical utility;

* See *Additional Notes*—(D).

† There are persons who believe, but probably without sufficient foundation, that this fact, and several others relating to electricity, generally supposed to be modern discoveries, were known to the ancients. Those who wish to see this opinion ingeniously and learnedly defended, will be gratified by a perusal of M. Dutens' work, before quoted; and also, an interesting paper in the *Memoirs of the Literary and Philosophical Society of Manchester*, vol. iii, by William Falconer, M. D. F. R. S. To which may be added a curious passage in signor Boccalini's *Advertisements from Parnassus (Century* 1, *Chap.* 46,) published more than one hundred years before the date of Franklin's discovery. For a reference to this passage, I am indebted to the rev. Dr. Nisbet, president of Dickinson College, Pennsylvania; a gentleman whose profound erudition, embracing the literature and science

and, perhaps, the only one, in the science under consideration, which was the result of preconceived opinion, and of experiments instituted with an express view to ascertain the truth. Dr. Franklin's ideas were soon afterwards confirmed by Messrs. Dalibard and Delor, of France; who had come to a similar conclusion before they were informed of what had been done on the other side of the Atlantic. The same illustrious American also first discovered, in conjunction with his friend Mr. Thomas Hopkinson, the peculiar power of *pointed bodies* to draw off the electrical matter more effectually, and at a greater distance, than others; founded on which was his ingenious invention for defending houses from the destructive effects of lightning, by the use of *metallic conductors.* About the same time, Dr. Franklin's friend, Mr. Kinnersly, distinguished himself by rediscovering the apparently contrary electricities of glass and resin, or sulphur, which M. du Fay had long before observed, but with the discovery of which he and Dr. Franklin were both unacquainted *. To solve the difficulty arising from this fact, the doctor, instead of recurring to the supposition of two different *kinds* of electric matter, as the French philosopher had done, proposed his celebrated theory of *positive* and *negative* electricity, or the *plus* and *minus* states of bodies charged with this fluid; a theory which had been before suggested by Dr. Watson, and which was

of almost all cultivated languages, is well known to the public; and with whose friendship I consider it one of the most happy circumstances of my life to be honoured.

* See *Experiments and Observations on Electricity,* &c., by Benjamin Franklin, LL. D. F. R. S. London, 4to. 1769.

afterwards generally received throughout the scientific world; and, though by no means without opposition, still continues to hold a more extensive influence than any other.

Electricity seems to have been first applied to *medical* purposes by Mr. Kratzenstein, professor of medicine at Halle, in 1744. From that period it gradually grew into notice, by means of the experiments of the abbé Nollet, Jallabert of Geneva, Sauvages of Montpellier, Bohadsch of Prague, Dr. Watson before mentioned, Dr. Franklin, and many others. The medical virtues of this wonderful fluid soon excited attention and inquiry throughout the scientific world. And although the repetition of experiments, which has been constantly going on from that period to the present, has served to correct many errors into which the enthusiastic fell in the beginning; yet electricity, after undergoing many revolutions of fashion, is now well established as an important article of the *Materia Medica.*

After the interesting discoveries of Dr. Franklin, the next great experimenters and discoverers in electricity were Mr. Canton of Great Britain, signor Beccaria of Italy, and Mr. Wilcke of Germany, who considerably enlarged the sphere of our knowledge respecting the conducting powers of different substances, and threw farther light on the *plus* and *minus* states of electrics. The doctrine of Franklin, that these two states arise from a redundancy or deficiency of the same matter, was but little opposed, until 1759, when Mr. Symmer, an English philosopher, revived the ideas of du Fay, with some new modifications of his own.

He taught the existence of *two electric fluids*, not independent, but always coexistent, and counteracting one another *. In this opinion he has been followed by some gentlemen of very respectable character in Great Britain and on the continent of Europe; though by far the greater number of the learned appear still to be in favour of the *Franklinian* theory †.

The progressive improvements of electrical *machines*, and of the various instruments for exhibiting the phenomena of this science, have generally kept pace with the gradual developement of its principles. Hence the honour of these improvements is, in general, due to the gentlemen already named. Beside these, several artists of respectable character have done much to forward the mechanical part of this branch of philosophy.

Soon after the grand discoveries of Franklin, Mr. Æpinus, a philosopher of high character in the Imperial Academy of St. Petersburg, assuming his principles, offered to the world some new and interesting views on this branch of science. Struck with the resemblance between the phenomena of electricity and magnetism, and believing that the attractions and repulsions of each might be reduced to regular and similar classes, he attempted to throw the laws of both into a perfectly systematic form, and to introduce the most precise mathematical calculations into regions which were before

* See *Additional Notes—(E).*

† The above-stated facts, relating to the rise and progress of electricity, are chiefly taken from Dr. Priestley's *History of Electricity*, 1794, London, 4to.

supposed, from their indefinite and mysterious character, least of all susceptible of being explored in this manner *. It is believed by many, that this hypothesis, to the unquestionable claim of ingenuity adds that of being founded in truth; and that it will probably lead to the solution of many difficulties hitherto deemed insolvable. However this may be, it must be confessed the ingenious Russian has enabled us, by his mathematical principles, to class many of the phenomena of which he treats, with a plausible precision, and to predict the result of proposed experiments with very pleasing success †.

During the last thirty years of the eighteenth century, though it cannot be said that so much has been done in electricity as in the like period immediately preceding; yet several important discoveries, within that time, have been announced. The inventions of the *electrophorus*, and the *condenser*, by professor Volta, and of the *doubler* of electricity, by the rev. Mr. Bennet, of Great Britain; the discovery of the effects produced by the electric matter on permanently elastic fluids, and on water, by Mr. Cavendish, and others; and the new results of experiments, with respect to the influence of electricity on vegetables, by Dr. Ingenhousz, and Messrs. Rouland, d'Ormoy, Carmoy, and others, of France, may be considered among the most interesting of recent improve-

* See *Additional Notes—(F).*

† See *Theoria Electricitatis et Magnetismi*, 1759, Petersburg, 4to. See also a good abstract of the doctrines of Æpinus, in the *Supplement to the Encyclopædia*, published by Dr. Gleig.

ments *. Mr. Cavendish and lord Mahon are the only distinguished writers on electricity, in the English language, who have attempted, like Æpinus, to introduce the mathematical form of investigation into this science. The publications of Dr. Priestley, Mr. Cavallo, and Mr. Adams, on the subject, are also worthy of honourable notice. The first, beside his excellent *History of Electricity*, instituted a number of original experiments; suggested many important inquiries; improved the electrical apparatus; and, on the whole, did much to advance our knowledge of this branch of philosophy. The latter gentlemen, in addition to many new experiments, have presented to the world condensed and very satisfactory views of the subject, both in a *philosophical* and *medical* view, and have contributed much to render it popular and useful.

SECTION II.

GALVANISM.

To this chapter belongs some notice of that principle, or influence, discovered a few years ago by Dr. Galvani, a philosopher of Bologna, and since, in honour of him, denominated Galvanism. It was first called *Animal Electricity*, a name which had been, for a number of years before, given to

* For a more full account of the above recent discoveries and improvements, see the last vol. of *Cavallo's* Electricity, 3 vols, 8vo edition 1795, and the art. *Electricity* in the *Encyclopædia*, and the *Supplement*.

a remarkable property observed in several fishes, of conveying a shock, or a benumbing sensation, to those who touched them *. But this property was always found to be extinct or dormant in such animals immediately after their death †. In 1762, Sulzer, a German, in his *Theory of agreeable and disagreeable Sensations*, gave some hints of a curious effect resulting from the junction of two pieces of different kinds of metal, and applying them, thus joined, to the tongue; but these hints seem to have been disregarded, and were soon buried in oblivion. In 1791 professor Galvani announced a discovery made by him, that the muscles of dead animals might be stimulated and brought into action, by means both of artificial and atmospherical electricity. He also discovered, that, independent of any collection of the electric fluid for the purpose, the same action might be produced in the dead animal, or even in a detached limb, merely by making a communication between the nerves and the muscles with substances that are conductors of the electric matter ‡. Galvani's first experiments were made on dead *frogs;* but the discovery, soon after being announced, was pursued; experiments were made on different animals; and a number of new facts, tending to show the connexion between *Galvanism* and electricity, and the circumstances

* These are the *torpedo,* the *gymnotus electricus*, the *silurus electricus,* and a fourth, found near one of the *Comoro* islands, by lieut. William Patterson, of which an account is given in the 76th vol. of the *Philosophical Transactions.*

† See *Additional Notes—(G).*

‡ *Aloysii Galvani de Viribus Electricitatis,* &c. 4to. Bononiæ, 1791.

in which they differ, were brought to light by professor Volta, and Dr. Eusebius Valli, of Italy; by Mr. von Humboldt, and Dr. Pfaff, of Germany; by Dr. Munro, Dr. Fowler, Mr. Cavallo, and Dr. Lind, of Great Britain; and by Coulomb, Fourcroy, Sabbatier, Pelletan, and others, of France.

Hitherto this influence or agent had been chiefly investigated with reference to its operation on *animal* substances. Hence its popular name was, for a considerable time, *animal electricity.* But it being soon found, that its agency was more extensive; that it possessed powers not indicated by this denomination; and that of course the retention of this name would lead to error, the word *Galvanism* was adopted in its stead. This extension of the Galvanic principle was connected with new discoveries and improvements, from various quarters; these, however, for a considerable time, were generally small, and unimportant in their nature.

But among all the recent discoveries in *Galvanism,* that made by professor Volta, in 1800, is most remarkable in its nature, and most interesting in its relations. His mode of constructing a *pile,* for condensing, retaining, and communicating a perpetual current of the *Galvanic influence,* is generally known*. The curious phenomena which

* The pile of Volta is thus formed. Take a number of plates of *silver,* an equal number of *zinc,* and the same number of pieces of *card* or *woollen cloth.* Let these last be well soaked in *water,* or water saturated with common *salt,* or, which is perhaps still better, with *nitre.* A *pile* is then to be formed of these substances, in the following manner. A piece of zinc, a piece of silver, and a piece of wet cloth or card, are to be successively

this pile exhibits; the connexion which these phenomena indicate with the principles both of electricity and of chemistry; and the numerous experiments and successive improvements in the management of this Galvanic battery by Messrs. Carlisle, Nicholson, Cruickshank, Davy, and others, of Great Britain; by van Marum, of Holland; and by Fourcroy, Vauquelin, and Thenard, of France, have not only excited much attention in the scientific world, but may also be ranked among the rich additions to philosophy which modern times have produced.

It must be admitted, however, that little more has been done, in this new branch of philosophy, than to ascertain a number of facts, sometimes

placed on each other; then another piece of zinc, and so on in the order of the first layer. In this manner, the pieces are to be arranged, or in any other manner, provided a regular alternation be observed, until the requisite number shall be laid. The instrument is then fit for use. The pieces of card should be somewhat less than the pieces of metal, and, after being well moistened, should be gently squeezed before they are applied, that the superfluous moisture may not run down the pile, or insinuate itself between the pieces of metal.

The instrument constructed in this manner affords a perpetual current of the Galvanic influence; and if one hand be applied to the lowest plate, and another to the uppermost, a shock is felt, as often as the contact is repeated. The shock received from this pile is somewhat like that given by a Leyden phial; but more nearly resembles that given by a *Torpedo,* which animal this apparatus also resembles in giving incessant shocks. The intensity of the charge is, however, too small to make its way through the dry skin; it is therefore necessary that each hand should be well wetted, and a piece of metal be grasped in each to make the touch;—and the larger the piece of metal which is thus held in the hand, the stronger the shock. Garnett's *Annals of Philos.* vol. i, p. 10, &c.

contradictory in their aspect, and generally inexplicable, without either forming a theory sufficiently fixed or luminous to satisfy the inquirer, or instructing us in what manner this principle may be applied for the benefit of mankind *. Professor Galvani, signor Volta, and several other distinguished experimenters, have supposed the Galvanic phenomena to arise from the operation of the *electric* fluid. They observed that this substance seemed to move with rapidity; that it produced a sensation similar to the electric shock; that it passed with facility through metals, and other conductors of electricity; while it was stopped in its course by glass, sealing-wax, and other substances which we know to be nonconductors of the electric matter. Others, on the contrary, observing several phenomena, which were thought to be incompatible with the known laws of electricity, or inexplicable by them, have rejected this opinion, and resorted to different means of solving the difficulty.

M. Fabroni, who made a number of ingenious experiments in *Galvanism*, was the first who systematically attempted to prove that the effects which he observed arose from *chemical* causes †. This opinion has led to much curious investigation; and various experiments evince that the agent in question produces, most powerfully, some effects,

* Since the above was written, very curious information has been received from Germany, respecting the application of *Galvanism* to *medical* purposes. It appears to possess great efficacy in removing many diseases arising from nervous derangement and muscular debility.

† See Nicholson's *Philosophical Journal*, vol. iii, p. 308.

particularly *decompositions*, which have been hitherto considered as belonging to the province of chemistry alone*. At the close of the century this question was far from being satisfactorily solved. But as the subject has excited so much attention among philosophers, in every part of Europe, and as new facts will probably be brought to light every day, we may hope that the time is not very distant, when a sufficient number of facts will be arranged to form a consistent and satisfactory theory, and when Galvanism will take its place among the most dignified and useful of the sciences†.

SECTION III.

MAGNETISM.

This branch of philosophy, during the same period, has been an object of less attention than electricity, and of fewer speculations; probably on account of the smaller range of its phenomena, and its being less capable of popular exhibition. Still, however, it has been considerably cultivated, and has received some important improvements, since the time of Dr. Gilbert, the great father of magnetical philosophy. The number of facts concerning this mysterious kind of attraction has been greatly augmented. The points in which it resembles, and those in which it differs from electricity,

* See *Additional Notes*—(*H*).

† For further information on this subject, see the *Supplement* to the *Encyclopædia*, art. Galvanism. See also Garnett's *Annals of Philosophy* for 1800.

have been more satisfactorily ascertained; and a nearer approach made than formerly to a systematic arrangement of the magnetic laws.

The unexpected and daring introduction of mathematical principles and demonstration into the dark regions of *electricity*, by Mr. Æpinus, was mentioned, in a former page, as one of the signal improvements of the last century. This ingenious philosopher has done the same in *magnetism*, and with equal success*. And though this subjection of the magnetic principles to the most precise and definite of all species of investigation does not appear to have led, as yet, to any extraordinary discoveries, or radical reforms in theory; yet it has been by no means without its use, and may conduct to invaluable acquisitions †.

The *Mariner's Compass*, within the period in question, has been considerably improved. This important instrument, after its invention in 1302, long remained in a rude and imperfect state. But Dr. Knight's discovery of the mode of making artificial magnets, about the year 1744, together with the results of some other experiments, enabled him to render the compass much more convenient and useful ‡. To his improvements may be added the further emendations of Mr. Smeaton and Mr. M'Culloch, both of Great Britain.

The *variation* of the magnetic *needle* has been a subject of much attention and of much ingenious speculation, during the past century. The obser-

* *Tentamen Theoriæ Magn. et Electr. Petrop.* 1759.

† See *Additional Notes*—(*I*).

‡ See *Additional Notes*—(*K*).

vations made by Dr. Halley, and published in 1701, in the form of a *variation chart*, were of great use to navigators, and contributed not a little toward reducing the principles of this variation to something like an intelligible form. The next attempt of the same kind, worthy of notice, was that of Euler. This philosopher, equally remarkable for the extent of his learning, and the vigour and comprehensiveness of his mind, undertook, about the middle of the century, to account for the magnetic irregularities, and to ascertain the position of the needle in every part of the earth. He executed his task with singular ingenuity and perseverance, and with a plausible appearance of success. But his theory, and the whole structure founded upon it, were soon found liable to such objections, that they were considered of little value, excepting so far as they might furnish a guide in the further prosecution of the inquiry. Since the time of Euler, many others have exerted their genius in the same investigation; but without producing more certainty or satisfaction. Among the latest explorers of this dark but important subject, Mr. Churchman, a respectable citizen of America, deserves to be honourably mentioned. He has, in his own opinion, made valuable improvements on the theories of Halley and of Euler; corrected various errors into which those great philosophers fell; and given an hypothesis which bids fair to be of more practical utility than theirs to the nautical adventurer. How soon this hypothesis may be brought to the test of a complete course of experiments, or how it may bear this test, when subjected to it, are questions yet to be solved. In the mean time, the ingenuity, zeal, and perseverance, evinced in Mr. Churchman's late publications on this subject, deserve the attention, the thanks, and the encouragement of the philosophic world *.

Many other writers, of acknowledged scientific eminence, have distinguished themselves by new experiments, and ingenious hypotheses on magnetic attraction, within the period of which we are speaking. Among these may be mentioned Muschenbroeck †, Whiston, Celsius ‡, van Swinden, Lambert §, Euler ||, Knight ¶, Mitchel, Canton, and Cavallo. To detail the opinions entertained, and the facts successively brought to light by each, would far exceed our prescribed limits. But, after all the inquiries of these philosophers, it must be acknowledged that "clouds and darkness rest" upon this part of science; that even its general principles are little understood; and that we are yet far from being furnished with materials for a satisfactory system on the subject. Perhaps another century may accomplish this, which, when

* See Churchman's *Magnetic Atlas*, 4to, 3d edition, 1800.

† *Dissert. Physico-Experimentalis de Magnete.*

‡ *Tentamina Magnetica*, 4to. Also *Memoirs on the Analogy between Elect. and Mag.* 3 vols, 8vo, 1785.

§ The experiments and calculations of M. Lambert, on the *polarity* and *variations* of the magnetic needle, deserve particular attention. He was a very accurate and sagacious philosopher. See the *Memoirs of the Academy of Berlin*, for 1756, published in 1758.

|| *Euleri Opuscula*, tom. iii, *continens Theoriam Magnetis*, Berlin, 1751.

¶ *An Attempt to explain the Phenomena of Nature by Two Principles, &c.* 4to, 1748.

viewed in its various relations, must be regarded as a grand *desideratum* in philosophy *.

In 1774 arose the idea of a certain sympathy existing between the magnet and the human body, by means of which the former might be applied to the cure of diseases. This opinion appears to have originated with father Hehl, of Germany, who greatly recommended the use of the magnet in medicine. On some experiments and suggestions of Hehl, the famous Mesmer, a German physician, about the year 1766 erected his fanciful system of *Animal Magnetism*. The noise made by the opinions and arts of this celebrated empiric, and his coadjutors, in Germany, in France, and indeed, though in a less degree, throughout every other part of Europe, is well known to all acquainted with the literary history of that period; as well as the detection, the decline, and the final disgrace of them and their principles †.

M. Prevost, of Geneva, in 1788, published a new doctrine concerning Magnetism, in an ingenious and interesting dissertation on the subject. In this work he expresses a belief that there are *two magnetic fluids*, which, by their union, compose a *third*, which he calls *combined fluid*. These two fluids, he thinks, are both elastic like air; the particles of each attract those of its own kind, but not so strongly as those of the opposite kind. A strong elective attraction, which the combined fluid

* See *Additional Notes—(L)*.

† For an amusing account of the noise and pretensions made by Mesmer, see Willich's *Lectures on Diet and Regimen*, &c. See also Report of the Commissioners appointed by the French King to examine into Animal Magnetism.

possesses for iron, decomposes part of the fluid in the iron, and each of its ingredients occupies opposite ends of the bar. Bars in this state approach, if the ends nearest each other contain different ingredients, but recede if they contain the same *.

SECTION IV.

MOTION AND MOVING FORCES.

This part of science also, within the century under consideration, has received no small improvement. The laws of *motion*, as laid down by sir Isaac Newton, though found, by succeeding philosophers, to be in general correct, were yet by no means perfectly so. His principles of motion in *resisting mediums* particularly failed, when brought to the test of accurate experiment. Numerous have been the attempts to supply the defects, and to correct the errors of these principles: among which the labours of D. Bernoulli, and of M. d'Alembert, deserve to be considered as by far the most distinguished and successful. The latter in particular, in the course of his investigations, discovered a general rule, adequate to the determination of many important questions in the science of motion, and applying to the most compound and perplexing cases †.

The inaccuracy of Newton's principles, with regard to *projectiles*, was first ascertained and announced by M. Ressons, a French artillerist, in 1716. Nothing material, however, was done to-

* See *Essai sur l'Origine des Forces Magnétiques*, 1788.

† Condorcet on the *Mind*, p. 275.

ward the establishment of new and more just laws, till 1742, when Benjamin Robins, of Great Britain, published his *New Principles of Gunnery*, a very able and interesting work.

Mr. Robins certainly did more to improve the science of *military projectiles* than any individual, not to say than all other individuals, who had gone before him. He made a great number of well-devised and important experiments; and, in the work above-mentioned, left a lasting monument both of genius and of labour.

From the experiments detailed in this work, which was published in 1742, it incontestably appeared, that the resistance made by the air to projectiles which have a rapid motion, is much greater than had been supposed by Newton and Huygens; that it is, indeed, so great, that the path described by any shot whatever is very different from the curve of a *parabola*, and, consequently, that all applications of that conic section to gunnery are false and useless. Mr. Robins's experiments were made with shot of one ounce weight only: it was, therefore, much to be wished, that such persons as had opportunity might repeat the same experiments with balls of a larger size. Mr. Charles Hutton, of the Royal Military Academy at Woolwich, performed this service to science. He even used in his experiments balls from *twenty* to *fifty* ounces weight. The result of these experiments confirmed Mr. Robins's principles in the most ample manner.

Mr. Robins, however, in estimating the mechanical force of *Gunpowder*, fell into an error, which has been since corrected by the acute and persevering count Rumford* of America. The former states this force, according to his experiments, to be 1000 times as great as the mean pressure of the atmosphere; while the celebrated Daniel Bernoulli determined it to be not less than 10000 times as great. Such a difference of opinion led count Rumford to pursue a course of experiments, of which some were published in the *Philosophical Transactions* for 1781, and the remainder in the *Transactions* of the same Society for 1797; with the view principally of determining the initial expansive force of Gunpowder. By one of these experiments it appeared, that, calculating even on Mr. Robins's own principles, the force of Gunpowder, instead of being 1000 times, must at least be 1308 times as great as the mean pressure of the atmosphere. From this experiment the count thought himself warranted in concluding, that the principles assumed by Mr. Robins were erroneous, and that his mode of ascertaining the force of Gunpowder could never satisfactorily determine it. Despairing of success in that way, he resolved to make an attempt for ascertaining this force by actual measurement; and, after many unsuccessful experiments, he was at length led to conclude that this force was at least 50000 times as great as the mean pressure of the atmosphere †.

In addition to the inquiries of these British philosophers, several ingenious men on the continent of Europe contributed to the extension and confirmation of Robins's theory. In this list M. d'An-

* See *Additional Notes*—(*M*).

† Rumford's *Philosophical Essays*, 8vo.

toni, of Italy, and Messrs. d'Arcy and le Roy, of France, are entitled to particular distinction *. Beside these, many experiments have been made, and valuable ideas suggested, respecting motion in resisting mediums, by Gravesande, by J. Bernoulli, by Euler, by Simpson, by M. Bouguer; and by M. Condorcet, abbé Bossut, chevaliers Buat and Borda, and other members of the Royal Academy of Sciences at Paris. And although this part of mechanical philosophy can scarcely be said yet to have received satisfactory elucidation; still much has been done toward the attainment of this object by the mathematicians and artists of the last age; and especially by those of France, who, in the various parts of science immediately subservient to the business of the *Engineer*, have certainly, in modern times, exceeded all the rest of the world.

The discoveries and improvements made, in the course of the last century, with respect to the construction and motion of *pendulums*, are neither few nor unimportant. For the purpose of counteracting the effects produced in the dimensions of the pendulum by heat and cold, from which disorder and error necessarily arise, the contrivances of ingenious men have been numerous and successful. For the purpose, also, of regulating the *curve* in which this body shall move, various devices and calculations have been adopted. The principal of these improvements are, the *Mercurial Pendulum*, invented by George Graham; the *Gridiron Pendulum*; that formed with a rod of *baked and var-*

* Hutton's *Mathematical Dictionary*.

nished wood; the contrivances, by means of a *flexible rod,* and other apparatus, to make the pendulum move in the curve of a *cycloid;* to say nothing of many other ingenious inventions to regulate the motions and to extend the application of this important instrument.

In that part of philosophy which relates to the structure and motion of *machines,* many great minds have been employed, in the course of the last age, and not without making some advances in this department of science.—M. Amontons, of the Royal Academy of Sciences at Paris, about the beginning of the century, very successfully developed some of the general laws of machinery. After him Mr. Emerson, of Great Britain, a distinguished mathematician, investigated and systematised this subject, with still more practical care and accuracy. In 1735 the celebrated Euler undertook to give a general and systematic view of machines, in order to found a complete theory, immediately conducive to the improvement of mechanics. In 1743 he published the first part of his theory, containing many new dynamical theorems of great importance*. He afterwards prosecuted the subject further†, and with so much success, as to excite deep regret that he had not continued his useful labours. Since the experiments and publications of Euler, many philosophers of inferior name have turned their attention to the same inquiry; but without laying the scientific world under the same obligations, by exhibit-

* *Comment. Petropolitani.* tom. i.

† *Comment. Petrop.* tom. iii, and *Mem. Acad. Berlin,* 1747 and 1752.

ing original or very interesting views of the subject. Among these it would be improper to pass, without respectful notice, the valuable services rendered to practical mechanics by Mr. Smeaton and Mr. Bramah, both of Great Britain. The instances of the ingenious application of mechanical principles to the construction of different machines, by which the last century is distinguished, are too numerous, and the authors of many of them too well known, to render a detailed view of them proper in this place.

SECTION V.

HYDRAULICS.

In the principles and practice of this part of science great improvements have been made by the philosophers of the last age. To calculate upon sure and accurate grounds the resistance and motion of dense fluids, so as to furnish a result which might be relied on by engineers, and other mechanics, was considered at the beginning of the century one of the most interesting and difficult problems in mechanical philosophy. Newton first endeavoured to reduce the laws of moving fluids to the precise form of mathematical calculation. In this, however, though he displayed great ingenuity, he was unsuccessful. His demonstrations, when brought to the test of practice, were found inaccurate and inapplicable. Guglielmini, a celebrated Italian, succeeded him, assuming his principles, and aiming to attain the object in view by the same path. He also failed; his calculations turning out equally remote from the truth with those of his illustrious predecessor. After Guglielmini, professor Michelotti, of Turin, D. Bernoulli, of Switzerland, and the abbé Bossut, of Paris, instituted many experiments, to ascertain the theory or mechanism of hydraulic motion. The last gentleman, in particular, conducted his experiments with great labour, care, and perseverance, published a very important work on the subject, and opened a path of inquiry in this field of science, so new, and in a manner so judicious, that he must always be considered as holding a high rank in the hydraulic history of the age in which he lived. After all, however, he left the subject very imperfectly explored. Bossut was succeeded by his countryman, the chevalier Buat, who took up the inquiry where the abbé had left it, prosecuted it with singular skill and assiduity, and formed a system much nearer to the truth than all who had gone before him.—But distinguished as the chevalier has justly rendered himself, by his achievements in this branch of philosophy, he cannot be said so much to have discovered new principles, as to have classed and systematised, with great skill and ingenuity, the principles flowing from M. d'Alembert's unwearied experiments and calculations on this subject. Still the *Hydraulique* of Buat may be considered the most ingenious, comprehensive, and practical work, on the department of science of which it treats, to be found in any language. The great excellence of this work is, that its doctrines are deduced not so much from mathematical calculation, as from a laborious comparison of facts. It furnishes most important information to the engineer; and enables him now to resolve, with sufficient precision, many questions, in answer to which little but conjecture, and that too often most mischievously wide of the truth, could be offered before. In short, the general proposition, deduced from the chevalier's numerous facts and experiments, respecting the motion of fluids, has been pronounced one of the most valuable results of modern inquiry *.

Much light has been thrown, during the last century, on the doctrine of *Tides*. Newton was the first who gave a satisfactory explanation of this subject. He showed that the tides are caused by the attraction of the sun and moon, and laid down some of the general laws of this attraction. But it has been remarked, that the wide steps taken by this philosopher, in his investigation, left ordinary minds frequently at a loss; and that many of his principles require very great mathematical knowledge to satisfy us of their truth. Accordingly the *Academy of Sciences* at Paris, soon after the death of the illustrious Briton, wishing to have this as well as some other parts of philosophy exhibited in a satisfactory, and, as far as could be, in a popular manner, published a prize question relative to the tides. This produced three excellent dissertations on the subject, by Mr. Maclaurin, D. Bernoulli, and Euler. Of these the work of Bernoulli is considered the best, and is, perhaps, the most

* See *Encyclopædia*. Art. *Water-Works*.

complete extant*. And it is worthy of observation, that while he threw greater light than all who had gone before him on the subject which he immediately undertook to illustrate, he furnished an additional and very powerful argument in support of the *Newtonian* system.

The construction of *Aqueducts* has been rendered, by the labours of modern philosophers, more simple, easy, and precise. And, in consequence of these improvements, they have, within the last century, greatly increased in number. For the valuable experiments and discoveries which have been made on this subject, we are principally indebted to the great hydraulic philosophers on the continent, whose names were before mentioned. To those names may be added the distinguished experimenters and observers, on the same subject, Desaguliers, Belidor, de Parcieux, and Perronet, who successively laboured to deduce a system of doctrines from the numerous facts before them; and whose very mistakes contributed to elucidate this obscure branch of science, which, however, is yet far from being fully understood.

* The abbé Bernardin de St. Pierre, in a late work, entitled *Etudes de la Nature*, rejects the Newtonian theory of Tides, and ascribes this class of phenomena to the liquefaction of the polar ice and snow. To this amiable writer the praise of ingenuity, and of possessing a happy talent of amusing and interesting his readers, cannot be denied. Neither can it be questioned that his work contains a considerable portion of sound and pleasing philosophy. But surely this and some other of his doctrines are utterly unworthy of a mind, which had been conversant with the inquiries and the writings of the great practical philosophers of the eighteenth century.

Very great improvements have also been made, during the period in question, in the principles and construction of *Water-Mills*. The proper mode of adjusting forces, and calculating velocities, in this, as well as in almost every other branch of hydraulics, has long been considered among the most difficult problems in philosophy.—Dr. Desaguliers, early in the century, made a number of experiments on mills, and suggested some important improvements in their principles and construction. About the same time, M. Belidor, of France, Mr. Emerson, of Britain, and J. Bernoulli, employed their great learning and talents on this subject, and made considerable progress in its illustration. These were followed by Mr. Lambert, of Berlin, Mr. Elvius, of Sweden, Professor Karstner, of Gottingen, M. de Parcieux, before mentioned, and Messrs. Smeaton, Barker, and Burns, of Great Britain. To attempt an enumeration in detail of all the inventions, discoveries, and useful suggestions produced by these several philosophers and artists, would swell this account beyond all bounds. It is sufficient to say, that although that part of the science of hydraulics which relates to mills did not arrive at absolute certainty and perfection in their hands; yet they made so many successive additions to the knowledge of preceding theorists, that to each large acknowledgements are due from the friends of human improvement. Nor ought the still later inquiries of Mr. Waring of Philadelphia, on the same subject, to be forgotten. His memoir on the *maximum* velocity of a wheel or other body, moved by a given quantity of fluid, may be regarded as a singular monument of accurate and successful investigation*. The *theory of mills*, which he deduces from his experiments and calculations, is said to correspond with fact, to a degree greatly beyond all other attempts†.

The various improvements which the last century produced in the construction of *pumps*, are also worthy of notice. Since the doctrine of the pressure of the atmosphere has been reduced to a regular system, and the general laws of moving fluids have been better understood, several advantages in the formation and management of this class of engines naturally followed. Those who most distinguished themselves during the century, by inventions, or laborious investigations, on this subject, are Messrs. Hadley, Desaguliers, Haskins, and Beighton, of Great Britain, Messrs. J. and D. Bernoulli, and Wirtz, of Switzerland, and Messrs. Pitot, Bossut, Belidor, de la Borda, d'Alembert, de la Grange, and de Buat, of France.

SECTION VI.

PNEUMATICS.

In Pneumatics, or that science which treats of the mechanical properties of elastic fluids, modern discoveries and improvements have been very nu-

* See *Trans. Amer. Philos. Society*, vol. iii.

† Mr. Waring was an obscure character, a native and resident of Philadelphia. He belonged to the Society of Friends, and taught a school in that city. Though little known, he was a real philosopher. He died of the pestilence which raged in that city in 1793.

merous and important. Ever since the famous *Torricellian* experiment, in the seventeenth century, proved that air was a gravitating substance, the attention of philosophers has been employed, with great success, in investigating the properties, and ascertaining the laws of this fluid. By numerous and patient inquiries, they have gone far toward reducing to regular system the principles which govern the density, the weight, the elasticity, and the motions of the atmosphere. And the various mechanical properties of air, as they became, in succession, better understood, have been rendered subservient to the utility of man, by their application to the arts of life.

The *Barometer* has, within the last century, received many and very important improvements, from Rowning, de Luc, Roy, Shuckburgh, Caswell, Nairne, Jones, and others*. The application of this instrument to the measurement of altitudes was first suggested by Dr. Halley, and afterwards better explained and systematised, by several of the gentlemen just mentioned, especially by the celebrated M. de Luc, of Geneva. The *Air-Pump*, during the same period, was much improved by Hawksbee, Gravesande, abbé Nollet, Smeaton, Russell, the rev. Dr. Prince, of Salem in America†, Lavoisier, and finally Cuthbertson, of Amsterdam; by the last of whom, we are taught to believe, this machine has been carried to a degree of perfection beyond which little advance-

* See *Encyclopædia*, Art. Barometer and Pneumatics. See also *Philosophical Transactions*, vol. lxxvii.

† See the *Transactions of the Amer. Acad. of Arts and Sciences*, vol. i.

ment is to be expected. That part of pneumatics, also, which relates to the construction of *Chimneys*, the comfort of human habitations, and the economy of fuel, has been, in modern times, the subject of much inquiry, and very useful improvement, by Dr. Desaguliers and Mr. Anderson, of Great Britain, and by the illustrious Americans, Franklin, count Rumford, and many others. To which may be added a number, almost countless, of wind instruments and machines, which modern ingenuity has invented, and which have grown out of our increasing knowledge of the qualities and laws of the important fluid in which we are immersed.

In this period, beyond all doubt, we are to place the invention of Balloons. In 1729, Bartholomew Gusman, a Jesuit, of Lisbon, caused an aërostatic machine, in the form of a *bird*, to be constructed; and made it to ascend, by means of a fire kindled under it, in the presence of the king, queen, and a great concourse of spectators. Unfortunately, in rising, it struck against a cornice, was torn, and fell to the ground. The inventor proposed renewing his experiment; but the people had denounced him to the Inquisition as a sorcerer, and he withdrew into Spain, where he died in an hospital.

In 1766, the Hon. Henry Cavendish discovered that inflammable air (the *hydrogen gas* of the French nomenclaturists) was at least seven times as light as common air. It soon afterwards occurred to the celebrated Dr. Black, that if a thin bag were filled with this gaseous substance, it would, according to the established laws of specific gravity, rise in the common atmosphere; but he did not pursue the inquiry. The same idea was next conceived by Mr. Cavallo, to whom is generally ascribed the honour of commencing the experiments on this subject. He had made but little progress, however, in these experiments, when the discovery of Stephen and John Montgolfier, paper-manufacturers of France, was announced in 1782, and engaged the attention of the philosophical world. Observing the natural ascent of smoke and clouds in the atmosphere, those artists were led to suppose that heated air, if enclosed in a suitable covering, would also prove buoyant. Accordingly, after several smaller experiments, by which this idea was fully confirmed, they inflated a large balloon with rarefied air, on the 5th of June, 1783, which immediately and rapidly rose to the height of six thousand feet, and answered their most sanguine expectations. It was soon found that machines of this kind might be so contrived as to convey small animals, and even human beings, through the air with ease. The first human adventurer in this aërial navigation was M. Pilatre de Rozier, a daring Frenchman; who rose in a large balloon, from a garden in the city of Paris, on the 15th of October, 1783, and remained a considerable time suspended in the air. He made several aërial voyages of greater extent afterwards, and in two of them was attended by other persons. In a short time, however, the use of rarefied air in aërostation was, for the most part, laid aside, as inconvenient and unsafe; and recurring once more to the discovery of Mr. Cavendish, the philosophers of Paris concluded that a balloon, inflated with inflammable air, would answer all the purposes of that contrived by the Montgolfiers, and would also possess several additional advantages. They made their first experiment on the 23d of August, 1783, which was attended with complete success; and the first human beings who ventured to ascend in a balloon raised upon this plan were Messrs. Charles and Roberts, who rose from Paris, on the 1st day of December in the same year. The inflammable air balloons have been generally used since that time; many aërial voyages have been performed in Europe and America; and what is remarkable, out of all the numerous instances of such hazardous enterprise, only one is recollected, which was attended with any fatal accident*.

The invention of balloons, though far-famed and brilliant, cannot be considered as having hitherto added much to the comfort or utility of man. The only practical purposes which it has been made to subserve, are those of aiding in meteorological inquiries, and inspecting the fortifications and reconnoitring the camp of an enemy, which could not be approached by other means. It has been applied to this latter purpose in at least one, if not more instances, by the French engineers, during the late war†. But who can undertake to assign the limits beyond which the ingenuity and the enterprise of man shall not pass? Though this spe-

* This is a reference to the death of M. Pilatre de Rozier and M. Romain; who rose in a balloon, from Boulogne, in the month of June, 1785, and after having been a mile high, for about half an hour, the balloon took fire, and the two adventurers were dashed to pieces by their fall.

† Gregory's *Economy of Nature*, 2d edit., vol. i, p. 506.

cies of navigation labours under difficulties which appear at present insurmountable; though the want of some means to control and regulate the movements of the aërial vessel is so essential as to excite a fear that it cannot be supplied; yet who can tell what further experience and discoveries may produce? Who can tell but another century may give rise to such improvements, that navigating the air may be as safe, as easy, and rendered subservient to as many practical purposes, as navigating the ocean? It must be acknowledged, indeed, that this is not very probable; but things more unexpected, and more remote from our habits of thinking, have doubtless occurred.

Under this head, also, properly come the great improvements which have been lately made in *Steam Engines*, doubtless among the most important and useful kinds of machinery that human ingenuity ever contrived. The idea of making steam subservient to powerful mechanical operations seems to have been first entertained by the marquis of Worcester, in the reign of Charles II of England. But little more was done, either by him, or during his time, than to speculate on the subject. It was not till the close of the seventeenth century that captain Savary, an ingenious and enterprising man, actually erected several steam engines, and obtained a patent for what he considered his own invention. He afterwards improved and simplified his machines himself; but the improvements which they have undergone since his time, are still more numerous. For these improvements the world is principally indebted to Mr. Newcomen, Mr. Beighton, and above all to

Mr. Watt, who, with an ardour, an acuteness, and a philosophic comprehension, which do him immortal honour, has so extended the principles of these machines, so increased their power, so successfully obviated the difficulties and inconveniences attending their operation, so accommodated their construction to peculiar circumstances, and carried the economy of steam, and, consequently, of fuel, to such an astonishing extent, that he may be ranked among the greatest mechanical geniuses and benefactors of mankind that the eighteenth century has produced*.

The application of steam to the purposes of *cookery*, and of *propelling vessels* on the water, is also to be ranked among modern inventions. To the latter of these objects several persons of America have paid particular attention, and with promising success. And although it must be granted that formidable difficulties have arisen in the execution of all the plans hitherto proposed, yet to doubt of the practicability of ultimately overcoming these difficulties, can scarcely be thought either to gratify a mind of true philosophic enterprise, or to be worthy of such a mind.

Late navigators and travellers have furnished valuable materials towards forming a theory of the *winds*. It must be acknowledged that nothing entirely satisfactory has yet been offered to the world on this subject. Still many facts have been brought to light; important discoveries have been made; and from the number and talents of the gentlemen who have been for some time engaged

* See *Additional Notes*—(N).

in exploring this dark recess of philosophy, still greater advances in our knowledge of it may soon be expected. For some instructive publications on this subject, we are indebted to Dr. Halley, and Mr. Dalton, of Great Britain; Mr. Kirwan, of Ireland; and Messrs. de Luc and Prevost, of Geneva. Various instruments, which answer valuable purposes for measuring the direction, the force, and the velocity of winds, have also been invented, within a few years past, by Dr. Linn, Mr. Pickering, and others of Great Britain. These inventions have been denominated the *Anemoscope*, the *Anemometer*, &c.

Finally, the doctrines of *Acoustics* have been very successfully illustrated, since the time of Newton, by various inquirers. Many facts relating to the velocity, the intenseness, and the general principles of sounds, have been established by numerous experiments. The capacity of different bodies to propagate sound has become better understood by the investigations of modern philosophers. Mr. Hawksbee, of Great Britain, first showed that sound is propagated further in *dense* than in *rarefied* air; M. Brisson, of France, and others, demonstrated, by various interesting experiments, that a medium more dense than air conveys sound still better than this fluid; and Dr. Young, of Dublin, has, within a few years, made some new and instructive inquiries into the principles of acoustics. To which may be added the interesting experiments lately made, showing the different intensity, and the variety of tones of sound, in different gases, by several philosophers.

That the different gases have different degrees of power in the propagation of sound, both with respect to intensity and tone, has been known since the year 1786; about which time Dr. Priestley, and professor Perolle, of Turin, instituted a set of experiments on this subject, in which they substantially agreed. Since that time professor Jacquin, of Vienna, at the desire of Dr. Chladni, undertook a new course of experiments, with a view to the investigation of this subject. The results of these experiments are so different, and even contradictory, when compared with the former, that it is difficult to say on which side the truth lies.

SECTION VII.

OPTICS.

In this science great improvements have taken place in modern times. In 1704 Sir Isaac Newton first published his grand work on *Optics;* and although many of his most interesting discoveries were made and announced towards the close of the seventeenth century, yet the collection and publication of them, in a systematic form, was reserved to be one of the distinguishing honours of the eighteenth. How numerous and important these discoveries were, is generally known. He ascertained the different refrangibility of the rays of light; he made some progress in exploring the principles and laws of colours, which had been so little understood before his time; he first explained the physical cause, and laid down with mathematical precision, the general laws of the reflection and refraction of light; beside many other valuable, but less important additions to the science of optics. It must be acknowledged that his doctrines are by no means free from errors and defects; but these are few in comparison of their great merits, and have been chiefly corrected or supplied by the labours of subsequent philosophers.

Since the discoveries of Newton many important additions have been made to our knowledge of the nature and properties of *Light*. The *materiality* of this substance, and the great *velocity* of its motion, were more fully illustrated and confirmed than they had been before, by Dr. Bradley and Mr. Molyneux, in 1727. A few years afterwards M. Bouguer, a celebrated French philosopher, distinguished himself by his experiments and observations on the same substance; particularly on the laws of its reflection and refraction. On this subject, indeed, he is placed, by a very adequate judge, among the most eminent observers and discoverers whom the eighteenth century produced*. Another species of action of other bodies on the rays of light, producing what philosophers have called *inflection* and *deflection*, was suggested by the illustrious Dr. Rittenhouse of America †, but

* See Priestley's *History of Optics*, 4to, London, 1772; from which many of the facts related in this sketch are taken.

They who have perused this work need not be informed, that it is a very interesting one, and that the labours of Dr. Priestley, in collecting so many historical facts relative to the science of Optics, together with his own experiments, hints, and inquiries on the subject, entitle him to an honourable station among those who have deserved well of this science in the eighteenth century.

† *Transactions American Philosophical Society*, vol. ii.

was first demonstrated by the ingenious experiments of Mr. Brougham*. From these and other facts, it appears that light is operated upon by material substances; that it is subjected to the laws of attraction, and, of consequence, possesses *gravity*. In the same sphere of experiment and observation may be mentioned Dr. Smith and Mr. Mitchel, of Great Britain, who made many valuable computations with respect to the intensity, and the best mode of measuring this subtle fluid. The property which various bodies, both animal and vegetable, possess of imbibing and emitting light, has also been investigated with more success by modern philosophers than during any former period. To which may be added, that a multitude of facts of the most interesting kind, relating to the *effects* of light on animal, vegetable, and mineral substances, have been made known within a few years past; and the nature and principles of some of these effects ingeniously and satisfactorily explored.

The theory and laws of *Vision* have received very great elucidation during the last age. Bishop Berkeley, in his *Essay towards a Theory of Vision*, published in 1709, solved many difficulties which had attended the subject, and threw much new light upon it. He distinguished more accurately than any who had gone before him, between the immediate objects of sight, and those of the other senses, which become early and insensibly associated with them. He first showed that *distance*, of itself, cannot be determined immediately by

* *Philosophical Transactions* for 1796.

sight alone; but that we learn to judge of it by certain sensations and perceptions which are connected with it. He led the way, also, in pointing out the difference between that *extension* and *figure* which we discover by means of *vision*, and that which we perceive by *touch*. By means of these investigations and discoveries he enabled philosophers to account for many phenomena in optics, of which the most learned had before given very erroneous accounts, or acknowledged themselves unable to furnish any satisfactory solutions. About the same time some valuable experiments and instructive works on the seat and principles of vision were published by M. de la Hire, M. le Cat, M. Bouguer, and several other French philosophers. To these succeeded the inquiries of Harris, Porterfield, Jurin, Smith, and still more recently of Reid* and Wells†. In particular, the very difficult question of *apparent magnitude* and *distance* has been treated with great ability by Berkeley and Harris; the phenomena of single and double vision have been solved by several of the persons above mentioned; and many remarkable fallacies of vision explained by Mr. Melville, M. Bouguer, and others.

The principles and laws of *Colours* have also been much better understood since the commencement of the eighteenth century than before. On this subject it seems now to be generally agreed, that the immortal Newton fell into essential mis-

* *Inquiry into the Human Mind on the Principles of Common Sense*, &c.

† *An Essay upon Single Vision*, &c. 8vo. 1792.

takes. His idea, that the colours of bodies depend on the *magnitude* of their elementary particles, has, it is believed, at present, few advocates. After him this subject was considered, though in a more practical way, and with reference to the art of *dyeing*, by several French philosophers; especially by Dufay, Hellot, and Macquer, who conducted their inquiries with great ability, pains, and perseverance, at the national expense. More recently, Mr. Delaval, of Great Britain, refining on the conjectures of Newton, attempted to deduce the varieties of colour from the different *densities* and *inflammability* of bodies. This work was for some time popular; but appears lately to have given way, in the public opinion, to the more enlightened and correct philosophy delivered on this subject by M. Berthollet, and Dr. Bancroft, who found the whole doctrine of colours on *chemical* principles—supposing that particular bodies reflect, transmit, or absorb particular rays of light, in consequence of certain *affinities*, or *elective attractions*, existing between the differently coloured matters, and the different rays of light, reflected, transmitted, absorbed, or made latent*.

But the discoveries and improvements in the construction of *optical instruments*, which the last age produced, are still more brilliant and interesting than any hitherto mentioned. Much was done, during the period in question, in the improvement of *Telescopes*. The *Refracting Telescope* was first in use. In this instrument no sig-

* See *Experimental Researches concerning the Philosophy of Permanent Colours*, by Edward Bancroft, M. D. F. R. S. 1794.

nal advantages of construction seem to have been devised from the time of Huygens, till the middle of the eighteenth century. It was then that Mr. Dollond, a celebrated artist of Great Britain, discovered a method of correcting the inconvenience and errors arising from the different refrangibility of the solar rays; a difficulty, which, since the time of Newton, had been generally considered as insurmountable. He ascertained that lenses of *crown* and of *flint* glass might be so prepared and adjusted as to correct the refractive, and of course the chromatic, powers of each other. On this discovery he founded the construction of his celebrated *Achromatic Telescope*, which, doubtless, deserves to be ranked among the most valuable acquisitions of the age*. Mr. Dollond pursued this improvement by increasing the number of glasses, with so much success, as to make the refracting instruments of his time superior to the reflecting of equal length. The principle which he discovered was explored still further, and the Telescope which he contrived carried to a higher degree of perfection soon afterwards, by Mr. Zeiher, of Petersburgh, who ascertained, by experiments, that increasing the quantity of *lead* in the formation of lenses, augmented the power so much desired in this instrument. It ought, perhaps, to be mentioned, that the hints and publications of the celebrated Euler on this subject, though found erroneous, probably contributed something to Mr. Dollond's discovery; and that the distinguished mathematicians, Clairaut and d'Alembert, about the same

* See *Additional Notes*—(O).

time, rendered themselves very conspicuous among the philosophers of Europe, by their ingenious calculations and suggestions, in aid of the achromatic instrument.

A new method of constructing *Achromatic Telescopes* was discovered, a few years ago, by professor Robert Blair, of Edinburgh. This method consists in the use of one or more *fluid mediums*, of which the dispersive powers, being opposed to each other, correct the focal irregularities not only of the extreme rays of the Newtonian Spectrum, but likewise of those near the middle; to which former opticians had little, if at all, attended. From some cause or other, however, this kind of achromatic telescope has not been much used.

But, from the necessary imperfection, and the small limits to which the *dioptric* plan of magnifying distant objects is confined, the improvement of the *Reflecting Telescope* became, early in the century, an object of particular attention. This instrument, which had been invented, in the preceding century, by Mr. James Gregory, of Aberdeen, and which had been executed, on a different plan, by sir Isaac Newton, was greatly improved by Mr. Hadley, who, in 1719, presented a very powerful Telescope of this kind to the Royal Society. In 1734 Mr. Short, an ingenious artist of Edinburgh, devised still further improvements in this instrument. These were chiefly effected by a new method which he discovered of grinding mirrors. But the secret art which enabled him to do this with so much success, is said to have died with him. After him, Mr. Mudge, of Plymouth, by making *specula* of a composition of different metals, and by inventing a method of grinding them to a true figure, which had been considered so difficult a problem by his predecessors, effected yet greater improvements. Mr. Mudge was followed by his countryman, Mr. Edwards, who also laboured, with some success, on the same instrument; but this has been since done much more effectually by Mr. Watson, an artist of London still living. It was, however, reserved for the great astronomer Herschel, to furnish the world with reflecting telescopes of the most wonderful magnifying power*. The extraordinary extent to which he has carried his improvements, and the astonishing discoveries which they have enabled him to make, are too recent, and too well known, to make a detail of them necessary here.

During the period which we are considering, *microscopes* have been also carried to a very high degree of perfection. In 1702 Mr. Wilson invented one, of the single kind, which is still much in use. In 1710 Mr. Adams presented to the Royal Society another, also single, but of much greater magnifying power. To which succeeded, soon afterwards, the ingenious device of Mr. Grey, of a temporary microscope, by means of a globule of water. In 1738 or 1739, Mr. Lieberkuhn made two very important improvements in microscopes, by the invention of the *Solar Microscope*, and that for viewing *opaque objects*. These were followed by the *reflecting microscope* of Dr. Smith, said to be superior to all others. Beside those

* The great Telescope of Herschel, 40 feet in length, is undoubtedly entitled to a conspicuous place among the WONDERS OF THE EIGHTEENTH CENTURY.

above mentioned, discoveries and improvements relative to microscopes, too numerous to be recounted, have been made by philosophers and practical opticians. The most conspicuous of these are Culpepper, Baker, Ellis, Lyonet, Martin, Cuff, Adams, and Withering; who have either contrived microscopes suitable for particular purposes, or suggested inventions and additions of more general application.

There is probably no division of this review, under which another modern invention, the *Telegraph*, may with more propriety be placed than this. Though something like *Telegraphic* communications had been attempted many centuries before, on particular military or civil emergencies; yet nothing of this kind was reduced to regular system, or much known, till the beginning of the eighteenth century*, when M. Amontons, of France, exhibited a telegraph on a new and convenient plan. It was not, however, until after the commencement of the French revolution that this machine was generally applied to useful purposes, or became an object of much attention. Toward the end of the year 1793 M. Chappe announced an invention under this name. Whether he were acquainted with the contrivance of M. Amontons is not known; but be this as it may, his was nearly on the same plan. The invention of M.

* It is said by a writer in the *Philosophical Magazine* of London, that the celebrated Robert Hooke, the contemporary and friend of Boyle, invented a *Telegraph*, on the same general plan as those which have been since used; and formally announced and described it, in a paper read before the Royal Society, May 21st, 1684.

Chappe immediately became an object of public attention. Additions and alterations in his plan were proposed, some of them highly advantageous; and telegraphs of different kinds came into use in various parts of the continent of Europe, and in Great Britain. How great the importance of this channel of intelligence is at present, and how much more so it may be rendered by those improvements in its construction and management which we may reasonably expect to take place, will readily occur to every mind. To say nothing of the dispatch with which information might be conveyed, by this means, in time of war, and the evils of various kinds it might prevent, it may hereafter become an instrument of commercial communication of the highest utility, and be rendered subservient to many valuable national purposes*.

The late experiments and conclusions of Dr. Herschel, with respect to the rays of light and heat, are curious, and highly interesting. He seems to have demonstrated that the different prismatic colours have different degrees of temperature; that radiant heat, as well as light, is not only refrangible, but also subject to the laws of dispersion, arising from its different refrangibility; that those rays of light which have the greatest *illuminating* power are the *yellow*, and those which

* Mr. Jonathan Grout, of Massachusetts, in 1799, invented a Telegraph on a plan which is said to be essentially different from any now in use in Europe. It has been for some time in operation between Boston and Martha's Vineyard, at which distance (90 miles) Mr. Grout has asked a question and received an answer in less than ten minutes.

have the greatest *heating* power the *red*; and, of course, that, contrary to the general belief, the maximum of *illumination*, and the maximum of *heat*, do not coincide*.

SECTION VIII.

ASTRONOMY.

Though this subject is mentioned last, it holds a very conspicuous place among those branches of mechanical philosophy which have received great accessions of discovery and improvement during the century in question. At the beginning of this period the *Principia* of the immortal Newton had given a new face to astronomical science†. Much had been done by his predecessors, and especially by the sagacious Kepler, to prepare the way for

* See *Transactions of the Royal Society* for 1800.

† Among the honours of the eighteenth century, it ought to be considered as none of the least, that the immortal Newton lived the last 27 years of his life, and closed his glorious career in this age. The character of this stupendous Genius is too well known to require any details on the subject in this place; but as his name so frequently occurs in these volumes, and especially in the section on Astronomy, it may not be improper to compress into a few lines the following facts and dates concerning him.—He was born in Lincolnshire, in the year 1642. He was educated at the University of Cambridge; where he graduated A. B. in 1664, and A. M. in 1668. He had made some of his greatest discoveries, and had laid the foundation of his *Principia* and his *Optics*, before he was 24 years of age. He was made Warden of the Mint in 1696, and Master of that institution in 1699, which office he held till his death, which took place in 1727, in the 85th year of his age. He received the honour of *knighthood* from queen Anne, in 1705.

his grand discoveries; but it was reserved for this luminary of the first magnitude to shed a degree of light on the laws of our planetary system, which has served to guide every exertion, and point out the way to the progress which has since been made. It was he who first applied the simple principle of gravitation to account for the movements of the celestial bodies; who laid down the laws of this great and all pervading attraction; and thence, by the assistance of a sublime geometry, deduced the revolutions of the planetary orbs, both primary and secondary, including the minute irregularities of each, with some errors indeed, but with a degree of conformity to nature and subsequent observation, which must ever astonish and delight the inquiring mind. The British philosopher leaving astronomy in this improved state, no wonder that those who came after him should at once, with growing ardour, and with greater ease, pursue a course which he had so happily marked out.

At the beginning of the century under review, we find Flamstead*, the first Astronomer Royal of England, devoting himself to this science with great zeal and success. He particularly directed his attention to the *fixed stars*; and after a series of patient and most laborious observations, published, in 1719, a catalogue of stars, more extensive and accurate than had ever been formed by one man. To him, both in office, and in astronomical fame, succeeded Dr. Halley†, who made a

* The Rev. John Flamstead was born in 1646; appointed Astronomer Royal in 1674; and died in 1719.

† Edmund Halley was born in London, in the year 1656; succeeded Flamstead as Astronomer Royal in 1719; and died in 1742.

number of important discoveries, and useful publications. Among many others which might be mentioned, he discovered the *Acceleration of the Moon,* and gave a very ingenious method of finding her *parallax.* He composed tables of the Sun, the Moon, and all the planets. He also recommended the mode of ascertaining the *Longitude* by *Lunar Observations;* a mode which has been since much improved, and generally adopted; and which is, at present, the most certain guide of the mariner. After him, at the head of the Royal Observatory was placed Dr. Bradley, who greatly distinguished himself as a practical astronomer. He was the first who made observations with sufficient accuracy to detect the smaller inequalities in the motions of the planets and fixed stars. By means of this accuracy, he discovered, in 1727, the *aberration of the stars,* a phenomenon produced by the compound motion of the earth, and the rays of light; and furnishing new proof, both of the materiality and amazing velocity of light, and also of the reality of that motion which had been ascribed to the earth. The same gentleman, in 1737, discovered the *nutation of the earth's axis*—that libratory motion, which is occasioned by the inclination of the moon's orbit to the ecliptic, and the retrograde revolution of her nodes; thus, in the course of ten years, making two of the most important additions to astronomical knowledge that the century produced*.

* The Rev. James Bradley was born in the year 1692, and educated at Oxford. On the death of Dr. Halley he was appointed Astronomer Royal, in which office he continued till his death, which took place in 1762.

While these noble and successful exertions were making in Great Britain, to improve the science of astronomy, the philosophers of France were employing themselves in the same field of inquiry, and with very honourable success. The real figure of the globe we inhabit had not been, before this time, satisfactorily ascertained. M. Cassini, the Astronomer Royal at Paris, believed its figure to be that of a *prolate spheroid*, or in other words, that the *polar diameter* was greater than the *equatorial;* while Newton had been led, by his principles, to a conclusion directly opposite, and had taught that it must be an *oblate spheroid*, or flattened at the poles. To determine the question, between these contending parties, the French Royal Academy of Sciences, under the authority and patronage of Lewis XV, resolved to have two degrees of the meridian measured, the one as near the Equator, and the other as near the Pole, as possible. For this purpose, one company of philosophers, consisting of Messrs. Godin, Condamine, and Bouguer, to whom the King of Spain added don Ulloa and don Juan, was dispatched, in 1735, to South America; and another company, consisting of Messrs. Maupertuis, Clairault, Camus, le Monier, and Outhier, attended by professor Celsius, of Upsal, was sent to Lapland. These companies, after devoting several years to the task committed to them, and encountering numerous difficulties in the prosecution of it, at length completed their design. The result proved to be an ample confirmation of Newton's opinion; for a degree near the Pole being found to measure more than one near the Equator, they necessarily inferred that the polar degree must be part of a larger circle*.

At the beginning of the eighteenth century, our knowledge of the *Moon* was extremely defective. Since that period, so many discoveries have been made respecting this attendant on our earth, and the laws of her motion have been so ably and diligently investigated, that this part of astronomy may now be ranked among those which are most fully known and understood. For these investigations we are indebted to Clairault, d'Alembert, Euler, Mayer, Simpson, Walmsly, Burg, Bouvard, de la Grange, de la Place, and others. By the labours of these great astronomers, the inequalities in the moon's motion have been detected, ascertained, and reduced to a system; accurate *Lunar Tables* have been formed; and the theory of this satellite has been carried to such a degree of perfection, that her place in the heavens may be computed with a degree of precision, which would have been pronounced, a few years ago, altogether impossible. With respect to the condition and aspect of the moon's *surface*, many important discoveries have been made, and much valuable information given to the world, by Mr. Schroeter †, a celebrated astronomer of Goettingen, and by

* It is impossible to recollect the attempt by M. Bernardin de St. Pierre, in his *Studies of Nature,* to revive the opinion of Cassini on this subject without surprise. That so learned and ingenious a man should oppose such distinct mathematical demonstration, is one of those caprices of respectable minds not easily to be accounted for.

† See *Selenotopographische Fragmente,* &c. by Johan. Hieronymus Schroeter, 4to. 1791.

Dr. Herschel, of Great Britain; who, by the aid of very powerful and accurate instruments, and with the skill and perseverance for which they are so eminently distinguished, have made surprising progress in investigating this department of the lunar phenomena.

When Newton died, several of the *inequalities* of the planetary motions, arising from the disturbing forces of various bodies, were with difficulty reconciled with the astronomical principles which he had laid down. These inequalities have been successively investigated since that time, their causes ascertained, their laws fixed, their perfect consistency with the Newtonian theory demonstrated, and thus a very formidable objection to that theory satisfactorily removed.—It is known to mathematicians, that this celebrated philosopher, calculating the effect of the sun's force in producing the *precession of the equinoxes*, fell into an errour, and made it less, by one half, than the truth. The true quantity of this motion was first determined by M. d'Alembert, in 1749; who also, in the course of his inquiries, more fully explained the *nutation of the earth's axis*, which had been discovered a few years before by Dr. Bradley. With no less diligence the inequalities in the revolutions of all the planets, and especially of *Jupiter* and *Saturn*, have been examined, ascertained, and reduced to regular principles. In these difficult investigations, many astronomers have employed themselves, in the course of the last century, and by their labours rendered important services to this science; but, perhaps, none of the number deserve more honourable distinction than

Euler, de la Place, and de la Grange, whose accurate observations, and rigid and delicate analyses, with a view to explore the anomalies in question, display great penetration, diligence, and perseverance.

The year 1781 was rendered remarkable by the discovery of *a new primary Planet.* This discovery was made by the celebrated Herschel, an astronomer of Hanover, residing in Great Britain. He had, for a number of years, distinguished himself by his successful exertions in augmenting the powers of optical instruments, and particularly in improving the reflecting telescope. With an instrument of this kind, of great excellence, he first determined the existence of the *Planet,* which he denominated *Georgium Sidus,* in honour of the British King; but which is now generally called, by the consent of astronomers, after his own name. From his observations, and those of others, it has been since found that this planet is attended by *six* secondaries, and much progress has been made in ascertaining the respective times and laws of their revolutions *.

But this discovery is not the only one which will transmit the name of Dr. Herschel to posterity with distinguished honour. In 1787, he discovered a *sixth* satellite of *Saturn,* and the year after a *seventh,* attending the same planet. He ascertained the rotation of *Saturn's Ring,* which may be regarded as one of the most important additions made to astronomical science since those of Dr. Bradley. He discovered a *second ring* be-

* *Additional Notes—(P).*

longing to that planet, and actually observed fixed stars between this and the one before known. He discovered also around the same planet a *quintuple belt of spots*, by which he ascertained the reality and the time of its diurnal motion. He has published new and valuable observations on the sun, the moon, and indeed on almost all the bodies belonging to the solar system. He has greatly enlarged our acquaintance with the fixed stars; and, in a word, so much extended our knowledge of astronomy, that his life may be considered as forming one of the most important æras in the history of this branch of philosophy.

This celebrated Astronomer has given a very sublime and curious account of the *Construction of the Heavens*, with his discovery of some thousands of *nebulæ*, or clouds of stars; many of which are much larger collections of stars than all those together which are visible to our naked eyes, added to those which form the galaxy, or milky zone that surrounds us*. He observes, that in the vicinity of those clusters of stars there are proportionally fewer stars than in other parts of the heavens; and hence he concludes that they have attracted each other, on the supposition that infinite space was at first equally sprinkled with them. Dr. Herschel thinks he has further shown, that the whole sidereal system is gradually moving round

* Democritus, many ages ago, affirmed that the *Milky Way* was produced by the united splendour of many small stars, as we are told by Plutarch.

Δημοκριτος πολλῶν και μικρῶν και συνεχῶν αστεριῶν συμφωτιζομενῶν αλληλοις συναυγασμον δια την πυκνῶσιν. Plutarch. De Placit. Lib. iii, Cap. 1.

some centre, which may be an opaque mass of matter*.

At the close of the seventeenth century, the respective *distances* of the several planets from the sun were far from being accurately determined. These, by successive observations, have been since ascertained, with a great degree of precision; and the various astronomical uses which this knowledge is calculated to subserve, have been displayed in the most satisfactory manner. Particularly the observations made by many philosophers on the *transits* of *Venus* and *Mercury*, which the eighteenth century exhibited, have thrown much light on this subject, and on several questions of great importance in astronomy.

It is but a few years since our knowledge of *Comets* was in its infancy. Dr. Halley, at the beginning of the period under consideration, made the first attempt to give a systematic view of this part of the science in his *Synopsis Astronomiæ Cometicæ*, published in 1705. But his inquiries concerning these excentric bodies, though ingenious and highly valuable, were far from being adequate or satisfactory. By the labours of modern astronomers, our acquaintance with the comets has been wonderfully extended. *Sixty-eight* new ones have been observed; the return of many of them has been ascertained and demonstrated †,

* See *Philosophical Transactions*, vol. lxxix.

† M. de la Lande, in his *History of Astronomy*, for the year 1801, intimates, that the observations which took place in the course of that year have made it questionable whether the doctrine long entertained, and considered by him and other astronomers as settled, that comets revolve, be not erroneous. This doubt

and many curious facts respecting them discovered, and received ample illustration. The learned and indefatigable labours of father Boscovich, and of M. de la Place, for determining the orbits of comets, have been long known and praised by astronomers. The great works of M. Pingre, and of sir Henry Englefield, in this branch of astronomical philosophy, are entitled to a place among the most full and useful of those which have appeared on the subject*. But beside what has been effected by the useful inquiries of these gentlemen, the observations of many others, and particularly of de Lalande, and his countrymen, Messier and Mechain, and also of Burckhardt, an illustrious German astronomer, have contributed much to extend our knowledge of comets. It is further worthy of remark, that the difficulty of making observations on comets has been, within a few years, greatly diminished. The methods of calculating their elements are now short and easy, in comparison with what they were half a century ago. Operations which then occupied many days, may now be dispatched with accuracy, in a few hours.

The importance of accurate observations on the *fixed stars*, in order to ascertain their motion, places, and relative circumstances, is known to

will probably soon receive a solution, if the spirit of zeal and industry should continue which at present animates many European philosophers.

* *Treatise on Comets*, by M. Pingre, 2 vols, 4to, Paris, 1783. *The Determination of the Orbits of Comets, according to the Methods of father* Boscovich, and M. de la Place, *with new and complete Tables*, by sir Henry Englefield, 4to, 1799.

every astronomer. It is to the stars we are obliged to refer all the motions of the sun, the planets, and the comets. In this part of the science under consideration much has been done during the last century. The catalogue of stars formed by Flamstead, was before mentioned as one of the most complete ever derived from the labours of an individual. To this succeeded the observations and catalogues of de la Caille, Bradley, and Mayer, which it is scarcely necessary to say were highly valuable. After these, Mr. Bode, of Berlin, published, in 1782, a very extensive and improved catalogue, which is greatly esteemed among astronomers. He was followed by the celebrated baron von Zach, of Gotha, whose catalogues and tables, in many respects, excelled all that had preceded them. Beside these, the public has been favoured with interesting accounts of new stars, by Herschel, Maskelyne, the elder Lalande, and many others*. The number discovered by the powerful instruments of Herschel, in particular, is almost incredibly great. But the last, and the most complete series of observations ever made in this department of astronomy, is that lately announced by de Lalande the elder, and his nephew, le Francais Lalande, who, with the assistance of the ingenious and enterprising wife of the latter, have determined the places of *fifty thousand* stars, from the Pole to two or three degrees below the Tropic of Capricorn †.

We may also reckon among the great astrono-

* See *Additional Notes*—(Q).

† See Lalande's *History of Astronomy* for 1800.

mical improvements of the last age, the formation of many *Tables*, exhibiting the places and motions of the heavenly bodies. Among these are the *Cometarial Tables* of Dr. Halley, since enlarged and corrected by many hands, and particularly by a number of eminent French astronomers. To the same list also belong *Tables* of the *Sun* and *Moon*, by le Monier, and de la Hire; the *Solar Tables* of de la Caille, Dawes, de Lambre, and von Zach; and the successively improved *Lunar Tables* of Clairault, Euler, Mayer, Mason, and finally, of Burckhardt, founded on the observations of Burg and Bouvard. Tables of all the primary *Planets*, and their *Secondaries*, have been completed during the period in question; among the most valuable of which are those of Bradley, Cassini, de Lambre, Wargentin, Vidal, Oriani, Schubert, Burckhardt, and de Lalande. Tables of *Parallax* and *Refraction* have been formed by Bradley, Dunthorne, and Shepherd, particularly the last, whose work is a wonderful monument of industry and perseverance. To these might be added a multitude of others, published by individuals, and learned societies, various sets of which may be found in modern books of astronomy. Those printed in de Lalande's great systematic work, are probably exceeded by none extant in fulness and accuracy. By means of these *Tables*, many complex calculations, which, without their aid, would cost the labour of several hours, or even days, may now be performed in an eighth or tenth part of the time which they formerly employed, and with much greater assurance of a true result.

Previous to the eighteenth century, though

Eclipses, of various kinds, had been observed and calculated, yet these operations had rarely been made subservient to any important practical purpose. Within a few years past, philosophers have paid more attention to this part of astronomy. Methods have been devised of calculating eclipses with more ease and expedition than before. Large collections of these calculations have been made, for a long series of years, with the view of deducing from them the longitude of cities, and determining other astronomical and geographical questions. Among those who have distinguished themselves in this branch of astronomy, Mr. Triesnecker, of Germany, and M. Goudin, of France, are entitled to peculiar honour*.

To discover an easy and certain method of finding the *longitude*, has long been a grand *deside-*

* The attempt made by certain infidels, during the eighteenth century, to derive an argument against the chronology of the sacred writings from some astronomical records, said to be found in Asia, is well known; as are also the ample refutation of their reasoning, and the total disappointment of their hopes from this quarter. We have been recently informed, that some of the learned men of France, connected with the late military expedition to *Egypt*, assert, that in the course of their inquiries in that country, they discovered astronomical records, which prove the age of the world to be many thousands of years greater than the sacred history represents it. It is not the part of a wise man to *answer a matter before he heareth it;* and therefore until more shall be known concerning the facts stated, and the reasonings employed by these men, it would be improper to attempt a discussion of the subject. But the extreme fallacy to which arguments derived from sources of this kind are liable, must be obvious to every astronomer; and he must have little acquaintance with the history of human knowledge who does not know, that assertions as bold as those in question have more than once been demonstrated

ratum among astronomers and navigators. In 1714, an association was formed in Great Britain, under the denomination of the *Board of Longitude*, aided by the authority and patronage of the government. The exertions and the liberality of this body have done honour to their age and country, and in a very considerable degree attained their important object. The most approved mode of ascertaining the longitude now in use, viz. by observing the distance of the *moon* from the sun, or from certain stars, though repeatedly suggested, was never reduced to practice till the eighteenth century. In promoting this object Dr. Halley early distinguished himself. To him succeeded several others, who formed *Lunar Tables*, with a view to facilitate the necessary calculations; but among these, none laboured with so much success as professor Mayer*, of Gottingen, whose tables were brought to such a degree of accuracy as to be thought worthy of a large premium from the Board of Longitude before mentioned. Mayer's tables were afterwards improved by Mr. Charles Mason, of England, who reached a still greater degree of precision in his calculations. And finally, to the rev. Dr. Maskelyne, the present Astronomer Royal,

to be false; that expectations as sanguine have been often blasted; and that modern discoveries in science, and the observations of travellers, instead of discrediting the sacred history, have uniformly tended to illustrate and confirm it. See *Additional Notes*—(*R*).

* Tobias Mayer, the celebrated astronomer, was born in Germany in the year 1723, and died in 1762. For his *Astronomical Tables and Precepts*, the English Board of Longitude gave his widow 3000*l*. sterling.

is due the honour of contributing much toward the perfection of the plan, and of introducing it into general practice.

Another method of finding the Longitude, by observations on the *Eclipses of Jupiter's moons*, though practised as early as 1688, has yet been much improved during the period under discussion. For these improvements, which are chiefly founded on the superior extent and accuracy of modern tables, we are indebted principally to Drs. Bradley and Pound, M. Cassini the younger, Mr. Wargentin, and M. Delambre, the tables of the last of whom have been generally adopted in many of the late nautical almanacks. A third mode of determining the Longitude, by well regulated *Time-keepers*, is almost wholly a production of the last age. For although some attempts of the kind were made in the preceding century, nothing effectual was done until 1714, when Henry Sully, an Englishman, published a small tract at Vienna, on the subject of watch-making, and announced some improvements in the art, with a view to the Longitude, which were said to be valuable, and attended with success. This plan, however, was afterwards brought much nearer to perfection, by the ingenious and persevering labours of John Harrison, also of England, who, in 1726, produced a time-keeper of such uncommon accuracy as not to err above one second in a month, for ten years together. Watches of a similar kind, which have proved of great utility to navigators, were also formed soon after Harrison's, by Kendal, Arnold, and others of Great Britain, and by le Roy, Berthoud, and several other distinguished French artists. The happy effects of these discoveries and improvements in aiding navigation, and, of course, their favourable influence on commerce and the interests of humanity, are so obvious as not to require formal explanation.

But no age, assuredly, can vie with the last, in the accuracy and astonishing powers of the *astronomical instruments* which it produced. The principal ones, among those of an *optical* kind, were mentioned in a former part of this chapter, and need not be again recounted. In addition to these, many curious instruments and *machines*, serving to illustrate and exemplify the principles of astronomy, have been devised by several ingenious men. The first deserving of notice is the *Orrery*, invented by Mr. George Graham, an English mathematical-instrument-maker, and presented to George I*. The next is a machine, under the same name, contrived by Mr. James Ferguson, also of England, and including some improvements on the former. To these succeeded a *Planetarium*, of very curious structure, by Mr. William Jones, of London, and the celebrated astronomical *Sphere*, by Dr. Long, professor in the university of Cambridge; to say nothing of a multitude of other inventions of a similar kind, by different artists and astronomers.

* The origin of the name given to this machine is as follows. Mr. Rowley, a mathematical-instrument-maker, having obtained one from Graham, the inventor, to be sent abroad, with some of his own instruments, he copied it, and made one for the *Earl of Orrery*. Sir Richard Steele, who knew nothing of Mr. Graham's right to the invention, thinking to compliment the noble encourager, called it an *Orrery*, and gave Rowley the praise due to Graham.

But among all the contrivances of this nature which have been executed by modern artists, the machine invented by the illustrious American, Dr. David Rittenhouse, and modestly called by him an *Orrery*, after the production of Graham, is by far the most curious and valuable, whether we consider its beautiful and ingenious structure, or the extent and accuracy with which it displays the celestial phenomena *.

Among the instruments for making astronomical observations, invented during the last century, there is none more important than the celebrated *Quadrant*, invented by Mr. Godfrey, of Philadelphia, though afterwards claimed as a production of Mr. Hadley, whose name it still bears †. The inestimable value of this instrument, for various purposes, and especially for the direction of the mariner, is well known. Since the original plan of constructing it was announced, improvements of much value have been suggested by the rev. Dr. Ewing ‡, provost of the university of Pennsylvania, by professor Patterson §, of the same institution, and by Mr. Magellan, of London. We may next mention the *Astronomical* or *Equatorial Sector*, an instrument of great utility, invented by the ingeni-

* For a further account of this celebrated *Orrery*, see the *Transactions of the American Philosophical Society*, vol. i. Those who wish to see a brief and comprehensive view of the genius, character, and works of Dr. Rittenhouse, will find a good sketch of them in an *Eulogium*, pronounced in honour of his memory, before the American Philosophical Society, by Dr. Rush.

† See *Additional Notes—(S)*.

‡ Transactions of the American Philosophical Society, vol. i.

§ *Ibid.* vol. iv.

ous Mr. Graham, before mentioned; the *Transit and Equal Altitude Instrument*, first made for le Monnier, the French astronomer, by Mr. Sisson, of London; and the *Grand Astronomical Circle*, by the chevalier de Borda and others, the most complete and comprehensive instrument in use among astronomers, being in fact a kind of portable observatory, and probably carrying the delicate accuracy of its indications to nearly as great a length as human art will admit. Nor ought it to be omitted here, that the method of *graduating* astronomical instruments has, within the last age, received the most astonishing improvements. Mr. Bird, of London, was long distinguished in this line; but more recently his countryman, Mr. Ramsden, has invented a method incomparably more easy, expeditious, and accurate than any before known. The abridgement of labour by this new method is scarcely credible. An operation which cost Mr. Bird several days, we are told, can now be performed much better upon Mr. Ramsden's plan, and nearly in as many minutes.

Beside the invention of new astronomical instruments, the last age is also remarkable for the great improvement of almost all that were before known, and in use. The services, by these means, rendered to astronomy by the artists mentioned in the last paragraph, and also by Short, Graham, Herschel, Troughton, M. Lenoir, and others, are too numerous and important to be adequately acknowledged in this place. These improvements have, no doubt, served greatly to abridge the labour of astronomical calculations, and to confer new accuracy upon every part of the science.

At the conclusion of the seventeenth century, the number of regularly established and endowed public *Observatories* was small. It is believed that only *two*, or at most *three*, of any distinction existed at that time. Within the last century, the number of these institutions has greatly increased. They are now established in almost every part of Europe; richly furnished with the best apparatus for making observations; and continually sending forth discoveries and improvements, as the best evidence of their utility.

But astronomy has not only been enriched by the augmentation of its own immediate stores; it has been also improved, during the period in question, by the collateral aid of other sciences and arts. The improvements in the *mechanic arts*, by furnishing the astronomer with more perfect instruments, have materially furthered him in his course. The discoveries in *dynamics* and *optics*, and the refinements which have taken place in *mathematical* science, though apparently of small moment when considered in themselves, yet, when applied to astronomical investigations, have proved highly important and useful. Formerly astronomy could only be improved through the medium of actual observation; but when the great Newtonian theory of the solar system was once established, a new path of inquiry, and new grounds of calculation, were laid down. *Data*, from that period, were afforded for ascertaining, with great precision, the orbits, the revolutions, and the inequalities of the several planetary bodies; and new light and aid poured in on every side, from the geometrician and the artist, as well as from the immediate inquirer in this sublime science.

Under this head it is proper to mention the introduction of the *New* or *Gregorian Style* of chronology into Great Britain in 1752. In 1582 pope Gregory XIII, finding perplexity to arise in the computation of time, from some errors in the *Julian Calendar*, which, antecedently to that period, had been used throughout Christendom, thought proper to order the formation and adoption of a new style of reckoning. The astronomers and mathematicians whom he summoned to Rome for this purpose, after spending several years in investigating the subject, and adjusting the principles of another system, produced what has been since called the *Gregorian Calendar*. In forming this method of computation ten days were anticipated or taken away from the old Calendar, and a plan attempted for maintaining a greater degree of accuracy, by a proper distribution of *Epacts* through the year. The *Gregorian Style*, thus formed, was soon adopted by all the catholic states, and in most of the protestant countries, before the commencement of the eighteenth century. In Britain, however, and her dependencies, and in a few other protestant states, the *Julian* or *Old Style* was not given up for a number of years afterwards. In 1752, however, by an act of the British parliament, the *Gregorian Calendar* was adopted; and, at the same time, the *Ecclesiastical Year*, which had before commenced on the 25th of March, was made to coincide with the *Civil Year*, and ordered, like that, to be computed from the first of January*.

Beside the great names, and the important discoveries and improvements above detailed, it would be easy to add to the list many others worthy of notice. The numerous observations and writings of Ferguson, Lax, Vince, and others of Great Britain; of Bailly, de Parceval, Bernier, Sejour, and Duvaucel, of France; of Lambert, Grischow, Olbers, von Wahl, Wurm, and Klugel, of Germany; of Bianchini, Frisi, Manfredi, Zanotti, Oddi, Cagnoli, and Oriani, in Italy; of Klingenstierna, Mallet, Prosperin, and Melanderhielm, in Sweden; of Rœmer, Loowenoern, Bugge, and Wurbierg, in Denmark; and of many others, in almost every part of Europe, who have all contributed something to the astronomical improvements of the age, and facilitated the acquisition of astronomical knowledge.

Nor has *America* been destitute of zealous students, and successful observers in astronomy. Beside the illustrious Rittenhouse, before mentioned, whose name alone would rescue his country from the charge of deficiency in astronomical genius, we can boast of Colden †, Winthrop, Ewing, Bow-

* It is scarcely necessary to inform the intelligent reader that the delay of adopting this Calendar in Britain till 1752, rendered it necessary to drop *eleven* days, instead of *ten*.

† See *Principles of Action in Matter, and the Motion of the Planets explained from those Principles*, &c. by Cadwallader Colden, Esq. 4to, London, Dodsley, 1753. And also a subsequent publication by the same author, in the form of a *Letter to the Earl of Macclesfield*, explaining the doctrines contained in the former work. Mr. Colden was, for some years prior to the American

doin, Madison, Page, Patterson, Ellicott, Willard, and several others*, who, if they have not made splendid discoveries, or great additions to astronomical science, have yet published useful observations, and contributed to promote that degree of taste for this branch of philosophy which exists in our country.

From the foregoing review, it appears, that almost every part of mechanical philosophy, during the eighteenth century, has undergone great and radical improvements; and that the path is evidently marked out to still greater and more interesting attainments. In *Electricity*, *Galvanism*, *Pneumatics*, *Optics*, and *Astronomy*, the additions to our knowledge, during this period, are pre-eminently conspicuous. For much of this progress we are indebted to accident; but our obligations are also great to the genius and industry of individuals, and the labours and publications of many learned societies, who have with honourable zeal and perseverance encouraged experiments and enterprises of discovery, and collected and made known a multitude of important facts. It is also

revolution, lieutenant-governor of the province of New-York. Whatever may be thought of some of the opinions exhibited in these publications, they display genius, learning, and, for the country in which they were written, an unusual taste for mathematical and astronomical inquiries.

* The specimens which have been given to the public of the astronomical learning and skill of most of the gentlemen mentioned above, and of some other Americans, may be found in the volumes of *Transactions* which have been published by the *American Philosophical Society*, and in the *Memoirs of the American Academy of Arts and Sciences*.

a remarkable characteristic of the age, that every branch of natural philosophy has been investigated in modern times, in a more *practical* manner than it ever had been before, and more extensively and generally applied to purposes of *economy* and the *arts*. While the explorers of science have gratified liberal curiosity, and gained reputation for themselves, their inquiries have been rendered subservient to the abridgement of labour; the increase both of expedition and elegance of workmanship, in manufactures; and the promotion of human comfort, to a degree beyond all former precedent. In short, the number of heads and of hands at work, in the various departments of mechanical philosophy, at the close of the century under consideration, was unquestionably much greater than it ever had been since science was an object of human study. That much further, and more satisfactory light, therefore, may be expected to break in upon us, at no great distance of time, on many points at present involved in darkness, can hardly be doubted. "But the subject," says an eloquent writer, "is still greater than our exertions, 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 among the clouds. It is *the work which God worketh from the beginning to the end*, infinite and inscrutable *."

* Bishop Watson's *Chemical Essays*, vol. i, p. 15.

CHAPTER II.

CHEMICAL PHILOSOPHY.

As Mechanical Philosophy has respect to those motions of the larger bodies of the universe which fall under the inspection of our senses, so Chemical Philosophy is the science which explains those motions that take place among the minute component parts of bodies, and that are known chiefly by the effects which they produce; in other words, its object is, " to ascertain the ingredients that enter into the composition of bodies—to examine the nature of these ingredients, the manner in which, and the laws by which, they combine, and the properties resulting from their combination." It may safely be asserted, that there is no branch of science in which the discoveries and improvements, during the last century, have been more numerous, or more important, than in this. Indeed, such has been their number, and their interesting nature, that to exhibit them in detail would be to fill many volumes.

Though some of the facts and principles which enter into all the systems of modern chemistry have been known for many centuries, and indeed as far back as history reaches; yet, as a regular science, it could scarcely be said to have had an existence prior to the middle of the seventeenth century. It was about that time that the learned societies in Europe began to be formed, and the reign of Alchemy to decline. In the inquiries then instituted in chemical philosophy, the celebrated Mr. Boyle led the way. His speculations and experiments on light, heat, air, water, and other subjects allied to those, were in several respects useful, and prepared the way for subsequent improvements. To his learned labours succeeded those of Dr. Mayow, who not only prosecuted the inquiries commenced by Boyle, but had also the honour of devising others, equally new and important. He went far in discovering some of the properties of that portion of the atmosphere which has been since called *vital air* and *oxygen*, and ascertained the necessity of its presence for the purposes of combustion and respiration*. The discoveries and the works of this experimental philosopher, however, notwithstanding their curious and valuable nature, had fallen into oblivion, and a century after their publication were scarcely at all known among the learned of Europe.

In the list of luminaries in chemical science, the immortal Newton next appears. Though his mind was chiefly occupied in exploring other regions of philosophy, he was by no means regardless of this; and about the beginning of the eighteenth century he first suggested the idea of arranging the phenomena of chemistry under the head of a peculiar species of attraction. The chemists who lived before this great philosopher supposed that all solvents, or substances capable of dissolving

* *Tractatus Quinque Medico-Physici,* p. 12 and 106.

others, were composed of particles which had the form of wedges or hooks; that solution consisted in the insinuation of these wedges or hooks, between the particles of the bodies to be dissolved; and that chemical combination was merely the linking of the different particles together, by means of holes in one set of them, into which the hooks or the wedges of the other set were thrust. Such explanations, absurd as they may appear, were generally fashionable, until Newton first ascribed the chemical union of bodies to an *attraction* between the particles themselves: a doctrine which was soon unanimously received, and has continued ever since to prevail. The nature and laws of this attraction were afterwards better explained and systematised by Mr. Geoffroy, a philosopher of France, who invented a method of representing the different chemical affinities by figures and diagrams, and arranging them in tables; a method which has since been generally received into practice, and greatly contributed to the facility and advancement of this science.

Contemporary with Geoffroy was Boerhaave, who, among the various objects to which he directed his great and excellent mind, rendered himself conspicuous by his attention to chemistry. He made many new experiments, and improved almost every part of chemical philosophy which was then known. He was particularly distinguished by maintaining, in opposition to Boyle and Newton, that *heat* was a real specific *substance*, a fluid universally diffused, and one of the most important agents in nature. In supporting this doctrine he triumphed over his illustrious opponents, and established a principle which has been in substance generally adopted by the philosophical world since that time.

At an early period of the eighteenth century Stahl, an eminent German chemist, published his theory of *Phlogiston*, which produced one of the most remarkable revolutions in chemical philosophy that ever occurred*. This theory had been invented and published, in the preceding century, by Becher, a philosopher of Germany; but he died before it obtained that character and currency which it afterwards acquired. It was reserved for Stahl to adopt and systematise his doctrines in a manner so plausible and consistent as to secure for them a general reception. According to this celebrated theorist there is only one substance in nature capable of combustion, which, therefore, he called *Phlogiston;* and all those bodies which can be made to burn contain more or less of it. Combustion is merely the separation of this substance, which, during the process, flies off, leaving behind the incombustible body with which it was connected. He supposed the conversion of sulphur into an acid, by the action of heat, most completely to illustrate and confirm his doctrine; and, indeed,

* George Ernest Stahl was born in Franconia, in 1660, and died in 1734, in the 75th year of his age. He was undoubtedly a man of great talents and learning, and the author of many valuable works; the most important of which relate to his systems of *Medicine* and of *Chemistry*. He published an edition of the *Physica Subterranea* of Becher, after the death of that great chemist, and adopted the theory which this work displayed; but he simplified and improved it so much, that he made it entirely his own; and accordingly it has been ever since known by the name of the *Stahlian* theory.

so ingeniously devised, and so extremely plausible were his experiments on this subject, that he was considered as having satisfactorily established, both in the *analytic* and *synthetic* methods, the principle for which he contended. Objections, it is true, were made to this theory, for it was soon found that sulphur would not burn, if air were completely excluded, and that the sulphuric acid was heavier than the supposed compound from which it was produced. But still the *phlogistic* doctrine prevailed. The simple, luminous, and satisfactory manner in which it appeared to account for various phenomena, and the numerous facts which seemed to give it support, aided by the ingenious refinements of its partisans, for a considerable time bore down all opposition.

The theory of Stahl maintained its ground for more than half a century. It commanded the general assent of chemical philosophers, and was especially adopted and defended by some of the most eminent men which the age produced. And although it is now rejected by a great majority of those who cultivate the science of chemistry, yet neither the ingenuity of the system, nor the talents of its author, can for a moment be questioned. Indeed, the doctrine of this great man, though at present generally considered as erroneous, was by no means a useless effort. Before the publication of his theory, the different branches of this science had been studied in a manner too detached and unsystematic; experiments had been made with too little accuracy; and scarcely any luminous and generalising views had yet been given of the subject. In the fair and ingenious fabric of

Stahl, the scattered fragments produced by preceding inquirers were arranged and combined; experiments began to be conducted with a spirit of more acute and precise observation; and the whole aspect of this department of philosophy became more regular and scientific.

Assuming his theory, as in general the only true one, and proceeding on its fundamental principles, the philosophers who followed him devised considerable improvements, and made many important discoveries. The rev. Dr. Hales revived the pursuit of *pneumatic* chemistry, which had been generally neglected since the time of Mayow; and, indeed, the honour of being the father of this branch of the science belongs more eminently to him than to any other individual*. He found that many substances were readily convertible from the fixed to the gaseous state, and *vice versa;* he carried his inquiries into the effects of fermentation, dissolution, combination, combustion, and respiration, further than any who had gone before him; he made great improvements in the necessary machinery and apparatus for pneumatic experiments; and, on the whole, was the author of many valuable additions to the science.

The doctrine of *Latent Heat* was first taught by Dr. Black, of the university of Edinburgh, in the year 1757. His discovery, and the doctrine which he founded on this discovery, may be considered

* The rev. Stephen Hales, D. D., was born in 1677. He was a great chemist and vegetable physiologist. Beside many communications to the Royal Society, he published two volumes of Statical Essays, which are highly esteemed. He died in 1761.

as comprised in the following propositions. Whenever a *solid* is converted into a *fluid*, it combines with a certain portion of caloric, without any augmentation of its temperature, and it is this portion of caloric which occasions the change. When this fluid is reconverted into a solid, the caloric which produced the fluidity leaves it without any diminution of its temperature; and it is this abstraction which occasions the change. Thus the combination of a certain portion of caloric with *ice* causes it to become *water*, and the abstraction of a certain portion of caloric from water causes it to become ice. Water, then, is a compound of ice and caloric; and, in general, all fluids are combinations of the solid to which they may be converted by cold, and a certain portion of caloric. The same principle, according to this philosopher, applies to the conversion of *liquids* into *elastic fluids*, or the reverse; this conversion and reconversion depending on the addition or abstraction of caloric. To this caloric Dr. Black gave the name of *latent heat*, because its presence is not indicated by the thermometer. The great importance of this discovery, and the extensive application which has been since made of it, in explaining *fluidity*, *congelation*, *evaporation*, *animal heat*, and many other phenomena, render the period of its annunciation to the world one of the most interesting æras in the history of chemical science.

In the mean time, sir Torbern Bergman, an illustrious Swede, was busily engaged in exploring the same department of philosophy *. In the

* Sir Torbern Bergman was born in the year 1735, and died in 1784. He is, beyond all doubt, entitled to a place

course of his inquiries, he threw great light on the subject of *elective attractions;* enlarged and explained more satisfactorily the tables of *affinities;* gave much new and valuable information relative to the constitution of *volcanic* and other mineral substances; made a considerable reform in the *nomenclature* of the science, and accomplished so large an amount of improvement, that he may be justly styled one of the great fathers of chemistry. Contemporary with Bergman was his celebrated countryman Scheele, one of the most extraordinary men and distinguished philosophers of the age in which he lived*. He has been justly

among the greatest men of his age. He was highly distinguished as a chemist, mineralogist, geometrician, and astronomer. In the two first-mentioned branches of science he was particularly eminent. In the history of chemistry, few names occur more frequently, or are associated with more important services, than his.

* Charles William Scheele was born Dec. 19, 1742. He was bound an apprentice, when very young, to an apothecary at Gottenburg, where he first felt the impulse of that genius which afterwards made him so conspicuous. He durst not, indeed, devote himself openly to chemical experiments; but he contrived to make himself master of the science by devoting those hours to study which were assigned to him for sleep. He afterwards went to Sweden, and settled as an apothecary at Köping. Here Bergman first found him, saw his merit, and encouraged it; adopted his opinions, defended him with zeal, and took upon himself the charge of publishing his treatises. Encouraged and excited by this magnanimous patronage, the genius of Scheele, though unassisted by education or wealth, burst forth with astonishing lustre. To wonderful acuteness, ardour, and persevering diligence in his philosophical investigations, he added singular purity and amiableness of moral and social character. His outward appearance, however, was by no means expressive of that great mind which lay concealed, as it were, under a veil. He died in 1786, in the 44th year of his age.

called the *Newton* of chemistry. Without the aid of education or of wealth, his genius burst forth, and shone with astonishing lustre; insomuch that at the age of forty-four, when he died—an age at which most other great men have but begun to attract public attention—he had finished a career of discoveries which have no equal in the annals of chemistry. He made new and ingenious *analyses* of many bodies, the composition of which had never before been accurately investigated. He discovered vital or *oxygenous* air, about the same time with Dr. Priestley, and without any knowledge of what had been done by that celebrated philosopher. He discovered a number of new *acids*, and exceedingly enlarged the lists of chemical substances. He made known a number of new *paints* and *dyes*, and in various ways contributed to the progress of arts and manufactures. In short, he instituted such a variety of original and interesting experiments, and threw so much light on almost every branch of chemical science, that a volume might be filled with their history, and with the praises of his ingenuity, diligence, enterprise, and success.

Next in this honourable catalogue stands Dr. Priestley, whose fame as the author of numberless valuable experiments, and many important discoveries, is known in every part of the world where philosophy is cultivated. His labours, particularly in pneumatic chemistry, have been extensive, various, and persevering, to a wonderful degree. Among many other services rendered to this branch of science, he discovered the *nitrous* and *oxygenous* airs; he first exhibited acids and alkalies in the *gaseous* form; he discovered the power of vegetation to restore vitiated air*; he ascertained the influence of light in enabling vegetables to yield pure air; and elucidated both the principles of respiration, and the influence of oxygenous air on the blood. But the great extent and value of his inquiries, respecting the analyses of the atmosphere, and the production of various factitious airs, can be fully understood only by the perusal of his instructive volumes on these subjects.

To the list of successive luminaries in chemistry, now under review, it would be improper not to add the name of M. Macquer, who contributed in an eminent degree to the advancement of chemical knowledge by his excellent works, long held in the highest esteem in every part of Europe. His ingenious experiments and numerous discoveries, particularly respecting *arsenic*, *dyes*, and *earths*, will ever entitle him to honour and gratitude from philosophers. By the labours of these great men, and of many others—whose names might with propriety be mentioned, did not our limits forbid such an enlargement of the list—the boundaries of chemical philosophy had been more extended, and its stores of experiment and discovery more enriched, within the twenty years immediately preceding the introduction of the theory of the French academicians, than in any whole century before.

But some of the discoveries made by these and other chemists must be more particularly detailed, in order to present the reader with a tolerable

* See *Additional Notes*—(*T*).

view of the progress made in chemical science at this eventful period.

Not long after Dr. Black had published his doctrine of *Latent Heat,* his discovery of *Carbonic Acid* gave additional lustre to his character, and formed a new æra in the history of chemistry.

Paracelsus and Van Helmont were acquainted with the fact, that air is extricated from solid bodies during certain processes; and the latter gave to air thus produced the name of *gas,* by which word he meant to express every thing which is driven off from bodies in the state of vapour by heat. Boyle called these kinds of air *artificial airs,* and suspected that they might be different from the air of the atmosphere. Hales ascertained the quantity of air that could be extricated from a great variety of bodies, and showed that it formed an essential part of their composition. Dr. Black proved that the substances called *lime, magnesia,* and *alkalies,* are compounds, consisting of a *peculiar species of air,* and pure lime, magnesia, and alkali. To this species of air he gave the name of *fixed air,* because it existed in these bodies in a fixed state, though he knew not the materials of which it is composed. The air or gas was afterwards investigated by Dr. Priestley, and a great number of its properties ascertained. From these properties Mr. Keir first concluded that it was *acid;* and this opinion was soon confirmed by the experiments of Bergman, Fontana, and others. Dr. Priestley at first suspected that this acid entered as an element into the composition of atmospherical air; and Bergman, adopting the same opinion, gave it the name of *aerial acid.* Mr. Bewly called it *mephitic acid*, because it could not be respired without occasioning death. Mr. Keir called it *calcareous acid;* and, at last, M. Lavoisier, after discovering that it is formed by the combination of *carbon* and *oxygen*, gave it the name of *carbonic acid gas*, which it now generally bears *.

The discovery of *inflammable hydrogenous air*, in 1766, deserves also to be recorded as a remarkable event. This air was obtained by Dr. Mayow, and afterwards by Dr. Hales, from various substances, and had been known, long before, in mines, under the name of the *fire damp.* But Mr. Henry Cavendish ought to be considered as its real discoverer; since it was he who, in the year above-mentioned, first examined it, pointed out the difference between it and atmospheric air, and ascertained the greatest number of its properties †. It was found by M. Lavoisier to be twelve times as light as common air. Its nonrespirable character was more fully determined by Scheele, Fontana, and Davy. The products resulting from the combination of hydrogen with the *sulphuric*, *phosphoric*, and *carbonic* acids, were discovered and investigated principally by Scheele, Bergman, Fourcroy, Vauquelin, Gengembre, Kirwan, and Volta. It was first called *Hydrogen* by the French academicians, because it enters into the composition of *water*.

A short time after the discovery of Mr. Caven-

* Thomson's *Chemistry.* In some sentences the author has borrowed not only the facts, but also the language of this respectable writer.

† *Philosophical Transactions* for 1766.

dish, pneumatic chemistry was enriched by the addition of *Azotic* gas to the list of substances before known.—This gas was discovered in 1772 by Dr. Rutherford, now professor of botany in the university of Edinburgh, and an account of it published in his thesis *De Aere Mephitico*, in the same year. M. Lavoisier, in 1775, made known this gas as a component part of atmospheric air. About the same time it was procured by Scheele, and proved to be a distinct fluid. Its specific gravity has been investigated and determined by Kirwan and Lavoisier, the latter of whom makes it 0.00115, or to common air as 942.6 to 1000. The *combustibility* of azotic gas, and the production of *nitric acid* by this process, were first discovered by Mr. Cavendish, and communicated to the Royal Society in 1785. The name *Azote* was given to this gas by the French academicians, and is derived from its incapacity to support life.

The discovery of *Oxygen* was another very important step in the course of chemical improvement. The gas, the base of which is commonly known by this denomination, was discovered by Dr. Priestley, on the 1st of August, 1774, and called by him *dephlogisticated air*. Mr. Scheele, of Sweden, as was before observed, discovered it in 1775, without any previous knowledge of what Dr. Priestley had done; and gave it the name of *empyreal air*. Condorcet gave it first the name of *vital air*, and M. Lavoisier afterwards gave it the name of *oxygen gas*, which is now generally adopted.

The discovery of this substance, and the investigation of its properties, deserve to be ranked among the most important events recorded in the history of chemistry. The explanation which they have afforded to the principles of *combustion*, *respiration*, *acidity*, &c. places their value in a very interesting point of light. To this discovery, and these investigations, we may trace the commencement of that grand revolution in chemical science, which was soon afterwards established.

Paracelsus believed that there was only one acid principle in nature, which communicated taste and solubility to the bodies with which it was combined. Becher embraced the same opinion, and added to it, that this acid principle was a compound of *earth* and *water*, which he considered as two elements. Stahl, as we have seen, adopted the theory of Becher, and endeavoured to prove that the acid principle is *sulphuric acid*, of which, according to him, all the other acids are mere compounds; but his proofs were only conjectures or vague experiments, from which nothing could be deduced. Nevertheless, his opinion, like every other which he advanced in chemistry, continued to have supporters for a long time, and was even sanctioned by Macquer. At last its defects began to be perceived. Bergman and Scheele declared openly against it; and their discoveries, together with those of Lavoisier, demonstrated the falsehood of both parts of the theory, by showing that sulphuric acid does not exist in the other acids, and that it is not composed of water and earth, but of sulphur and oxygen.

The opinion, however, that acidity is owing to some principle common to all the salts, was not abandoned. Wallerius, Meyer, and Sage, had advanced different theories in succession about the nature of this principle; but as they were formed rather on conjecture and analogy than direct proof, they obtained but few advocates. At last M. Lavoisier, in 1778, by a number of ingenious and accurate experiments proved that several combustible substances, when united with oxygen, form acids; that a great number of acids contain oxygen; and that, when this principle is separated from them, they lose their acid properties. He concluded, therefore, that oxygen is the *acidifying principle*, as the word imports, and that acids are nothing more than combustible substances combined with oxygen, and differing from one another according to the nature of the combustible basis. This doctrine has been since confirmed by experiment, and is now generally received among chemists*.

For our knowledge of the *composition of atmospheric air*, we are indebted to the chemical philosophers of this period. The first step in this inquiry was taken by that unwearied experimenter, Dr. Priestley, in 1774, by the discovery of oxygen gas. This gas, according to the prevailing theory of the time, he considered as air totally deprived of phlogiston. Azotic gas, on the other hand, was air saturated with phlogiston. Hence he considered common air as oxygen gas combined with an indefinite portion of phlogiston, and varying in purity according to that portion, being always pure in an inverse proportion to the quantity of phlogiston it contained.

* Thomson's *Chemistry*.

While Dr. Priestley was making experiments on oxygen gas, Scheele, of Sweden, proceeded to the analysis of air in a different manner. From his experiments he concluded that common air is compounded of two different elastic fluids, viz. *foul air*, which constitutes more than two thirds of the whole, and *another air*, which is alone capable of supporting flame and animal life, and to which he gave the name of *empyreal air*. The *foul air* of Scheele was the same with the *phlogisticated air* of Priestley; and the *empyreal air* of the former was the same with the *dephlogisticated air* of the latter, or with what is at present called *oxygen gas*.

While Scheele was occupied with these experiments, Lavoisier was assiduously employed on the same subject, and was led, by a different road, to precisely the same conclusions. He found that common air is composed of azotic and oxygen gases; and, from a variety of experiments, he determined the proportions to be 73 parts of azotic gas, and 27 parts of oxygen gas. These experiments were made in the year 1776.

The discovery of the *composition of water*, before alluded to, next follows in the list of those brilliant acquisitions which distinguish the annals of chemical science during this period.—Water was believed, by the ancients, to be one of the four elements of which every other body is composed. The opinion of its being a simple substance seems generally to have prevailed until the year 1781, when Mr. Henry Cavendish, of Great Britain, discovered, by several experiments, that it is a compound, and formed by the union of oxygen and hydrogen. In a few months afterwards, the conclusion of Mr. Cavendish was confirmed by the experiments of M. Lavoisier and others: insomuch, that, during the last fifteen or twenty years, the composition of water has been generally considered as one of the best established facts in chemistry. It has been *decomposed* and *recomposed*, and found to consist of 85 parts, by weight, of oxygen, and 15 of hydrogen.

This discovery soon began to change the principles of chemical science. By furnishing a satisfactory explanation of many phenomena which were formerly difficult of explanation, if not wholly inexplicable, it has perhaps contributed more than any other single discovery to promote the progress of this branch of philosophy.

All the great chemists, whose names have been mentioned, were at this time votaries of the *phlogistic* theory of Stahl. Their experiments and discoveries, indeed, were sometimes found to militate strongly against this popular doctrine, and some of them ventured occasionally to call in question its leading principles. Still, however, discerning no preferable ground on which to rest, and finding some ingenious devices to reconcile discordant appearances, they adhered, in general, to the opinions of the illustrious German. But the fair structure of this great philosopher was doomed, like most human labours, to be soon overturned by the restless hand of innovation. The experiments on *metals;* the discovery of various facts and principles with respect to the matter of *heat;* and especially the discovery of *oxygen*, and of the *composition of water*, began to produce a conviction in the minds of some leading chemists in France, that the doctrine of *phlogiston* was utterly insufficient to account for the phenomena which they witnessed. Macquer and Bayen seem to have been among the first who declared their dissatisfaction with Stahl's theory. Their objections were adopted by a number of contemporary inquirers; but they contented themselves with an ingenious modification of the system, instead of an entire abandonment of it. To these objections succeeded a number of papers, in the *Annales de Chimie*, and the *Journal de Physique*, by Lavoisier and others, which indicated a growing dissatisfaction with the popular opinions, gradually introduced new modes of reasoning, and promised the approach of a grand epoch in the history of this science.

But it was not only the *doctrines* of chemistry that called for reform. Complaints had been long made, that the *nomenclature* of the science was inaccurate, perplexed, and inadequate*. To remove these complaints, many attempts had been made by chemical philosophers. It has been already observed, that Bergman laboured much to forward this branch of improvement. Scheele contributed to the correction of several old names, and added many new ones to the list; and Macquer discarded a number of the ancient terms, and substituted others less exceptionable in their place. Still, how-

* Some of the most familiar preparations were distinguished, by the old chemists, by the most ridiculous and unmeaning names. They loaded their nomenclature with such jargon as the following: *Liver of sulphur—mercury of life—butter of antimony—horned moon—the double secret—the coralline secret—the salt of many virtues—the foliated earth of tartar, &c.* To these, some still more capricious and inconvenient might be added. The difficulties and the mischief of retaining such a language must be apparent to every chemist.

ever, the evil, notwithstanding these partial reforms, continued and increased, until it became a serious impediment in the course of the student. Hitherto the number of objects which had engaged the attention of chemists, had been comparatively small. The *acids* amounted only to *five*; the *earths* to *four*; the *metals* to *twelve* or *fourteen*; and the *neutral salts* hardly exceeded *twenty*. To remember the names of so small a number of bodies, however inaccurate, or injudiciously selected, was no difficult task; but when the discoveries of Hales, Black, and Cavendish, had laid the foundation of pneumatic chemistry, the boundaries of the science began to enlarge with inconceivable rapidity, and the number of objects became, in themselves, and in their combinations, little short of immense. To have borne the names of all these objects in the memory, without any catenation between them upon philosophic principles, without establishing a system of mutual dependance and relation more simple and intelligible than had hitherto been done, would have been a task beyond ordinary powers. Such was the state of things, when a variety of concurring circumstances led to another and a greater revolution than had before occurred.

As early as 1782 M. de Morveau (now M. Guyton) proposed a *general* reform in the language of chemistry. At that time he had undertaken the management of the chemical part of the *Encyclopédie Méthodique**. Before entering on the execution of this great task, he thought it proper to

* See the Memoirs of *Morveau*, *Lavoisier*, and *Fourcroy*, read before the Royal Academy on this subject, in St. John's *Method of Chemical Nomenclature*, &c. 8vo. London. 1788.

lay the outlines of his plan before the most eminent chemists of France, that his labours, when completed, might have the stamp and authority of a national system. To this end, he published a memoir, after reducing to a regular form the various doctrines which had been, for a number of years, maturing in the minds of several of them, explaining his ideas on the subject of the proposed reform, exhibiting the principles on which he was about to proceed, and giving, at the same time, a new nomenclature, to which he invited the attention and the criticism of the philosophical world. After this publication by Guyton, several years elapsed before any thing decisive was done. He continued to labour in the improvement of his nomenclature; but at length, sensible of the magnitude and difficulty of the undertaking, he determined to avail himself of the advice and assistance of the members of the Royal Academy. For this purpose, he particularly associated with himself Messrs. Lavoisier*, Berthollet, and de Fourcroy. These four gentlemen, after spending much time on the subject; after combining their learning and wisdom in many patient consultations†; at length, in the month of April, 1787, presented to the academy their new *antiphlogistic theory*, accompanied with a new nomenclature, made out on the principles before laid down by Guyton, and which were both, in a few weeks afterwards, published to the world‡. About the same time was pub-

* See *Additional Notes*—(*U*).

† See the *Journal de Physique* for the month of May in that year.

‡ This body of chemical doctrines is sometimes called the *Lavoisierian* system. Considering the agency he had in its forma-

lished a new table of symbols and chemical characters, by Messrs. Hassenfratz and Adet, formed upon the principles of the proposed system, and fitted to illustrate the learned labours of their countrymen, which it accompanied. This table is generally supposed to contain many improvements on those of Geoffroy, Bergman, and Cullen.

To give in detail a distinct account of all the changes included in this new plan, would far exceed the limits prescribed to the present sketch. The following brief statement may suffice. Stahl and his followers had always supposed the *metals* to be compound substances, made up of a certain calx or earth, and *phlogiston;* but the new theorists, believing that there was no proof of such composition, set them down in their tables as *simple bodies.* The advocates for the former hypothesis had long contended that *sulphur*, *phosphorus*, *azotic* air, and various other substances of a like kind, were also compounds; whereas the believers in the new system took for granted that such composition could not be proved. In the old doctrine, *water* was placed among the simple bodies; but by the experiments of Cavendish and others, it was thought sufficient evidence had been given, that it is a compound substance. According to the former theory, the acid principle was considered as a compound of earth and water; the only radical acid in nature was supposed to be the

tion, this is scarcely ascribing too much to Lavoisier; for though many of the leading experiments on which the theory is founded were made by others, yet the task of digesting, arranging, and combining the whole into a consistent and regular system, was principally performed by him.

sulphuric, and all others different combinations of this primitive one: while, according to the latter doctrine, the acids are many in number, and result from the union of *oxygen* to different acidifiable bases. In short, while the disciples of Stahl undertook to account for almost all the phenomena of chemistry by the aid of *phlogiston*, the associated academicians considered it as a creature of the fancy, which had no real existence; and taught that all the facts and appearances in this science may be more satisfactorily explained without the aid of this imaginary substance. To these particulars it may be added, that, in this new theory, the number of chemical objects is greatly increased, and that articles which had occupied an inferior place in the old tables, are here made to hold a more conspicuous and important station.

The *nomenclature* in which this new theory was clothed, also deserves our notice. It was formed on the five following principles, laid down by Guyton in the memoir above mentioned—viz. 1. That every substance should be denominated by a *name*, and not by a *phrase*. 2. That the names should be, as much as possible, expressive of the *nature* of the things intended to be signified by them. 3. That when the character of the substance to be named was not sufficiently known to determine on a denomination expressive of its nature, a name without meaning should be preferred to one which might give an erroneous idea. 4. That, in the choice of new denominations, those which had their root in the most generally known dead languages, should be preferred, in order that the word might be suggested by the sense, and the sense by the word. And, 5. That the denominations should be arranged with care, to suit the genius of the language for which they were proposed. In conformity with these principles, the new terms introduced were taken, for the most part, from the *Greek* language; some from the *Latin;* and a few are formed by a mixture of syllables from each: and, that the change might not be carried to an unnecessary extent, as many of the old names were retained as could be made to incorporate with the new system. These denominations were arranged in systematic order, and the whole plan so constructed that the substances brought to light by succeeding discoveries might be placed under their proper heads, without derangement or disadvantage.

For some time after its publication, this new system of doctrines and of nomenclature was received by French chemists only, and indeed was by no means without opposition, even among them. Some members of the academy entered their protest against it, in moderate and respectful, but firm, language*. While they acknowledged that the *phlogistic* theory was attended with difficulties, they expressed a fear that the *antiphlogistic* plan was attended with as many, and of not less magnitude. Instead of moving to reject it, however, they proposed that it should be submitted to the trial of time, to the test of experiments, and to the elucidating influence of contending inquiries and opinions. This was accordingly done. The academy gave it to the world, without pronouncing

* See their representation, in the *Memoirs of the Royal Academy* for June, 1787.

on its merits, and it soon became the popular system of France.

The next year after the publication of the new theory and nomenclature by the Royal Academy, they were exhibited in an English dress, and began to be more generally studied than before by British chemists. Among these, the number of converts to the improved doctrines and language soon became considerable. But this favourable reception was by no means universal: Dr. Black, Dr. Priestley, Mr. Kirwan, and Mr. Keir, with a few other conspicuous characters, took their stand among the opposing party; and several of them wrote largely and ably against the new opinions and terms. It is obvious that any system opposed by such men must have serious obstacles to encounter. But the system in question made its way with wonderful success, amidst all opposition. Early in the year 1791, Mr. Kirwan, after combating in defence of phlogiston for a long time, and with admirable prowess, laid down his arms, and declared himself a convert to the new doctrine. In the same month Dr. Black gave up his objections, and went over to the antiphlogistian ranks. And, among all the distinguished British chemical philosophers, Dr. Priestley and Mr. Keir alone adhered to the opposition with which they set out. The former, especially, it must be acknowledged, defended the phlogistic citadel with a degree of skill, firmness, and force; and displayed an extent of resources, and a dignified zeal in the warfare, which must do him immortal honour among all who respect talents, and to whom science is dear.

Dr. Priestley uniformly continued to object that the fundamental principles of the new theory are erroneous, and that, of course, much of its language is altogether improper. He contended, with unabating confidence, that the *metals* are compound bodies; that *water* is a simple substance; that fixed air is formed by the union of inflammable and dephlogisticated airs; that phlogisticated air, or *azote*, is not a simple but a compound substance; that the antiphlogistic doctrine rests upon a foundation narrow and precarious, and professes to derive its support from experiments few in number, ambiguous in their nature, and explicable on either hypothesis with nearly equal ease; and, on the whole, that discarding phlogiston is so far from diminishing the difficulties of the chemical inquirer, that it multiplies and extends them*. In defending each of these positions, this illustrious veteran in science has undoubtedly exhibited astonishing industry, as well as great erudition and acuteness. How far the result of the controversy will justify his perseverance, it is difficult, and would certainly be presumptuous in one comparatively little acquainted with the subject, to predict. But when so great a majority of the philosophical world agree in supporting the doctrines which he opposed, it is, perhaps, rather more probable that the phlogistic theory will be ultimately pronounced the weaker. At all events, however, he is abundantly entitled to the honour of having made the best of his cause.

In Germany, and the neighbouring countries on

* See his late work, *The Doctrine of Phlogiston Established*, &c.

the continent, the French doctrines and nomenclature made their way rather more slowly than in Great Britain. Nearly two years after they had met with a general reception among the British chemists, they were introduced to those of Germany, chiefly by van Mons and Girtanner. They were received, on this introduction, in a favourable manner; and, after surmounting the first prejudices which a change so radical and extensive is always apt to excite, soon became generally popular. Since that time the prevalence of the new system has become almost universal. Indeed, there is no example, since the revival of learning, of a theory being more promptly and generally received, or defended with more ability and zeal, by the great body of philosophers, in all parts of the world, than this. If we except Dr. Priestley, Mr. Keir, and the *Lunar Society* of Birmingham, in Great Britain; M. Sage, and a few others, in France; and Crell, Mayer, Gmelin, and Westrumb, in Germany, we now hear of no distinguished advocates for the old opinions.

Beside the signal revolution in chemical theory which has been stated, every part of the century under consideration, and especially the latter half of it, has abounded in experiments and discoveries of great importance, particularly when considered with reference to their systematic relations.

Few questions in science have given rise to more discussion than that which relates to the *nature of Heat.* Whether it be a distinct *substance*, or a mere *quality* of substance, has long been the subject of disputation. By the ancient philosophers, heat seems to have been considered as a peculiar subtile fluid or element; and this opinion appears to have prevailed until the time of lord Bacon. That philosopher was the first, it is believed, who advanced the hypothesis that heat is a quality of matter, and depends on a peculiar vibration of its particles. This opinion was afterwards adopted by Boyle and Newton, whose authority rendered it considerably popular: the ancient opinion, however, was still held by many. Boerhaave, at an early period of the eighteenth century, entered the lists against Newton on this subject, and maintained, with great force of argument, that heat is a *distinct substance.* From the time of Boerhaave till towards the close of the century under review, this doctrine was almost universally received. Stahl, Macquer, Black, Priestley, Scheele, Bergman, Lavoisier, Crawford, Irvine, Kirwan, Pictet, de la Place, and most other distinguished chemists, though differing as to some details of opinion on this subject, all agree in considering heat as a distinct positive substance.

But, towards the close of the century, the doctrine of Bacon was revived by count Rumford and Mr. Davy. These philosophers, observing that caloric continues to be extricated from a body subjected to friction, so long as the friction is kept up, and the texture or form of the body is not destroyed; and that this heat-yielding process goes on to an *indefinite* extent; concluded that this phenomenon is inexplicable on the supposition of heat being matter; and that those effects which have been referred to the operation of a peculiar calorific matter, depend entirely on a *vibratory motion* of the particles of bodies; and that, from the generation, communication, or abstraction, of this motion, all the phenomena ascribed to caloric are to be explained *.

This doctrine, however, has but few advocates. The suffrages of modern philosophers are almost unanimous in favour of the opinion that caloric, or heat, is a distinct fluid. The latter opinion, indeed, seems to be confirmed, to a degree little short of demonstration, by the late experiments of Dr. Herschel on this subject; who has shown, that the rays of *light*, and the rays of *heat*, emitted from the sun, are distinct and separable; that the latter, as well as the former, are *refracted* by transparent bodies, and *reflected* by polished surfaces; and that both consist of particles which mutually repel each other, and which produce no sensible effect upon the weight of other bodies †.

It cannot be denied, indeed, that some difficulties attend the doctrine of heat being a distinct and positive substance. Nor is the following, which count Rumford suggests, by any means one of the smallest; viz. "that any thing which any insulated body, or system of bodies, can continue to furnish, *without limitation*, cannot be a material substance." Yet the *electric fluid* is granted, on all hands, to be a distinct substance; and we know that this fluid is constantly furnished, *without limitation*, by means of friction. On the whole, the old opinion seems still, with all its difficulties, to stand on firmer

* See *Rumford's Essays;* and *Contributions to Medical and Physical Knowledge.*

† *Philosophical Transactions* for 1800.

ground than any other, and to have by far the greatest number of advocates.

The doctrine of *radiant heat*, or that heat resembles light in being propagated in *rays*, or right lines, was, in some measure, known to Mariotte, Lambert, and Scheele; but was more clearly established afterwards by the experiments of Saussure, Pictet, and count Rumford; and, finally, the laws of this propagation were more fully developed and laid down by Dr. Herschel, in his celebrated experiments on light and heat before mentioned.

Count Rumford concluded, from his experiments, that fluids do not *conduct* heat; but he ascribes to them what he denominates a *carrying* power: in other words, he supposes, that, in heating fluids, each particle must come in succession to the source of heat, and receive its portion; but that, among the particles themselves, all *interchange* and communication of heat is impossible. The experiments by which he considers himself as having established this point are certainly striking, and their results highly curious; but the justness of his conclusions has been called in question, and philosophers do not seem to view his decision as absolute and final. Further experiments must decide the controversy.

The first person who made experiments on *freezing mixtures*, was Mr. Fahrenheit, of Amsterdam, at an early period of the eighteenth century. But the subject was much more completely investigated by Mr. Walker, in a paper published in the *Philosophical Transactions* for 1795. Since that time several curious additional experiments have been made by professer Lowitz, of Petersburg; particularly the introduction of *muriate of lime*, which produces a very great degree of cold when mixed with snow. The experiments of Lowitz have been lately repeated and extended by Mr. Walker. By means of the above-mentioned mixture, Mr. W. H. Pepys, junior, of the London Philosophical Society, with the assistance of some friends, froze, on the eighth of February, 1799, fifty-six pounds avoirdupois of mercury into a solid mass. In this process, the mercury in Fahrenheit's thermometer sunk 62 deg. below 0—a degree of cold never before produced in Great Britain.

The inquiries of modern chemists into the nature and properties of *Light* have been scarcely less numerous and interesting. Those discoveries respecting this substance which fall under the science of *optics*, have been mentioned in another place. The capacity of other bodies to receive light, to retain it in a *fixed state*, and afterwards to part with it, without alteration, was discovered by the experiments of father Beccaria, Mr. Canton, Mr. Wilson, and M. de Grosser. The affinity between light and heat, and the similarity of their effects, in certain cases, have been diligently investigated by Dr. Franklin, Mr. Wedgewood, Messrs. Pictet, Chaptal, and Dorthes, and especially by count Rumford and Dr. Herschel. The researches of M. Berthollet and of Dr. Bancroft, in the philosophy of *permanent colours*, upon chemical principles, were mentioned in the preceding chapter. The experiments of Dr. Priestley, the abbé Tessier, Dr. Ingenhouz, and others, on the effects of light upon growing vegetables, and the curious inquiries of Herschel, into the different *heating and illuminating* *power* of the different prismatic colours, are also worthy of notice in the list of modern discoveries *. The importance of these inquiries, whether considered as insulated facts, or with reference to systematic chemistry, will readily occur to every scientific reader.

In 1769 Mr. Gahn, of Sweden, discovered that *phosphorus* was contained in *bones;* and his countryman, Scheele, very soon afterwards invented a method of obtaining this substance from them. The properties of *phosphorus* have been also more successfully investigated, during this period, than ever before, by Margraaf, Guyton, Lavoisier, and Pelletier. The properties and combinations of *carbon* have been very ably examined, within a few years past, by many eminent philosophers. The power of this substance, to correct impurities and to remove disagreeable odours, has been shown by the experiments of Mr. Lowitz, of Petersburg, and several others. The discovery, by Mr. Tennant, that the *diamond* is pure *carbon* in a state of *crystallization* †, is by no means a small or uninteresting step in the progress of chemical science.

As the diamond is not affected by a considerable heat, it was for many ages considered as incombustible. Sir Isaac Newton, observing that combustibles refract light more powerfully than other bodies, and that the diamond possesses this property in great perfection, suspected it, from that circumstance, to be capable of combustion. This singular conjecture was verified in 1694, by the Florentine Academicians, in the presence of Cosmo III, grand

* See *Additional Notes—(V).*

† *Philosophical Transactions,* 1797.

duke of Tuscany. By means of a burning glass they consumed several diamonds. Francis I, emperor of Germany, afterwards witnessed the destruction of several more in the heat of a furnace. These experiments were repeated by Rouelle, Macquer, and Darcet, who proved that the diamond was not merely evaporated, but actually burnt, and that if air was excluded it underwent no change.

No attempt, however, was made to ascertain the product till 1772. Lavoisier, in a memoir published that year, showed, that, when the diamond is burnt, *carbonic acid gas* is obtained; and that there is a striking analogy between it and charcoal. In 1785 Guyton-Morveau found that the diamond is combustible when dropped into melted nitre; that it burns without leaving any residuum, and in a manner analogous to charcoal. This experiment was repeated with more precision by Mr. Tennant, in 1797. The conclusion which he drew from it was, that, when diamond is burnt, the whole of the product is carbonic acid gas; that a given weight of diamond yields just as much carbonic acid gas as the same weight of charcoal; and that diamond and charcoal are both composed of the very same substance—or rather, to speak more precisely, diamond is pure carbon, while charcoal is a compound of carbon, or diamond, and oxygen, or it is what the French call an *oxyd of diamond*. Hence the difference of colour, hardness, specific gravity, and electrical properties, between common *charcoal* and the precious stone called *diamond*.

Since the commencement of the eighteenth century, a number of new *Metals* have been discovered, and the affinities and other properties of metallic substances in general have been better understood than before. Those who most eminently distinguished themselves in this department of chemistry, were Margraaf, Cronstedt, Klaproth, Scheele, Bergman, Vauquelin, Kirwan, Proust, Sage, and Lavoisier; to which might be added many other names. New *Earths* have been discovered, and their chemical properties ascertained, by several of the able chemists last mentioned, and also by Black, Gahn, Hope, Crawford, and Wedgewood. That class of chemical substances denominated *Alkalies*, has been better understood, of late years, than in the preceding century. For our knowledge of this department of the science in question, we are particularly indebted to the investigations of du Hamel, Black, Meyer, Priestley, Dieman, van Troostwyck, Bondt, Berthollet, and Austin. Modern chemists have also discovered many new *Acids*.

The acids known at the close of the eighteenth century amount to about *thirty*, the greater number of which have been discovered within the last *forty years*. Of these, nearly one third were discovered by the celebrated Scheele, and the remainder chiefly by Margraaf, Priestley, Lavoisier, Vauquelin, Berthollet, and Keir.

It was not till the century under review that chemical analysis was applied to investigate the composition of *animal* bodies. This has been attempted by a number of modern chemists, and with very honourable success. Among these, the inquiries of Scheele, Gren, Fourcroy, Vauquelin, and Girtanner, are entitled to very respectful notice. But the elaborate researches of Mr. Hatchet, in this interesting field of inquiry, are particularly well known, and do equal honour to his industry and acuteness*. The same department of chemistry has also been explored, with great success, by M. Merat Guillot† and others. These investigations have led to important discoveries, have thrown much light on the animal economy, and furnished many indications for the improvement of medicine and surgery.

Though *vegetable physiology* had been studied with some degree of success, by several persons, in the seventeenth century; yet, pursuing this species of inquiry through the medium of chemistry was scarcely thought of, and far less realised, till the eighteenth. Within a few years past chemists have directed much attention to the structure, composition, and food of plants; have greatly extended, by this means, the limits of the science; and have contributed much to the improvement of botany, agriculture, the materia medica, and various arts of life. Among those who have displayed the greatest acuteness, zeal, and success, in this department of chemical inquiry, we may reckon Dr. Hales and Dr. Priestley, of Great Britain; Dr. Ingenhouz and Mr. von Humbold, of Germany; Mr. Sennebier and Mr. Saussure, of Geneva; and several others.

The employment of chemistry by the *mineralogist*, as a means of analysing the various substances

* *Philosophical Transactions* for 1799 and 1800.

† *Annales de Chymie*, tom. xxxiv, p. 68.

which come before him, was first undertaken in the century under review. Margraaf and Pott, of Berlin, were among the earliest adventurers in this new field of inquiry. They were succeeded by Neumann, Bergman, and Scheele, who displayed great industry, address, and perseverance, in the same course of investigation, and went much further than their predecessors. To these may be added Klaproth, Sage, Vauquelin, Hatchett, and many more; to whom we are indebted for many new facts, and refined experiments, on the chemical properties of mineral bodies.

Since the grand revolution in chemical doctrines and language, effected by the labours of the French academicians, as above detailed, the new opinions, and the proposals of further reform in this science, have been numerous. Indeed, during the last fifteen or twenty years of the century, the number of students and experimenters in chemistry has been so prodigiously great, and the new plans announced for explaining and expressing its principles so multiplied and various, that a simple catalogue of them would fill many pages. All that can be attempted in this brief sketch, is to mention a few of those who have rendered themselves conspicuous by their inquiries or publications on chemical subjects.

A new nomenclature of chemistry was proposed, in 1796, by professor Dickson, of Trinity college, Dublin, and approved by his illustrious countryman, Mr. Kirwan. In this plan of chemical denominations there is an attempt to unite the advantages of both the principal systems, between which the philosophical world was then called to choose. Many of the old names, discarded by the French academicians, are restored by Dr. Dickson; while many substances, to which names are given by them, he has left out, as not sufficiently understood. He derives his new terms chiefly from the *Latin*, instead of the *Greek* language; and he prefers that mode of arrangement and classification which assigns the generic rank to *alkalies*, *earths*, and *metals*, and reserves the *acids* for the distinction of species. He retains, however, *oxygen*, and a few other words of Greek derivation. The advantages which, in the opinion of the Irish professor, would arise from the adoption of this nomenclature, are, that the old books on chemistry would thereby be more readily understood and more valuable, and that the acquisition of the science would be more simple and easy. Dr Dickson's plan, though it undoubtedly does no small honour to his learning and taste, has not, it is believed, been adopted by any distinguished teacher of this branch of philosophy.

It is proper also to take notice of a plan, by Dr. Lubbock, of Great Britain, for removing the difficulties and terminating the controversy respecting *phlogiston*. His idea of dividing all matter into two kinds—the *principium proprium*, and the *principium sorbile*—and of accounting for all chemical phenomena by the combinations of these, is very ingeniously defended in his work on the subject*. No less worthy of respectful notice is Mrs. Fulhame's attempt to correct the *antiphlogistic* theory, by referring to water as the source

* *Dissertatio Physico-Chemica, de Principio Sorbili.*

of oxygen in all oxydations; a very honourable monument of female enterprise and talents*. The plan of a new nomenclature, by Mr. Weiglib, a German chemist, also indicates considerable learning and ability†. To these may be added some proposed alterations in the French nomenclature, by Dr. Pearson‡, before mentioned, and by several other ingenious writers. Though none of these authors can be said to have produced revolutions in the science of chemistry, or perhaps to have suggested very important improvements, yet they are entitled to a respectful notice in the chemical history of the age.

In the course of the last six years, Dr. Mitchill, the ingenious and learned professor of chemistry in Columbia College, has proposed some new terms in this science, and announced some new opinions, of which it will be proper to take notice.

His doctrine of *pestilential fluids*, which has been laid before the public in various forms since 1796, holds the first place, both with respect to time and importance. He supposes that the union of *azote* and *oxygen*, either in the form of *oxyd* or *acid*, and more especially in the latter, constitutes the mischievous substance which, in its operation on the human body, produces pestilence. In correspondence with this opinion, he teaches that *alkaline* and *calcareous* remedies are the most effectual means of disarming the force and obviating the destructive effects of this poison. At the

* *Essay on Combustion.*

† *Encyclopædia.* Art. *Chemistry.*

‡ See his View of the French Nomenclature, 4to, 1799. London.

same time the professor proposed an alteration in the nomenclature, agreeing with his new doctrine, and illustrative of its principles. Considering *azote* as having an important agency in the process of *putrefaction*, he proposed to introduce the word *septon** instead of *azote*, and hence denominated the deleterious compounds above mentioned the *oxyd of septon*, and *septic acid*. The various facts and reasonings adduced by the professor in support of these opinions, and the extensive application of which he considers them as susceptible, have been so generally made known and discussed, both in Europe and America, as to preclude the necessity of giving further details.

In 1797 Dr. Mitchill, with a view to terminate the controversy between the *phlogistians* and their opponents, proposed to expunge *hydrogen* from the nomenclature, and to introduce *phlogiston*† in its place. He suggested, that giving this old and popular name to a known and definite substance, instead of using it in its former vague manner, and ascribing to this substance those qualities which had been formerly ascribed to a nonentity, would go far toward reconciling many points of difference between the advocates of the old and the new systems, and would throw much light on many chemical phenomena. The same gentleman soon afterwards proposed to discard the term *calorique*,

* This word is derived from σηπω, *putrefacio*: hence σηπτος, *putridus*, and τὸ σηπτον, *what peculiarly disposes bodies to rot.* Medical Repository, vol. ii, p. 50.

† Derived from φλογιζω, *inflammo*: hence τὸ φλογιστον, *the principle of inflammability*, or that which, in any substance, *burns with blaze.*

adopted by the French academicians, and to substitute the word *anticrouon** in its stead. He supposed, that denominating the matter of heat the great *principle of repulsion,* would lead to more correct philosophical views with respect to this substance, as well as render the language of chemistry more accurate. These several opinions and proposals have been some time before the public; and, whatever may be the ultimate judgement of chemists with regard to their adoption, the praise of great learning, ingenuity, and industry, must undoubtedly be given to their author †.

Beside the revolutions and improvements in the doctrines and in the language of chemistry which have been detailed, various *instruments* and *machines,* of great value for measuring chemical substances, or facilitating chemical processes, have been invented in the course of the last century. Of some of the most important of these it will be proper to give a short account.

At an early period of the century, while speculations on the nature and properties of *heat* engaged the attention of the philosophical world, various contrivances for measuring this fluid were

* Derived from the verb *αντικρουω, repello:* hence τὸ *αντικρουον, the principle of repulsion.*

† Those who wish to see a more detailed account of Dr. Mitchill's new chemical opinions and terms, will find it in his *Explanation of the Synopsis of Chemical Nomenclature and Arrangement,* &c., lately published. Much information on this subject may also be found in the volumes of the *Medical Repository,* and in several of the European journals. In these publications the reader will see the respectful manner in which the inquiries of the learned professor have been noticed in different parts of Europe.

invented and adopted*. The *Thermometer*, which had been first used about the beginning of the preceding century, was constructed on a new and improved plan, by sir Isaac Newton, in 1701. He chose, as fixed points of graduation, those at which water freezes and boils; a choice which the experiments of succeeding philosophers have proved to be the most wise and convenient. He also introduced the use of *oil* to fill the tube, instead of *alcohol*, under an idea that the former was liable to fewer disadvantages than the latter. But, after all the labours of sir Isaac, this important instrument was imperfect, and could by no means be considered as an exact standard for pointing out the various degrees of temperature. Accordingly, about the year 1724, Mr. Fahrenheit, of Amsterdam, suggested the use of thermometers made with *mercury*, and presented one of this kind to the Royal Society of London. It was soon found that this fluid was preferable to all others, being more homogeneous, more easily freed from air, more regularly expansible by different degrees of heat, and more difficult to congeal. Mr. Fahrenheit also proposed a new mode of graduating the instrument. His thermometer has since come into general use in Great Britain, America, and in the various parts of the world in which British habits prevail.

In 1730 M. Reaumur, a French philosopher, constructed a thermometer on a new plan. He adopted a mode of graduation different both from Newton and Fahrenheit, and resumed the use of

* See *Additional Notes*—(W).

alcohol. His plan was, of course, still far from being perfect. The thermometer now in use in France, and through a great part of the continent of Europe, under the name of Reaumur's, ought strictly to be called Mr. de Luc's, who made a very important alteration in M. Reaumur's mode of graduating the instrument, and again exchanged *alcohol* for *mercury.* In 1733 M. de l'Isle, of Petersburg, constructed a mercurial thermometer, which is generally used in Russia. Another, graduated in a different manner, by Celsius, and also filled with mercury, is most popular in Sweden *.

Beside these leading inventions and revolutions which the history of thermometers presents, the plans which have been suggested in modern times, for improving this instrument, are many and ingenious. These have been successively proposed by lord Cavendish in 1757; by Mr. Six in 1782; by Dr. Rutherford in 1790; and still more recently by Mr. Keith, whose new *self-registering* thermometer is said to be the most ingenious, simple, and perfect, of all that have hitherto appeared.

It was still, however, an important desideratum, to find some easy and exact method of measuring very high degrees of heat. Such a method was not long since invented by Mr. Wedgwood, of Staffordshire, a gentleman well known for his great improvements in the art of pottery. After

* See Dr. Martine's *Essay on the Construction and Graduation of Thermometers;* one of the best works extant on this subject. Mr. de Luc, of Geneva, and professor van Swinden, of Francker, have also written ably and instructively concerning Thermometers.

many experiments*, he produced an instrument which he called a *Pyrometer*, and which, by means of the contraction of *clay*, marks, with much precision, the different degrees of heat, from 947° of Fahrenheit's scale, to the greatest heat of a wind-furnace.

It was first observed by Dr. Black, that different bodies have different capacities for imbibing and retaining heat. The fact was afterwards noticed, and the subject further investigated, by Drs. Irvine and Crawford, and by professor Wilcke, of Stockholm. The last named gentleman called the quantity of caloric necessary to raise the temperature of substances a given number of degrees, their *specific heat*. For measuring this heat an instrument was contrived by Messrs. de la Place and Lavoisier, and called by the latter a *Calorimeter;* the nature and value of which may be seen in various books of chemistry.

Another instrument, invented in modern times, and which has engaged much of the attention of chemists, is the *Eudiometer*†. This instrument was invented by Dr. Priestley, and is used for ascertaining the purity of the atmospherical air, or the quantity of oxygen contained in it, which is indicated by the diminution of its volume on being mixed with nitrous air. The discovery of this property of nitrous gas, and the invention founded upon it, soon gave rise to many attempts to improve on the principle, and to contrive *eudiometers* of a more elegant and advantageous kind, and

* See *Philosophical Transactions* for 1782, 1784, 1786.

† See *Additional Notes*—(X).

with different materials. These attempts were made, and various plans successively proposed, by Cavendish, Fontana, Volta, Scheele, de Marti, Guyton, Achard, Berthollet, Davy, and several others. But the instrument, in its most favourable form, is still liable to much uncertainty and inaccuracy in its application.

The machine for impregnating water with *carbonic acid gas,* or *fixed air,* invented a few years ago by Dr. Nooth, deserves to be respectfully mentioned, as a monument of ingenuity, and as a very useful piece of furniture for every chemist and physician. Beside this, our list might be enlarged by the enumeration of many other instruments and machines which have been added to the chemical apparatus in modern times, and which have greatly contributed to the ease, elegance, and perfection, of chemical experiments.

After mentioning the great names, and the brilliant discoveries, which have been recounted in the foregoing pages, it would be unjust to omit taking notice of some other philosophers who have distinguished themselves by their publications or experiments in this branch of science. Among a great number, whose names and labours will be found honourably recorded in the scientific history of the age, we may mention bishop Watson, Mr. Nicholson, Dr. St. John, Mr. Henry, Mr. Cruikshank, Dr. Darwin, lord Dundonald, Mr. Lambe, Mr. Higgins, and Dr. Thomson, of Great Britain; Messrs. Chaptal, Monge, Monnet, Beaume, Cadet, Thouvenel, la Metherie, Adet, and Seguin, of France; and van Homberg, Juncker, Schrœder, Wenzel, Henkel, Jacquin, Meyer, Crell, and Hermbstadt, of Germany; to say nothing of many others, equally entitled to praise, in almost every cultivated part of Europe*.

From the above general statement, it appears that within the last half century the empire of chemistry has been wonderfully extended. It is but a short time since this science recognised, as the subjects of her sway, only a few *metals* and *medicines*. She has lately subjected to her sceptre the various kinds of *earths* found in the composition of our globe; the different *fluids* with which we are conversant, whether of the *aqueous* or *gaseous* form; the various kinds of *vegetable*, *animal*, and *mineral* bodies which surround us; and almost every substance capable of composition or analysis. In short, she has extended her claims to every species of *animate* and *inanimate* matter, and maintains authority over a territory of physical science which may be called immense, when compared with her former dominions.

But chemistry has not only gained, during the eighteenth century, a great extent of empire; it is also distinguished for having acquired, in the same period, a more *practical* and *useful* cast than ever before. By its ancient cultivators chemistry was chiefly regarded as an object of *curiosity*, or as a source of *amusement*. But in the hands of later chemists it has been converted into a very

* The contributions made to chemical knowledge by most of the above named gentlemen may be found either in distinct works, published by themselves, or in the *Philosophical Transactions*, the *Journal de Physique*, the *Annales de Chimie*, or other scientific journals.

instructive, interesting, and invaluable science. There is scarcely an art of human life which it is not fitted to subserve; scarcely a department of human inquiry or labour, either for health, pleasure, ornament, or profit, which it may not be made, in its present improved state, eminently to promote.

To the *husbandman* this science furnishes principles and agents of inestimable value. It teaches him the *food* of plants; the choice and use of *manures;* and the best means of promoting the vigour, growth, productiveness, and preservation, of the various vegetable tribes. To the *manufacturer* chemistry has lately become equally fruitful of instruction and assistance. In the arts of *brewing*, *tanning*, *dyeing*, and *bleaching*, its doctrines are precious guides. In making *soap*, *glass*, *pottery*, and all *metallic* wares, its principles are daily applied, and are capable of still more useful application as they become better understood. Indeed, every mechanic art, in the different processes of which heat, moisture, solution, mixture, or fermentation is necessary, must ever keep pace in improvement with this branch of philosophy. To the *physician* this science is of still greater value, and is daily growing in importance. He learns from it to compound his medicines; to disarm poisons of their force; to adjust remedies to diseases; and to adopt general means of preserving health. To the student of *natural history* the doctrines of chemistry furnish instruction and assistance at every step of his course; as many of his inquiries can be prosecuted with success only through the medium of careful analysis. To the *public economist* chemistry presents a treasure of useful information. By means of this science alone can he expect to attack with success the destroying pestilence, so far as it is an object of human prevention, and to guard against other evils to which the state of the elements gives rise. And to the successful prosecution of numberless plans of the philanthropist, some acquaintance with the subject in question seems indispensably necessary. Finally, to the *domestic economist* this science abounds with pleasing and wholesome lessons. It enables him to make a proper choice of *meats* and *drinks;* it directs him to those measures with respect to *aliment*, *cookery*, *clothing*, and *respiration*, which have the best tendency to promote health, enjoyment, and cheapness of living; and it sets him on his guard against many unseen evils, to which those who are ignorant of its laws are continually exposed. In a word, from a *speculative* science, chemistry, during the eighteenth century, has become eminently and extensively a *practical* one; from an obscure, humble, and uninteresting place among the objects of study, it has risen to a high and dignified station; and instead of merely gratifying curiosity, or furnishing amusement, it promises a degree of utility, of which no one can calculate the consequences, or see the end.

But while the great improvements which have been made in *chemical* philosophy during the last century are readily admitted, it may not be improper, before closing this chapter, to take notice of the gross abuses, which have been adopted by some of the most celebrated cultivators of the science in question, and which have contributed to lessen its value in the view of many serious inquirers. A few extravagant and enthusiastic votaries of chemistry have undertaken, on chemical principles, to account for all the phenomena of *motion*, *life*, and *mind;* and on those very facts which clearly prove wise design, and the superintending care of an INFINITE INTELLIGENCE, have attempted to build a fabric of *atheistical* philosophy. This is a striking instance of those *oppositions of science falsely so called*, of which an inspired writer speaks, and for which the past age has been remarkably distinguished.

How far the present fashionable system of chemical doctrine and language may stand the test of future experiments, and command the assent of future generations, is far from being certain. He who has attended to the course of things in the short space of time since it was published, will see little reason to expect for it that undisturbed and permanent reign which its advocates have fondly hoped. It is somewhere remarked by lord Bacon, that the sciences are apt to suffer by being too soon reduced to a system. There are probably few sciences to which this remark applies with such peculiar force as to chemistry. The structure at present most popular is fair and beautiful. An engaging simplicity reigns in almost every part. But many believe that this simplicity is deceptive. Some of the doctrines which hold an important place in the fabric are too vague and conjectural to be admitted with full confidence, and others are daily undergoing modifications, which threaten still further and more essential changes. Notwithstanding the mathematical precision with which the sanguine chemist affects to speak of his axioms, yet how discordant are the results of different experiments! These facts, it must be acknowledged, "betray the lameness of some received principles, and excite suspicions with respect to the legitimacy of some capital analyses." But the enlightened and enterprising philosopher will not be discouraged by such proofs of the imperfection of human knowledge. The builders of erroneous systems become indirectly the promoters of truth, by contributing to the examination and rejection of falsehood. The course of improvement has always been found to make its way through successive defiles of illusion, empiricism, and false theory. In this course honesty, attention, and patient perseverance, are the great requisites for obtaining success. With these, though we cannot expect to develop all the mysteries of nature, which is the prerogative of its Author alone; yet we may hope, in time, to detect analogies, to ascertain laws, to systematise scattered facts, and to unlock treasures of science, which appear at present far removed from human scrutiny, and against the knowledge of which the feebleness of our powers seems to raise an everlasting barrier.

CHAPTER III.

NATURAL HISTORY.

THIS department of science scarcely yields to either of the preceding in the extent and value of the improvements which it has received within the period under consideration. Many of the objects, indeed, to which natural history relates, have been, in some degree, known and studied by man, from the earliest ages, as means of supplying the wants, and obtaining the luxuries of life. Solomon, the king of Israel, we are told, *spake of trees, from the cedar tree that is in Lebanon, even unto the hyssop that springeth out of the wall;—he spake, also, of beasts, and of birds, and of creeping things, and of fishes**. And, if we may judge from the respectful terms in which such studies are mentioned, in this and in various other passages of sacred scripture, we may conclude they were held in high estimation in very early times. It was not, however, until long after the revival of letters and science in Europe, that natural history began to receive the attention due to its importance. Toward the close of the seventeenth century, after several learned societies in Great Britain, and on the continent, had been formed, the taste for this

* 1 Kings iv, 33.

branch of study commenced, and has been ever since gradually extending itself over the civilised world.

At an early period of the eighteenth century, many persons were busily employed in collecting and publishing facts in Natural History, especially in *Zoölogy* and *Botany*. Among these the name of the learned and indefatigable Albert Seba deserves particular notice. He resided in Holland, was intimate with Boerhaave, and compiled his large work on Natural History under the patronage of that eminent naturalist and physician. This work, under the title of *Thesaurus Rerum Naturalium*, was published in 1734, in four vols. folio. But though these inquirers rendered important service to this department of philosophy, it was rather by communicating a knowledge of details, than by enlightened and correct philosophising on the subjects which came before them. Scarcely any thing had been effected, on a great scale, previous to the appearance of Linnæus, an illustrious Swede, who, by his first publications, in 1735, gave a new aspect to the whole science, and commenced what has been with much justice styled the "golden age" of Natural History.—Almost every thing that had been done in the great business of *Classification*, before his time, was confused, and exceedingly defective; and, in some of the kingdoms of nature, few attempts of the kind had been made. It is not necessary to remind the intelligent reader how much this deficiency must have perplexed and retarded the inquirer, at every step of his course. It was reserved for Linnæus, a man equally distinguished for the benevolence and piety of his heart, the extent of his learning, and the greatness of his views, to remedy the defect. To his luminous and expanded mind, the arduous task of generalising and arranging seemed to be an easy and familiar process. He introduced new methods of classification into all the more important branches of natural history; made large additions to its known facts and principles; excited a thirst, before unequalled, for this kind of knowledge; and prepared the way for a great portion of the improvements which have been made by succeeding naturalists.

While the last age produced much new light in the philosophy of natural history, and added immense riches to its former stores, it also gave to this science new distinction as an object of study in seminaries of learning.—At the close of the seventeenth century, it is believed, only a few *professorships* had been instituted, even in the most distinguished universities, for instructing youth in this interesting department of knowledge. Since that time few important colleges or universities have failed to add such professorships to their former plans of instruction, and to place natural history among the indispensable objects of attention in an academic course. By these and other means new honours have been bestowed on this branch of science, new encouragement given to the zeal and exertions of inquirers, new roads to improvement opened, and new opportunities afforded, at once, of diffusing a taste for investigations of this nature, and of extending the information which genius and industry had gained.

But it will be more satisfactory to take a brief view of the several kingdoms of nature, and to state some leading facts concerning the progress which has been made in each *.

SECTION I.

ZOOLOGY.

At the beginning of the eighteenth century considerable progress had been made in this branch of Natural History, by the inquiries and discoveries of Harvey, Redi, Malpighi, Willoughby, and Ray. These illustrious men discarded several erroneous doctrines which had long been received, particularly the doctrine of *equivocal generation*, and threw much light on the principles of physiology. Ray, being dissatisfied with Aristotle's classification of animals, invented a new one, founded on the structure of the *heart*. To this he was particularly led by the discoveries of Harvey, relating to the *circulation of the blood*, which had been a little before announced, and excited much attention in the philosophical world. From the time of Ray till that of Linnæus †, Zoölogy was culti-

* The contents of this chapter have been principally collected from Smith's *Tracts on Natural History*, and many other works, on detached parts of the subject; some of which will be found quoted, or referred to, in the following pages. For a knowledge of some of the facts and names here detailed, I am indebted to professor Barton, of Philadelphia, who, in a conversation on the subject, furnished me with much valuable information, and with profitable hints for directing my inquiries.

† This "Prince of Naturalists" is so well known, that a formal account of him in this place is altogether unnecessary. He

vated with considerable success, and received some important accessions, as will appear from the names of several naturalists hereafter to be mentioned. But the service rendered to this department of science by the illustrious Swede was still more important, and cannot be contemplated without admiration. He described many new animals, and formed a new arrangement and nomenclature, in many respects original, and in general greatly superior to any that had gone before him. From this period writers on the various departments of the animal kingdom began rapidly to increase in number, in the extent of their information, and in the accurate and philosophical aspect of their descriptions.

Soon after Linnæus appeared M. Klein, of Dantzic, who strenuously combated a number of the alterations proposed by that illustrious naturalist, and signalised himself as his adversary. Klein gave to the world a new method of classification, founded on the *toes*, *hoofs*, &c.; and by his multifarious works, on almost every department of zoölogy, which he treated both systematically and physiologically, rendered very important service to the science. About the same time flourished M. Brisson, a French naturalist of very high character, and whose publications, particularly on *Quadrupeds* and *Birds*, rank in the first class on their respective subjects. Indeed, in the accuracy of his

was born at Roeshult, a village of Sweden, May 27, 1707. His first great work was published in 1732. Among the numerous public honours with which he was crowned, he was created knight of the Polar Star in 1753, and ennobled in 1757. He died in January, 1778, in the 71st year of his age.

descriptions, and the excellency of his plates, he may even be pronounced superior to Linnæus himself. After Brisson may be mentioned his countryman the count de Buffon *, who, though more sprightly and interesting as a writer, in which he excels all other natural historians, is far less accurate and philosophical. His neglect of regular systematic arrangement is a great defect, and must ever lessen the value of his works. He was a zealous cultivator of zoölogy, and by his splendid publications and captivating style made himself admired throughout the scientific world. And though many of his hypotheses are whimsical, extravagant, and delusive, it must yet be allowed that he did much to encourage and forward the study of nature; that he made many observations of great value; that he collected a multitude of interesting facts; and that his works hold a very important place in the zoölogical history of the age.

Contemporary with Buffon was Mr. Pennant, of Great Britain, who is unquestionably entitled to a place among the greatest zoölogists of the eighteenth century †. By his writings, as valuable as they are voluminous, he contributed greatly to the advancement of this branch of natural history. He was the author of a new arrangement

* George le Clerc, count de Buffon, was born in the year 1707, and died in 1788.

† Thomas Pennant, LL. D. F.R.S., was born in Flintshire, in North Wales, in the year 1726, and died in 1798. He cultivated zoölogy with great ardour, ability, and success; and was one of the most voluminous writers of the age.

of *Quadrupeds,* more nearly resembling Ray's, of the former century, than any other. On this subject his work may be pronounced equal to any, if not the best that has yet been presented to the student of nature. Within the same period, professor Blumenbach, of Goettingen, distinguished himself by his zoölogical and physical inquiries, and particularly by a new method of arranging *Quadrupeds.* To these great names may be added that of professor Pallas, of Petersburg, who, in zoölogy, as well as in several other branches of science, has done much, and is to be considered as ranking with the very first, if not as standing at the head of all the naturalists now living.

Beside these distinguished systematic writers on the subject of zoölogy in general, particular departments of the science have been cultivated, and greatly improved, by men scarcely less eminent, or less worthy of praise. Of some of these inquiries and publications a brief notice will be attempted.

It is proper to begin with the natural history of the *first* Linnæan class, the *Mammalia.* On this class, almost all the great writers whose names were just mentioned have made large and instructive publications. In addition to what has been accomplished by them, especially by Linnæus, Klein, Pennant, and Buffon, the labours of professor E. Zimmermann, of Brunswic, to throw light on this class of animals, do him great honour. His conception and execution of a *Zoölogical Chart,* accompanying his work on the *Mammalia,* may be considered as one of the most philosophical productions of the age. This ingenious invention has been extended and improved by M. Jauffret, a distinguished naturalist of France. Beside these, many others deserve notice for their successful labours in illustrating particular parts of this extensive field of inquiry.

Much has been done during the last century toward completing the natural history of *Man*. In the list of experimenters and authors on this subject, Albinus, a Dutch naturalist, holds the first place, with respect to time*. He was a very great anatomist; and was one of the first who attended, in a scientific manner, to the seat of *colour* in human beings. Among the writers on this subject it is also proper to take notice of Dr. John Mitchell, an English physician, who resided a number of years in Virginia. His *Essay on the Causes of the different Colours of People* is considered as a very honourable monument of his learning and talents†. The next important publication on the same branch of natural history was by the celebrated John Reinhold Forster‡, who threw considerable light upon it. He was followed by the rev. Dr. Smith, president of the college of New Jersey, who, in his ingenious and learned *Essay on the Causes of the Variety of Complexion*

* To Marcellus Malpighi, in the seventeenth century, we owe the discovery of the fact that the colour of negroes resides in the *corpus mucosum*. This fact was also known to J. N. Pechlin, as appears by his work *De Habitu et Colore Ethiopum*, &c., published in 1677.

† *Philosophical Transactions*, vol. xliii.

‡ See Forster's *Observations*, &c. 4to, 1778.

*and Figure in the Human Species**, gave a very instructive and interesting view of the subject. The natural history of man has also been treated, in a more general way, by Buffon and Verey†, of France; by Blumenbach‡, Zimmermann§, Ludwig||, and Soemmering¶, of Germany; and by professor Pallas, of Russia. To which may be added the great anatomical discoveries and improvements by the Monroes, Camper, the Hunters, Daubenton, Bourgelat, and many others.

The attempts which were made during the eighteenth century to throw light on the natural history of man, through the medium of inquiries concerning language, habits, religion, &c., are worthy of particular notice.—In this department of inquiry Mr. Jacob Bryant greatly distinguished himself, by his *Observations on Ancient History*, and his *Analysis of Ancient Mythology*. Next appeared the *Monde Primitif* of M. Court de Gebelin, a voluminous work, which displays great learning, and is by no means destitute of valuable information. The *Vocabularia Comparativa* of professor Pallas is a wonderful monument of learned labour, and

* Dr. Smith's *Essay* was favourably received, not only in his own country, but also in Great Britain, and on the continent of Europe, where several editions of it were circulated, in the English, French, and German languages.

† *Natural History of Man*, &c. 2 vols. 8vo.

‡ *De Generis Humani Varietate Nativa*, &c. Goettingen, 1795.

§ *Geographical History of Man*, &c. 8vo, 3 vols. Leipsic, 1778.

|| *Plan of a Natural History of the Human Species delineated*, &c. 1796.

¶ *Essay on the Difference between the Conformation of the European and the Negro*, &c.

will be highly interesting to every enlightened student of this part of natural history.—Still more recently, new and important light has been thrown on this subject by professor Barton, of Philadelphia, who, in his *New Views of the Origin of the Tribes and Nations of America*, has published *Vocabularies* of a number of Indian languages that were never before committed to the press; has compared these with languages more generally known, both on the eastern and western continents; and has thence deduced new evidence in support of the opinion, that the nations of America and those of Asia have a common origin.

The philosophy of man has been considered, during this period, in a different view, in the celebrated publications of Hartley and Helvetius. Professor Meiners, of Germany, has also written on the *Physical History of Man;* and M. Herder, of the same country, has published *Outlines of the History of Man* *. And, finally, the numerous voyagers and travellers, with whom modern times have abounded, have contributed greatly to enlarge our knowledge of the human character and powers, and have brought to light many facts toward the formation of a satisfactory system on this subject.

In the natural history of *Quadrupeds*, the amount of improvement during the last century was very great. All the distinguished systematic writers before mentioned have rendered extensive and important services to this branch of zoölogy; and the names of many other respectable naturalists might be enumerated, who have devoted their

* An English translation of it has been published.

investigations to particular species, and described them with great accuracy and splendour. The scientific journals and memoirs of learned societies, in every part of the century, exhibit a large and very interesting account of discoveries, and of new observations, by these diligent and useful inquirers.

But among the various investigations in this department of natural history, which distinguish the eighteenth century, few are more curious than those respecting the *Fossil Bones of Animals* now no longer known in the living state. These remains of animals, chiefly of the quadruped kind, have been discovered at many different periods, from the commencement of the century to its conclusion, and in almost every part of the world to which naturalists have had free access. It is believed the first writer of any distinction on this subject was Dr. Breynius, or Breyne, a German, who, at an early period of the century, published some papers on this branch of zoölogy in the *Philosophical Transactions.* The next was the abbé Fortis, who, in his *Travels in Dalmatia,* gave some interesting and instructive information on the same subject. Among many others who have distinguished themselves by their inquiries respecting these *fossil bones*, sir Hans Sloane, Daubenton, Buffon, Pallas *, Gmelin, and Dr. W. Hunter, deserve

* Professor Pallas expresses the fullest conviction, that the fossil bones found in *Siberia* were carried thither by the *Flood,* or by some such great inundation as the sacred history describes. His first idea was, that the climate was once warm enough to be the native country of the *elephant,* and that it had since undergone

particular notice. M. Cuvier, of France, has been for some time engaged in a very extensive work on this subject, which is likely to prove very interesting to the philosophical world. He enumerates *twenty-three species* of bones which have been found, all belonging to animals unknown at the present day, and of the existence of which there is no other trace than these relics. Of this number *twelve* were determined by preceding inquirers, and *eleven* he considers as having been first discovered and settled by himself. He speaks also of a number of other species, concerning which some uncertainty still remains*.

Of these *fossil bones* none have attracted more attention than those belonging to the unknown animal denominated the *Mammoth*†, found in several parts of the world, and especially in North America. A controversy for a long time existed,

a radical change. But when he visited, during his travels, the spots where these bones were found, he candidly renounced his former hypothesis, and expressed a full conviction, in conformity with the opinion of many other modern philosophers, that they must have been carried thither by water; and that nothing but a sudden and general irruption of waters, such as the *deluge* is represented to have been, could have transported those bones from their native regions so far to the north. In proof of this he informs us, that the bones are generally found *separate*, as if scattered by the waves; covered with a stratum of *mud;* and commonly intermixed with the remains of *marine animals and plants.* —*Coxe's Travels in Russia.*

* See *Additional Notes*—(Y).

† The name *mammoth* is said to have been first given to this animal in *Russia.* It is a corruption from *memoth,* a word derived from the *Arabic.*

whether this animal were a species of *elephant* or not; and both the affirmative and negative sides of the question were confidently maintained by eminent zoölogists. It is probable the dispute is now near being terminated, as, in the estimation of good judges, proof little short of demonstrative has appeared, confirming the opinion of those who assign this far-famed animal to the genus *elephas* *.

Soon after the first publications of Linnæus, *Ornithology*, or the history of the *second* class in his system, received considerable improvements from Edwards †, an English naturalist, who, though not remarkably distinguished as a systematic writer, became eminent and useful by the accuracy of his descriptions, and the excellence of his drawings. To his labours succeeded those of Mr. Frisch, a German, whose work is perhaps the most philosophical and interesting that was ever published on the subject. After him came the celebrated Latham, of Dartford, the author of a work on ornithology, which is probably the most extensive

* In the year 1801, Mr. C. W. Peale, of Philadelphia, proprietor of the *Museum* in that city, and who has been for a number of years distinguished by his taste for inquiries in natural history, succeeded in obtaining two complete skeletons of the *mammoth*, dug out of marle-pits, in the state of New-York. From an inspection of these skeletons it appears that they are the remains of *elephants*, differing but little, if any more, from either of the two species now known, than these latter do from each other. Mr. Peale is certainly entitled to the thanks of every lover of natural history for his zeal and exertions in this research.

† George Edwards was born in the year 1694, and died in 1773. His *Natural History of Birds* is in 7 vols. 4to.

and complete yet presented to the world. The history of birds has also been well treated by Brisson* and Buffon, of France; and those of *Africa* have been ably described by Vaillant, of the same country. In addition to which, it may be worthy of notice, that the plates published by order of the king of France, and intended to accompany Buffon's History of Birds, are certainly among the most elegant specimens of human art ever executed to promote the study of ornithology. Among those who have contributed to the improvement of ornithology, Sparrman, of Sweden, is also entitled to an honourable place. The plates of his *Museum Carlsonianum* are among the best that were ever published. They are said to be less tawdry and more natural than those of Buffon. A new classification of Birds has been presented to the public by Paul H. G. Moehring, of Germany, who died in 1792; and, still more recently, a new arrangement of the same class of animals has been made by la Cépède, of France.

That department of zoölogy which includes the *Amphibia*, or the *third* Linnæan class, has also been greatly extended and improved during the eighteenth century. Beside Linnæus, this class was treated, with much ability, by Mr. Catesby, an English gentleman, who resided for some time in America†. Next to him, Dr. Garden, who spent

* The *Ornithologie* of Brisson has been pronounced, by some good judges, to be, so far as respects the description of the species of birds, one of the most accurate works that have hitherto appeared.

† *Natural History of Carolina, Florida, and the Bahama Islands,* &c. By Mark Catesby. 2 vols. folio.

a number of years in South Carolina, communicated much new light with respect to the animals generally, and especially the *Amphibia*, of the new world*. Dr. Russell's great work on the *Serpents* of the Coromandel Coast† is a production of the highest excellence in its kind, the publication of which was an important event in the progress of natural history. The *Serpents* have also been largely treated of by the celebrated Fontana; and still more recently by M. la Cépède, of France, who formed a new arrangement of them, founded chiefly on the *scales*, and bearing, in several respects, a considerable resemblance to that of Linnæus. The same writer has published a work on *Oviparous Quadrupeds*, in which he has much improved on the labours of the great Swedish naturalist. The *Frogs* have been ably treated by Roesel, a German naturalist. The natural history of the *Tortoise* has been very ably and completely executed by Schoepf, a distinguished writer of Germany; and also by Schneider, of the same country. The *fascinating power* ascribed to *serpents* has been the subject of considerable discussion during the period under review. Those who have examined this subject in the most philosophical manner are M. la Cépède, professor Blumenbach, and especially professor Barton, of Philadelphia, whose *Essay* on

* Dr. Garden, who was a respectable physician of Charlestown, in South Carolina, communicated to Linnæus much valuable information concerning the animals of America. Few names occur more frequently, or are mentioned with more honour in the *Systema Naturæ*, than his.

† *An Account of Indian Serpents, &c.* By Patrick Russell, M.D. F.R.S. folio.

this subject is, perhaps, the most satisfactory hitherto presented to the student of natural history.

Dr. Robert Townson, a respectable naturalist of Great Britain, has contributed to extend our knowledge of the physiology of the *Amphibia.* His *Tracts and Observations in Natural History and Physiology,* published in 1799, contain many original observations concerning the respiration, absorption, &c., of this class of animals.

Within the same period, *Ichthyology,* or the history of the *fourth* Linnæan class, has been cultivated with great diligence and success. Lewis Marsigli, an Italian, by his *Historia Maris,* published in 1725, and by his work on the *Danube,* published in 1726, gave much new and valuable information on this subject. The *Philosophia Ichthyologica* of Artedi*, first given to the public in 1738, may be considered as one of the most important works on fishes, which the age produced. Next to Artedi came Linnæus, who greatly distinguished himself by a new arrangement of this class of animals, and by improving, in various respects, their natural history. He was followed by Gouan, of Montpellier, who, in his *Historia Piscium,* published in 1770, adopted the Linnæan arrangement, and rendered important service to this part of zoölogy. About the year 1786, M. Broussonet, of France, made a very instructive present to naturalists, in his work on the rare fishes, and those which had been before badly described. But, of

* Artedi was a Swede, the contemporary and friend of Linnæus. He was born in 1705, two years before his illustrious countryman; and died in 1735, being accidentally drowned in a canal at Amsterdam.

all the writers on this branch of zoölogical inquiry, Mark Eleazer Bloch, a Jew physician of Berlin, is said to be the most able and complete. To which may be added, that La Cépède, before mentioned, has commenced the publication of an extensive work on fishes, of which great expectations are formed*.

In addition to the great ichthyologists already mentioned, several other names are entitled to respectful notice.—Professor Monro's celebrated work on the physiology of fishes has been long and highly commended. Gronovius, Scopoli, and Klein have also written instructively on this class of the animal kingdom.

The inquiries and discoveries with respect to the *Insecta*, the *fifth* class in the Linnæan arrangement, have also been numerous and highly important during the period in question. Swammerdam was one of the first who paid particular attention to insects. He was followed by madame Merian, a celebrated German lady†, who, by her work on the Insects of *Surinam*, rendered very important services to Entomology. This illustrious female naturalist was followed by Linnæus, who first produced a systematic arrangement of insects, at once

* This great ichthyologist has already given four quarto volumes of his work to the public, containing a description of 309 fishes, of which 54 were before unknown to naturalists. When finished, it will probably be the most complete and splendid work, on this branch of natural history, in existence.—Garnet's *Annals of Philosophy* for 1800.

† Maria Sibylla Merian was born in 1647, and died in 1717. Her great work, entitled *Surinaamsche Insecten* (folio 1705), was, at the time of its publication, one of the most magnificent that had ever been produced in Europe.

sufficiently comprehensive, and, in a due degree, minute in its distinctions. He distributed all insects into *seven orders*, taking the distinctive marks from variations in the structure of the wings, or the entire absence of these organs. While the great Swede was engaged in these inquiries, Reaumur *, of France; Lyonet, of Holland; and Bonnett †, of Geneva, also distinguished themselves by their respective publications in entomology; and, though with different relative merits, decidedly improved upon all who had gone before them.

In this department of zoölogy also, within the period which we are considering, Drury and Donovan of England; Geoffrey of France; Fabricius ‡, of Denmark; De Geer, of Sweden; and, latest of all, Olivier §, of France; have laboured with great diligence and success. With respect to the different degrees of honour due to these celebrated naturalists, it is not easy, within small limits, to state them with precise justice. The best judges seem to

* *René Antoine Ferchault de Reaumur* was born at Rochelle in 1683, and died in 1757. His *History of Insects*, in 6 vols 4to, is certainly one of the greatest works of the age in which he lived.

† Charles Bonnett was born in 1720, at Geneva, where he died in 1793. He was one of the most distinguished men of the eighteenth century. His inquiries and publications on *Insects* and the *Vermes* are greatly esteemed, and have been much celebrated among naturalists.

‡ Fabricius formed a new system essentially different from that of Linnæus. He employs, for the foundation of his arrangement, the diversities in those parts of the organisation with which insects take their *food*.—The arrangement of Linnæus is commonly preferred, especially in Great Britain; but that of Fabricius has many admirers on the continent of Europe.

§ Of Olivier's work it is not easy to speak decidedly, as it is yet in an unfinished state.

agree in assigning to Reaumur and Fabricius the first rank*. Beside these, Frisch, Rosenhof, Kleeman, Roesel, Sulzer, Schafer, and several other German entomologists, have written on this class of animals. In the present list, professor Pallas is also entitled to a distinguished place. His *Icones Insectarum* is a very valuable work. The *insects without wings* have been very ably described by J. Herlet, of Germany. To these names may be added that of Dr. Smith, the *Linnæus* of Great Britain, whose account of the rarer *lepidopterous insects of Georgia*, is entitled to a place among the most splendid, accurate, and valuable zoölogical works of the age†.

In the investigation of the *Vermes*, the *sixth* and last class of Linnæus, the advances made in modern times have been no less eminent. The first writer to be mentioned under this head is Donati, whose work on the vermes of the *Adriatic* is considered as highly instructive and important. After him, professor Bohadsch, of Prague, laboured much to improve the history of this class of animals, and with great success. Bohadsch was followed by M. Cuvier, of France, who proposed a new arrangement, and rendered considerable service to this

* When Reaumur and Fabricius are mentioned together, and a place assigned them in the first rank of entomologists, it is to be remembered that each has a different kind of excellence. Fabricius is a great technical or systematic entomologist; but he has done, comparatively speaking, little in regard to the physiology or philosophy of the subject. In this point of view nothing has appeared that will bear a comparison with the great work of Reaumur.

† *The Natural History of the Rarer Lepidopterous Insects of Georgia*, &c. 2 vols. folio, 1798.

branch of zoölogy. The vermes have also been treated, either generally or in part, by Joh. A. Murray, Jac. Theod. Klein, N. G. Leske, and Zeder, all of Germany. The *human vermes* have been very ably treated by Bloch, before mentioned. The vermes infesting the intestines of animals, generally, have been examined and described in a very satisfactory manner, by Goeze and Schranck, of Germany. The discoveries of Peysonnel, of France, with respect to *Corals* and *Corallines*, form one of the most interesting parts in the modern annals of natural history. *Corals*, at the beginning of the eighteenth century, were reckoned among the number of marine *plants*. In this rank they continued to stand, until M. Peysonnel, by a series of observations and experiments, from about the year 1720 to 1750, ascertained their *animal* nature. His doctrine was confirmed by the successive inquiries of Trembly, Donati, B. de Jussieu, and, finally, of the ingenious and accurate Mr. Ellis, whose work on this genus of animal substances is certainly among the best extant*. The celebrated Spallanzani, of Italy, also paid particular attention to the *corallines*, and wrote ably on the subject. On the fourth order of vermes, *Zoöphyta*, professor Pallas, of Russia, has given to the public a very valuable work, of which the systematic arrangement, and philosophical accuracy, must ever recommend it to the discerning inquirer. The fifth order, or *Infusoria*, has been treated with great successive improvements, by Bonnett, of Ge-

* *Essay toward the Natural History of the Corallines, and other Marine Productions of the like Kind.* 4to. 1775.

neva; Needham, of Great Britain; Adanson, of France; Spallanzani, of Italy; and, above all, by Muller, of Denmark: the last of whom has investigated and exhibited this department of zoölogy in a manner more extensive, complete, and satisfactory, than any of his predecessors.

Most of the naturalists above mentioned not only wrote with great ability on the several subjects connected with their names, but also made large additions to the facts and specimens made known by preceding inquirers. Few of them failed to connect with the ingenuity of system a large mass of new and useful information. A considerable number of new *Quadrupeds* have been brought to light during the period of which we are speaking, and added to the old lists. The species of *Birds* arranged and described by Linnæus amounted to near a thousand: since that time the number has been more than doubled, by the inquiries of the great ornithologists already mentioned; and also by the discoveries of sir Joseph Banks, Mauduit, Desfontaines, Dombey, Vaillant, and many others*. The class *Amphibia*, though not so much extended, by the discovery of new genera and species, as some of the other classes, has yet received considerable augmentation in this way. Of *Fishes*, Linnæus described about *four hundred* species; but, since he wrote, the catalogue has been so much enlarged by circumnavigators and travellers, that they now amount to considerably more than *one thou-*

* According to the latest accounts given by M. la Cépède, who has introduced, as was before observed, a new arrangement of birds, there are now known *two thousand five hundred and thirty-six* species.

sand. The number of new species of *Insects* discovered at different periods of the century is prodigiously great. Before the time of Linnæus, scarcely more than *two hundred* species were known. In the last editions of his works he described about *three thousand.* There are now known more than *twenty thousand* species. The same augmentation has taken place with respect to the *Vermes*, a class which, in the hands of Ellis, Pallas, Muller, and others before mentioned, has wonderfully enlarged its bounds.

Though America, during the period under review, has not produced many distinguished inquirers in zoölogy, it can boast of some who have rendered themselves conspicuous by pursuits of this nature. Mr. Catesby, and Dr. Garden, before mentioned, though not native Americans, resided long in that country, and threw much light on the animal kingdom, as it appears beyond the Atlantic. Mr. Glover, a planter of Virginia, also communicated to the public some valuable information respecting American zoölogy*. Mr. William Bartram, of Pennsylvania, an indefatigable and well informed student of nature, added considerably to the number of facts before known concerning the animals of the southern and western parts of the United States, and the adjacent territory†. Still more recently Dr. Barton, professor of Natural History in the University of Pennsylva-

* The principal part of Mr. Glover's communications respecting American zoölogy appeared in the *Philosophical Transactions,* about the year 1740.

† *Travels through North and South Carolina, Georgia, East and West Florida,* &c., from 1773 to 1778.

nia, has made very respectable additions to the zoölogical science of that country; and displayed a degree of genius, diligence, learning, and zeal, in this pursuit, which do honour to the rising republic, and bid fair to place him among the most accomplished and useful naturalists of his time*. Beside the labours of these and other scientific inquirers of America†, a large amount of information respecting the animals of that continent have been derived from intelligent foreigners, who have either visited and explored the interior of the country at different periods of the century under review, or devoted themselves to the acquisition of knowledge, from various sources, respecting the new world. Among these, Gronovius, Sarragin‡,

* See *Fragments of the Natural History of Pennsylvania*, *Essay on the fascinating Power ascribed to Serpents*, &c., and several memoirs on particular articles in zoölogy in the *American Philosophical Transactions*.

† It would be easy to mention the names of many respectable American gentlemen, who have done honour to themselves by giving new and valuable descriptions of particular animals which came under their observation. In such a list, Mr. Jefferson, Dr. Mitchill, the rev. Mr. Heckewelder, and a number of others, would be entitled to distinction. To these might be added the names of the rev. Drs. Belknap and Williams, who, in their respective histories of *New-Hampshire* and *Vermont*, after the example of Mr. Jefferson in his *Notes on Virginia*, have given valuable catalogues of the native animals of those States. But it is impossible for the author, consistently with the limits which he has prescribed to himself, to indulge the disposition which he feels to enter into such details.

‡ M. Sarragin, a French physician, who resided for some time in Canada, well deserves to be added to the list of those who have considerably extended our acquaintance with the animal and vegetable productions of the higher parts of North America. His different memoirs were published between the years 1706 and

Kalm, Schoepf, Buffon, and several others, deserve to be mentioned with honour.

SECTION II.

BOTANY.

In this branch of natural history the succession of discoveries and improvements, which the period before us has displayed, is in the highest degree honourable to modern science. At the opening of the eighteenth century, Botanical Philosophy, though it had been long cultivated, was still in a very confused and imperfect state. Numerous had been the attempts to arrange the vegetable tribes into an intelligible system, but great disorder and deficiency appeared in every plan. Among these attempts the most respectable and successful were those of Ray and Rivinus. The former, an English clergyman, before mentioned, had proposed his method to the world in 1682; but afterwards presented it in a new and improved form in 1703. He arranged all known vegetables under thirty-three classes, deriving the distinguishing character of each chiefly from the *fruit*. His system, though undoubtedly much superior to any which had been devised by his predecessors, was still very defective; and the characters of his plants were so many and

1728. His anatomical histories of the *Beaver, Musk-rat and Porcupine,* are valuable. M. Sarragin likewise distinguished himself by a publication on the *Sugar Maple (Acer Saccharinum)* of that country. The remarkable family of plants denominated *Saracenia* was so named in honour of this writer, by the illustrious Tournefort.

various, as to create an intricacy in a high degree perplexing and painful to the student. To the method of Ray, succeeded that of Rivinus, a professor of Botany in the university of Leipsic. This learned man was the first who laid aside the distinction between herbs and trees, which had been universally adopted by those who went before him. Relinquishing also the pursuit of natural affinities, and convinced of the insufficiency of characteristic marks drawn principally from the fruit, he attached himself to the *flower*, as furnishing characters abundantly numerous, distinguishing, and permanent. He reduced the number of the classes to eighteen, which were distinguished from each other by the *perfection* and *distribution* of the *flowers*, and particularly by the *regularity* and *number* of the *petals*. Rivinus did not live to complete the publication of his system; the whole of which was finally laid before the world in 1711, by one of his disciples.

After the system of Rivinus, the next worthy of attention is that of Tournefort. This great botanist set out with reviving the distinction of plants into herbs and trees, which had been exploded by Rivinus. In his method there are twenty-two classes, and one hundred and twenty-two orders, denominated *sections:* the former founded on the regularity and figure of the *petals*, together with the situation of the *receptacle* of the flowers; the latter on the *pistillum* and *calyx*. Botanical writers generally speak of Tournefort's as the first regular and complete arrangement. He was certainly the first who ascertained and exhibited the *genera* of plants in a scientific manner; and, indeed, in general merit as a systematic writer, he went far beyond all his predecessors. About the same time, Dr. Paul Hermann, professor of Botany at Leyden, proposed a new system *. He augmented the number of classes to twenty-five, founding their characters chiefly on the circumstances of the *seed*. He divided his classes into eighty-two sections or orders, having for their basis the number of *petals*, *seeds*, *capsules*, and *cells*; the figure of the *seeds* and *petals*; and the disposition of the *flowers*. This system appears to have gained but little popularity. To the method of Hermann succeeded that of Dr. Boerhaave, first published in 1710, and afterwards, with great additions, in 1720. He made a sort of combination of the systems of Ray, Tournefort, and Hermann, with additions and improvements from his own great mind. He increased the number of classes still further, to thirty-four, which were subdivided into one hundred and four sections or orders; the characters of which were derived from the *habit* or general appearance of the plants, combined with all the parts of fructification. He was the first who employed the *stamina* and *style* in determining the genus. To this luminary of science botany is much indebted. He introduced many new genera into his system; and was universally considered as one of the most successful inquirers and instructive writers of his time on this subject.

Next to the system of Boerhaave, the records of botany present us with the method of Christian

* Paul Hermann was a native of Saxony, and died in 1695. This learned man not only presented to the world botanical writings of great value, but also *engravings* of plants, which are executed with much delicacy, considering the period in which he lived.

Knaut, a German, who proposed what was afterwards styled "the system of Rivinus inverted." This plan was published, in 1716, under the title of *Methodus Plantarum Genuina.* It embraced seventeen classes, founded on the number of the *petals* alone; and one hundred and twenty-one orders, distinguished by the *fruit.* Knaut was followed by Dr. Hales, before mentioned, whose celebrated work on "Vegetable Statics" threw much light upon the physiology of plants, and indeed entitles him to the honour of being considered the great father of this branch of botanical science. To Hales succeeded Micheli, an Italian, whose *Nova Genera Plantarum* must be ranked among the fundamental works of the age, as it doubtless formed an important step in the course of reformation and improvement. Contemporary with Knaut, was Magnol, a celebrated professor of botany at Montpellier, whose system was published in 1720. He divided the vegetable kingdom into fifteen classes, which derived their characters entirely from the *calyx;* and these, according to him, embraced fifty-five orders, whose distinguishing characters were taken from the *figure* of the *calyx, petals,* and *seeds;* from the *disposition* of the *flowers;* from the *number* of *petals;* and from the *substance* of the *fruit.* In 1720, the same year in which Magnol published his system, there was another offered to the world by Julius Pontedera, a nobleman of Pisa. He attempted to combine the systems of Tournefort and Rivinus.

Such was the state of botanical philosophy until the year 1735; confused, intricate, unsettled, and exhibiting little but successive revolutions. And, if all the systems of classification were vague, unsatisfactory, and perplexing, the language in use among the different instructors in this science was at least equally so. Almost every part of the different nomenclatures, at this time, was loaded with uncouth, erroneous, or supernumerary words, and even barbarous sentences of description, which exceedingly increased the difficulties of the learner. Besides, numerous voyagers and travellers were now constantly enriching botany with new treasures, brought from every quarter of the earth; and while the names of those before known already loaded the memory, it became necessary to provide new ones, for the successive discoveries which were daily demanding attention. In a word, so great was the number of new species presenting themselves from every direction, and such the perplexity arising from defective arrangement, that botany became in danger of relapsing again into anarchy and total disorder*.

In this stage of the science Linnæus appeared. Endued with genius and learning; having a taste for researches in natural history rising to a sublime enthusiasm, and a disposition for persevering industry; he cultivated, with particular diligence, the science of botany. In 1735 he published a new system as the result of his labours, which produced a memorable æra in this branch of philosophy. This is usually called the *Sexual System*, from its foundation being laid in the doctrine, that plants are *male* and *female*, and propagate their species in a manner somewhat analogous to that of animals. Linnæus

* See *Tracts on Natural History*, by James E. Smith, M. D. F. R. S.

divided the whole vegetable kingdom into twenty-four classes; the distinguishing characters of which he founded on the *number*, the place of *insertion*, the *proportion*, the *connection*, and the *disposition*, of the *stamina*. These classes he subdivided into one hundred and twenty-eight orders. In the first thirteen classes, the orders are taken from the number and circumstances of the *pistilla*. In the fourteenth and fifteenth from the *pericarpium*; and in all the remaining classes from the number and circumstances of the *stamina*, excepting the twenty-fourth, which, from the parts of fructification being invisible, cannot be subjected to the grand principle of arrangement on which the system proceeds.

With respect to the fundamental doctrine of the *sexes* of plants, on which this method of classification rests, the honour of giving birth to it is said not to be due to the great Swedish naturalist. The ancients had some ideas of the doctrine, but they were vague and imperfect. We are informed by Aristotle, that Empedocles particularly taught *that the sexes were united in plants;* and also that the use of the *farina fœcundans* of the male *palm*, in impregnating the female, was very well known in his day. It appears, also, from several passages in Pliny, that he, as well as other naturalists of that time, extended the distinction of sexes, and the use of the male dust, to plants in general. Accordingly, it is certain that the ancient cultivators perceived the necessity, and were in the constant habit, with respect to several species of vegetables, of promoting the operation of the male flower on the female, in order to the production of fruit; still, being inattentive to the structure of flowers, and ignorant of the offices belonging to the several parts, they remained unacquainted with the true process of nature, though it was daily open to their observation *.

Thus this celebrated doctrine rested in apparent forgetfulness, until 1676, when Dr. Grew, a distinguished botanist of England, who had been long employed in microscopical observations and experiments on plants, mentioned the fact, and suggested its importance, in a paper read before the Royal Society in the month of November of that year. He expressed an opinion that the *stamina* and *styli* of vegetables are analogous to the organs of generation in animals, and adapted by nature to answer the same purpose; and that the *pollen* probably emits certain *vivific effluvia*, which may produce impregnation. The *sexual* doctrine was further confirmed by the observations and experiments of Camerarius, in 1695. In 1702, a small publication, by John Henry Burkhard, a German physician, appeared in the form of an "Epistle to Leibnitz;" in which the author not only adopted the idea of the *sexes* of plants, but also suggested the possibility of forming an *arrangement* of vegetables according to the difference of the parts of generation †. A few years afterward, two botanists of

* See Dutens's *Origine*, &c. and Pulteney's *Historical and Biographical Sketches of Botany in England*, 2 vols. 8vo. 1790.

† About the year 1738, when the growing fame of Linnæus made him an object of envy among some of his contemporaries, professor Heister, of Helmstadt, one of his antagonists, charged him with having taken his system, without acknowledgement, from the abovementioned work of Burkhard. Linnæus, however, it appears, proved that he never saw this obscure perform-

France, Geoffroy in 1711, and Vaillant in 1718, declared themselves in favour of Grew's opinion; while Tournefort and his friends opposed it with equal warmth*. In Great Britain, Blair, Bradley, Fairchild, and Miller, also appeared on the side of Grew's doctrine; but Alston, and some others, long retained their hostility against it with unabating zeal.

Such was the state of opinion with regard to this doctrine, when Linnæus adopted, unfolded, and made a splendid application of it to botanical science. And although we cannot ascribe to him the

ance; and even if he *had*, his friends contended, that it would have detracted little from his merit, that another had *slightly suggested* a plan which he so *ably executed*.—See Stoever's *Life of Linnæus*, translated by Trapp, 4to, 1794.—Professor Barton lately informed me, that he had seen a copy of Burkhard's publication, in the *Loganian Library*, at Philadelphia, and that he considered the sexual doctrine to have been very distinctly suggested by the author as the foundation of botanical arrangement.

* It is remarkable that the beautiful Latin *Poem* of M. de la Croix, entitled *Connubia Florum*, of which the *sexual* doctrine forms the foundation, was published as early as 1727. Some notice will be taken of this performance hereafter.

It is also worthy of notice, that James Logan, esq., a learned and ingenious gentleman of Philadelphia, who was afterwards president of the council, and chief justice of Pennsylvania, instituted a set of experiments on *maize*, with a particular view to the investigation of the *sexual* doctrine. An account of these experiments was first communicated in a letter to Peter Collinson, F.R.S., in 1735, and printed in the *Philosophical Transactions*, vol. xxxvi. This account was afterwards enlarged, and published in Latin, at Leyden, in 1739, under the title of *Experimenta et Meletemata de Plantarum Generatione*; and republished with an English translation, by Dr. Fothergill, in 8vo, 1747. These experiments were considered and appealed to as among the most decisive in establishing the doctrine they were intended to illustrate and confirm.—*Pulteney's Sketches*, &c. vol. ii, p. 278.

original discovery, yet he confirmed, extended, and improved it, and made it the basis of a system, which has commanded greater admiration and been more generally received than any before offered to the world. It will appear evident, on the slightest consideration of the subject, that the task of arrangement, in the vegetable kingdom, is a very perplexing and difficult one; and that every *artificial* classification must involve sacrifices of family resemblance, and natural connexion. But the philosophers of every country seem to have yielded to Linnæus the praise of having formed a system, on the whole, superior to all hitherto proposed.

But it was not only in the *doctrines* and *arrangement* of botany, but also in the *nomenclature* of the science, that this distinguished natural historian excelled all his predecessors. He created a new language, so simple, methodical, and convenient, that it has been pronounced likely to stand the test of ages, even if his sexual opinions should be discarded. In forming this language, he retained all the old names, which were consistent with his new principles; he adopted such others from the Greek and Latin, as were short, expressive, and sonorous; he dismissed the periphrastic and tedious descriptions of the former schools; he introduced *trivial names*, by which one, or at most two adjectives, distinguish a plant from all its other relative species *; in a word, he formed a language so sim-

* The following will serve as a specimen of the convenience and utility of the *trivial names* invented and applied by Linnæus. A kind of *Grass*, before his time, was called *Gramen Xerampelinum, Miliacea, prætenuis ramosaque sparsa panicula; sive Xerampelino congener, arvense, æstivum; gramen minutissimo semine.* He gave it a name consisting of two words, *Poa bulbosa*, which designated

ple and luminous, and so adjusted its several parts to his improved doctrines, that the acquisition of the science of botany became a far more easy task than before. In fact, this was so much the case, that, instead of remaining an abstruse study, confined to the schools, as formerly, it was converted into an agreeable amusement to persons of leisure in all ranks and situations.

The new classification and nomenclature of Linnæus soon attracted general attention. At first, as might have been expected, they met with powerful opposition. When they first made their appearance in Great Britain, Sloane, Dillenius, and other English naturalists, opposed them with warmth. Alston, of Scotland, retaining his old prejudices, did the same; insomuch that the influence of the doctrines taught by Ray threatened, for some time, to triumph over those delivered by Linnæus. This opposition, however, soon began to decline. As the works of the illustrious philosopher of Upsal increased in number and circulation, the weight and superiority of his opinions were gradually manifested, until, at length, the public adoption of the Linnæan system by professor Martyn of Cambridge, and professor Hope of Edinburgh; the adaptation of Ray's *Flora Anglicana* to this arrangement, by Hudson, about the year 1760; and, finally, the favourable reception given to the Swedish doctrines by the College of Physicians of London; completed the establishment of the *Sexual System* in Great Britain.

the plant more distinctly and intelligibly than the long and perplexing description before used.—Stoever's *Life of Linnæus*, p. 201.

The opposition to this system was no where stronger or more persevering than in France, where the authority of Tournefort had long been so high and imposing; and where so many great botanists resided, each jealous for the honour of his country, and for the reputation of his own opinions. It is true, several of the naturalists of that country embraced the system of the illustrious Swede. Among these, Sauvages, Gouan, Gerard, and le Monnier, deserve to be particularly named. But by far the greater number became his adversaries, and those most distinguished by their learning and talents. The system which they opposed, however, gradually rose into importance, and extended its empire. Personal prejudices, and national jealousies, were slowly yielded. And although it can by no means be said, even now, to be universally adopted, yet it is incomparably more popular than any other; and even those who reject some of the opinions which it involves, generally adopt its language as the most convenient and philosophical any where to be found *.

But the immediate achievements of Linnæus himself, in botanical philosophy, were not the only services which he rendered to this science. His researches and publications excited a general thirst for this kind of knowledge. From the school which he formed, many distinguished characters arose, who did honour to their instructor, and who greatly extended and improved his system. A number of these, incited by the zeal and the example of this patriarch in science, undertook distant voyages,

* Pulteney's *Historical and Biographical Sketches of Botany, &c.*

and tedious and hazardous journeys, for the purpose of exploring such regions of the earth as were before unknown; and thus daily brought home new stores of knowledge from every quarter of the globe.

Since the publication of the *Sexual System*, several new methods of classification have been proposed, and still more numerous plans suggested, for modifying and improving that of Linnæus. Among the former of these the following are most conspicuous. Beside his *sexual* system, the great Swedish naturalist founded a method of arrangement on the form and other circumstances of the *calyx*. To this method, which he published in the year 1737, he gave the name of *Methodus Calycina*. In this system the vegetable kingdom is divided into *eighteen* classes. In the same year Christian Gottlieb Ludwig, a native of Silesia, and a professor at Leipsic, published a new method, in which he divided vegetables into *twenty* classes, taking their distinctive characters from the *flower**. Next followed the natural method of van Royen, professor at Leyden, exhibited in his *Prodromus Floræ Leydenensis*, published in 1740, and which sustained a high character among botanists for ingenuity and elegance. To this succeeded that of baron Haller, one of the greatest men of the age in which he lived. He proposed, in 1742, a new natural system, founded on an assemblage of the various characters chosen by others. The botani-

* Ludwig was the author of several valuable works, of which his *Institutiones Historico-Physicæ Regni Vegetabilis*, &c., printed at Leipsic in 1757, is the principal one.

cal works of this philosopher rank in the very first class. He was a warm opponent of Linnæus, and sometimes, in this scientific warfare, departed from that mildness and urbanity which he owed both to himself and his adversary*. After Haller, Bernard de Jussieu, of France, published a new method of classification, also a natural one. To him succeeded his countryman la Marck, the author of the botanical part of the *Encyclopédie Méthodique*, who formed a new system. But although the works of the two last-named writers are instructive and valuable, they are comparatively little known or followed out of their own country. In 1751 the celebrated nosologist, Francis Boissier Sauvages, of Montpellier, published his *Methodus Foliorum, seu Plantæ Floræ Monspeliensis juxta Foliorum Ordinem.* In this work the author has attempted an arrangement of plants from the situation or position of the *leaves.* It is believed that no succeeding botanist has adopted this method. In 1764 professor Gleditsch, of Berlin, published a system, in some respects new, but differing so little from that of Linnæus, especially with respect to his ordinal distinctions, that it acquired but little celebrity.

The light thrown on *Vegetable Physiology* forms one of the most brilliant honours of the period under review. Little had been done in this branch of botanical science before the commencement of the eighteenth century. Grew and Malpighi, indeed, of the preceding age, had instituted

* *Tracts on Natural History,* by James Edward Smith.

some enlightened inquiries into the structure of plants; but they made little progress, compared with what has since been done. Early in the century under review, the rev. Dr. Hales, of Great Britain, pursued this investigation with great acuteness and diligence, and in his *Vegetable Statics* presented the world with a mass of information which will be long read and admired. About the same time, Duhamel, of France, was busily and successfully engaged in similar inquiries, and in his *Physique des Arbres*, and other publications, threw much new light on this part of botanical science. Duhamel was followed by Charles Bonnett, of Geneva, who proved one of the most distinguished vegetable physiologists of the age. His *Traité des Feuilles* is particularly curious and valuable.

Towards the close of the seventeenth century some attention had been paid to the different kinds of *Hairs*, which constitute a downy covering upon the surfaces of vegetables. But it was not till the year 1745, that this subject was treated in the full and masterly manner it deserved. In that year M. J. Stephen Guettard, a very ingenious and learned French botanist, began to publish his observations on the *hairs* and *glands* of plants. These observations he continued during several suceeeding years. He has even established a botanical *Method*, deduced from the form, the situation, and other circumstances, of the hairy and other glandular appearances on the surface of plants. He has shown, what perhaps would hardly have been suspected, that these appearances are, in general, constant and uniform in all the plants of the same family or genus. Hence, he has observed that they constitute good *generic*, but not *specific* characters*.

Sir John Hill, after much inquiry in vegetable physiology, published, in 1773, a very extensive work, which has been commonly called his *Vegetable System*, in which he proposes a method of arrangement founded on the *internal structure* of plants. About the same time, M. Tillet, of France, and the celebrated Spallanzani, of Italy, published the results of their observations and experiments on the organs and functions of vegetables, which have been generally considered as highly valuable. Beside what has been done by these naturalists, new light has been thrown on vegetable physiology by professor Walker and Dr. Darwin, of Great Britain; by des Fontaines and Vauquelin, of France; by Pontedera, of Italy; by Sennebier, and Saussure, senior and junior, of Geneva; and by Plenck and Reichel, of Germany.

But among the vegetable anatomists and physiologists who flourished towards the close of the eighteenth century, Joseph Gærtner, of Germany, deserves particular distinction. This great botanist was born in the year 1732, and died in 1792. He early devoted himself to the *fruit* of vegetables, not only as a part of vegetable physiology which had been too much neglected, but also as furnishing one of the best grounds of botanical arrangement. A method of this kind he exhibited in his great work, *De Fructibus et Seminibus Plantarum*, the first volume of which was published in 1788,

* Barton's *Elements of Botany.*

and the second in 1791; a work which abounds with valuable instruction in botanical science; and though the method which it contains is by no means free from objections, the author is entitled to much commendation for his labour, and must ever be ranked among those who have made large contributions to our knowledge of the vegetable kingdom.

The modern discoveries in chemistry have contributed much to enlarge our acquaintance with the composition, food, and growth of plants. Several of the vegetable physiologists mentioned in the foregoing paragraphs have rendered important aid to this branch of inquiry. To these may be added Priestley, of Great Britain; Hassenfratz, Fourcroy, Chaptal, Giobert, and Parmentier, of France; and Ingenhousz and von Humboldt, of Germany; whose experiments and various works have thrown new and very important light on some of the laws of vegetation.

Professor Thunberg, of Upsal, proposed, a few years ago, to alter the method of Linnæus, by suppressing the classes *Gynandria*, *Monoecia*, *Dioecia*, and *Polygamia*, and assigning to other classes the vegetables arranged by Linnæus and his followers under these denominations. The professor has pursued this method in his *Flora Japonica*, and in his *Prodromus Floræ Capensis.* It is not generally considered as an improvement on the method of Linnæus, but rather as rendering it, on the whole, still more artificial and perplexed. In this alteration, however, he has been followed by Gmelin, Withering, Swartz, and several other eminent botanists.

Botanical methods either partly or wholly original have been proposed, at different periods of the century, by Vaillant and Adanson, of France; by Alston, of Great Britain; and by Heister, Necker, and Medicus, of Germany. Alterations in the Linnæan system have also been suggested by Schreber, sir William Jones, and others.—But the author has not sufficient knowledge of any of them to attempt an account of their nature or merits.

Dr. Darwin, in his *Botanic Garden*, and his *Phytologia*, assuming the system of Linnæus, with some proposed alterations, exhibits great learning, genius, and taste. He carries further than any preceding botanist the idea of *plants being an inferior order of animals*, and ascribes to them *sensation*, *volition*, *passion*, *affection*, *virtue*, and *vice*. Indeed, he pushes the doctrine to such an extravagant length, and founds upon it so many fanciful positions and reasonings, that the sober and wary inquirer must often be offended at the obvious triumph of a lawless fancy over the cautious spirit of philosophy.

The botanists who have inquired with diligence, or described with ability, in particular branches of this science, within the period under review, are too numerous to be recounted. The *Cryptogamia* have been ably treated by Micheli, before mentioned, by Hedwig, Tode, M. Bulliard, professor Batsch, M. de Beauvois, and by Dickson and Masson *. The *Mosses* have been faithfully and

* Perhaps no class of plants has been investigated since the time of Linnæus with greater zeal and labour than the *Cryptogamia*. Indeed, the plants of this class have been investigated with a species of zeal, which led a late botanist, M. de Necker, to

successfully investigated by professor Dillenius*, of Oxford, by Bridel, of Gotha, by Zoega, of Denmark, and others. The *Lichens* have been examined and described with great care, by Acharius, of Sweden†, and by Hagen and Hoffman, of Germany: the *Ferns* by Plumier‡, of France, by Maratti, of Italy, by Bolton, of England, and by those above named, who have treated generally of the class to which they belong. The *Grasses* have been investigated and described by Scheuchzer, Schreber, Curtis, and many more: the *Oaks* of North America, by du Roi, of Germany, and with unusual elegance by M. Michaux, of France: the *Ferula*, or *Assafœtida-plant*, by professor Hope, of Edinburgh: the *Geranium*, by professor Burmann, M. l'Heretier, and the abbé Cavanilles§: the *Cotton-plant*, by van Rohr, of Denmark: the *Coffee-tree*, by Ellis, of Great Britain: the *Tea-tree*, by

denominate the enthusiastic rage for inquiries after them, *Cryptomania*.

* John Jacob Dillenius was born in Germany in 1687; came to England in 1721; and was appointed professor of botany in the university of Oxford about the year 1729; which office he held till his death, in 1747. Dillenius wrote a number of botanical publications; but that which has more than any other immortalised his name is the *Historia Muscorum*, &c., 4to, 1741. Indeed, his discoveries in the natural history of the *Mosses* were so numerous and brilliant, that he deserves more than any other individual to be called the father of this branch of botany.

† See his *Lichenographiæ Succiæ Prodromus*, 8vo, 1798.

‡ Father Plumier was one of the first good writers on the *Ferns*. His *Traité des Fougères de l'Amérique*, published in 1705, holds a high rank among the works on this part of botany.

§ The work of this latter gentleman on the *Geranium* is very elegant. He has enumerated and described *one hundred and twenty-eight species*.

Dr. Lettsom: and the *Tobacco-plant*, by Mr. Tatham: not to particularise a number of valuable descriptions, almost countless, of new and curious plants to be found in the memoirs of the *Linnæan Society* of Great Britain, and other associations of a similar kind in different parts of Europe. To these may be added, not as publications of the first class, but as doing honour to the infancy of botanical science in America, the natural history of the *Persimmon-tree*, by Dr. Woodhouse; of the *Tobacco-plant*, by Dr. Brailsford; of the *Phytolacca*, or *Poke*, by Dr. Schultz; of the *Stramonium*, or *James-Town-weed*, by Dr. Cooper; and of the *Sumach*, by Dr. Horsefield, all of the United States*.

But beside these botanical writers, who have published useful accounts of particular classes, orders, genera, or species, of plants, the last century has abounded beyond all former example with works on the plants of particular countries, or smaller districts. The plants of *Great Britain* have been either collected, or ably described, during this period, by Dillenius, Alston, Miller, Blackstone, Hudson, Lightfoot, Robson, Curtis, Withering, Berkenhout, and Smith. To this list of writers on English botany, may be added professor Martyn, who has written ably on the subject; Mr. Relhan, who has given a valuable *Flora Cantabrigiensis*; Mr. Abbot, whose *Flora Bedfordiensis* is also a useful work; and Mr. Sowerby, whose *English Botany*, and *English Fungi*, are worthy of much commendation. Hill and Wilson have

* See *Additional Notes*—(Z).

also written on English plants. The plants of *Ireland* have been described by Threlkeld, Keogh, and Smith; those of *France*, by Gouan, Gerard, Magnol, Adanson, Bulliard, Jussieu, la Marck, and several late botanists; those of *Switzerland*, by Haller; of *Holland*, by Commelin and Boerhaave; of *Germany*, by Crantz and Jacquin; of *Italy*, by Micheli and Allioni; of *Spain*, by the abbé Cavanilles; of *Russia*, by Pallas; of *Denmark*, with great splendour, by Oeder, Muller, and their associates; of *Lapland*, by Linnæus; of *Siberia*, by Gmelin; of *Egypt* and *Palestine*, by Celsius, Hasselquist, and others; of *Amboyna*, by Rumphius; of *Ceylon*, by Burmann; of *Coromandel*, by Roxburgh; of *Japan* and the Cape of *Good Hope*, by Kœmpfer and Thunberg; of the *Mauritius*, by Willemet; of *Cochin China*, by Loureiro; of *New Holland*, by Smith; of the *West-India* Islands, by Sloane, Browne, Houstoun, Plumier, Jacquin, and Swartz; of particular parts of *North America*, by Banister*, Vernon, Kreig†,

* John Banister, an Englishman, who settled in *Virginia* toward the latter end of the seventeenth century, and devoted himself to the investigation of the plants of that part of America. He not only collected plants, but also described them, and himself drew the figures of the rare species. He became a victim to his favourite pursuit. In one of his excursions for collecting plants, he fell from the rocks and perished. His botanical friends did honour to his memory, by calling a plant, of the *decandrous* class, *Banisteria*.

† About the beginning of the eighteenth century, William Vernon, an Englishman, and David Kreig, a German physician, led by their genius for botany, made a voyage to *Maryland*; where they resided for a considerable time, and examined its vegetable productions. They returned to Europe, after having collected an *Herbarium* of several hundred new and undescribed plants.

Catesby *, Mitchell †, Garden, Gallissonierre ‡, Kalm §, Wangenheim, Schoepf ‖, and Walter ¶,

* For some account of Mark Catesby, see vol. ii, chapter 26, of this work. His *Natural History of Carolina*, &c., was, at the time of its publication, in 1730—1743, the most splendid work of the kind that Great Britain ever produced; and, indeed, it had scarcely a rival in magnificence on earth. Many of the most beautiful and useful plants were, in this performance, for the first time, exhibited in their true proportions and natural colours. The number of subjects described and figured in the work is as follows: *Plants* 171, *Quadrupeds* 9, *Birds* 111, *Amphibia* 33, *Fishes* 46, *Insects* 31.

† Dr. John Mitchell, an Englishman, was sent to *Virginia*, in 1741, for the purpose of investigating the botanical treasures of America. After having discovered many new genera and species, he returned to England, about the year 1748. He transmitted not only to his countrymen, but also to Linnæus, much valuable information respecting American plants. The great Swedish botanist viewed him with so much respect, that he took care to perpetuate his name, by giving it to an American plant, the *Mitchella Repens*.

‡ The marquis de la Gallissonierre, who, about the middle of the century, was governor of Canada. He explored the natural history of that country with great industry, and returned to France laden with botanical riches.—Kalm's *Travels*.

§ A Swedish botanist, who was sent, in 1748, to America, for the purpose of discovering and collecting plants. After remaining between two and three years in the country, and collecting many new plants, in which pursuit he travelled through *Pennsylvania, New Jersey, New York*, and *Canada*, he returned to Sweden, and died in 1779.—See his *Travels*, translated by Forster, 2 vols 8vo, 1772.

‖ Wangenheim and Schoepf were two botanists who came to America with the German troops, during the late revolutionary war. Their works on American plants, though by no means entitled to a place in the first class of botanical publications, are yet of considerable value.

¶ Thomas Walter, a planter of *South Carolina*, who published, in 1788, *Flora Caroliniana*, a work of respectable character.

and by Clayton *, Bartram †, Colden ‡, Muhlenberg §, Marshall ||, Barton ¶, and Cutler **; and the plants of different portions of *South America*, by Plumier, Aublet, mad. Merian, don Ruiz, don Pavon, and others; and of the *South-Sea Islands*, by the indefatigable Dr. Forster, whose *Nova Genera Plantarum* may be considered as one of the

* Dr. Clayton, " a native and resident of *Virginia*. This accurate observer passed a long life in exploring and describing the plants of his country; and is supposed to have enlarged the botanical catalogue as much as any man who ever lived." *Notes on Virginia.*—Clayton's *Flora Virginica* appears to have been first published about the year 1743. It was afterwards republished by Gronovius, at Leyden, in 1762. It holds a very important station in the history of botany.

† See *Additional Notes—(A A.)*

‡ Cadwallader Colden, esq., lieutenant-governor of the province of New York, who was before mentioned. He had a great fondness for botanical studies. He made very valuable communications of American plants to Linnæus, especially those which appear under the title of *Plantæ Coldenhamenses*, in the *Acta Upsalensia*, for 1743 and 1744; and his name is mentioned frequently, and with great respect, in the *Species Plantarum* of that distinguished botanist. This gentleman's daughter, Miss Colden, was also fond of botany, and corresponded with Linnæus; who, in honour of one or both of them, in his *Flora Zeylanica*, gave to a plant of the *Tetrandrous* class, the name of *Coldenca.*—Stoever's *Life of Linnæus*, and Pulteney's *Sketches.*

§ *Index Floræ Lancastriensis.* Vols. iii and iv of the *Transactions of the American Philosophical Society.*

|| *Arbustrum Americanum*, 8vo, 1785.

¶ *Collection for an Essay towards a Materia Medica of the United States*; and other publications. Since the close of the century Dr. Barton has published an elementary work on botany, which is highly honourable to him. See *Additional Notes—(B B.)*

** *An Account of some of the Vegetable Productions naturally growing in America*, by Manasseh Cutler, D. D.—*Memoirs of the American Academy of Arts and Sciences*, vol. i.

most valuable additions made to botanical science since the time of Linnæus. The *Florula* of those islands by his son, Dr. George Forster, has also contributed to enlarge the sphere of our knowledge on this subject.

The catalogue of plants enumerated by the great botanist of Sweden last mentioned amounted to about *ten thousand*. Of these he actually described about *eight thousand*. The number since discovered and added to the list is very great. Beside the numerous discoveries of new plants by some of the celebrated systematic writers before mentioned, M. Commerson, of France, in the course of his circumnavigation with Bougainville, found near *fifteen hundred* new species. M. Dombey, of the same country, and don Mutis, of Spain, discovered a still greater number in South America. M. Desfontaines brought to light near *four hundred* nondescripts, found in Africa. Dr. Sibthorp brought *two hundred* new species from the Archipelago; professor Thunberg *six hundred* from Japan; M. Swartz more than *eight hundred* from the West-India Islands; and M. Michaux more than *four hundred* from the Levant, Persia, and North America. To these may be added the several thousands brought from almost every quarter of the globe by sir Hans Sloane *, Messrs. Lagerstroem, Osbeck,

* Sir Hans Sloane was born in Ireland, April 16, 1660. He studied medicine in London, where he long practised physic with great dignity and reputation. In 1687 he went to the island of *Jamaica*, in the character of physician to the duke of Albemarle, and touched at *Madeira*, *Barbadoes*, *Nevis*, and *St. Kitts*. He remained in *Jamaica* about fifteen months; returned to London in 1689; was chosen secretary of the Royal Society in 1693;

Toren, and Dahlberg, Dr. Solander, Dr. Sparman, sir Joseph Banks, Dr. Forster, and a long catalogue of modern circumnavigators and travellers, insomuch that the species now known and described considerably exceed *twenty thousand**.

To the details above stated, it is proper to subjoin, that the eighteenth century has been productive, beyond all former precedent, of great elegance in the execution of *drawings* and *descriptions* of plants. These are too numerous and too well known to render any particular account of them necessary here. It is sufficient to say, that all the means of communicating a knowledge of botany, whether we refer to the convenient nomenclature† now in use, to the modern concise

created a baronet on the accession of George I to the throne of Great Britain, being the first English physician on whom an hereditary title of honour had been conferred; was advanced to the presidency of the Royal Society in 1727; and died in 1752. To sir Hans Sloane the science of botany is greatly indebted. His discoveries in the West-India islands were very numerous and valuable. These discoveries, though actually made in the seventeenth century, were not fully laid before the public till the beginning of the eighteenth. In 1707 he published the first volume of his great work, entitled *A Voyage to the Islands Madeira, Barbadoes,* &c.; and in 1725 he completed it, by the publication of the second volume. This work may be considered as one of the most valuable presents made to botanical science in the course of the age.—Pulteney's *Sketches.*

* See Berkenhout's *Synopsis of Natural History*, 2 vols, 12mo, 1789.

† Condorcet, in his Panegyric on Linnæus, expresses himself thus:—"Linnæus has been reproached with having rendered *too easy* the nomenclature of botany, and occasioned thereby the appearance of a great number of small works. This objection seems only to prove what progress botany has made under him. Nothing, perhaps, evinces better how far a science is advanced, than

and intelligible style of *description*, to the splendid representations of nature, by means of accurate *figures** and *coloured plates* which every where assist the student, or to the multiplication of *Botanic Gardens*†, and of *Herbaria*, as appendages to seats of science, may be said to have reached a stage of improvement, within a few years, which the human mind never before contemplated. The recent exhibition of the Linnæan system by Dr. Thornton, of London, is not only highly honourable to himself and his country, but probably, also,

the facility of writing books of mediocrity on such a science, and the difficulty of composing works which contain novelty of matter."—Stoever's *Life of Linnæus*.

* See *Additional Notes—(C C.)*

† Though *Botanic Gardens* have been greatly multiplied, during the last century, in Europe, by scientific individuals, and by seminaries of learning, North America has never been able to boast of a single establishment which deserved the name. This deficiency is now likely to be in some measure supplied, so far as it respects the state of *New York*, by the laudable zeal of Dr. David Hosack, professor of botany in Columbia college. This gentleman has lately purchased ground for a botanic garden, in the vicinity of the city of New York; and is going on, at his own expense, to furnish it with the necessary stores of indigenous and exotic plants, for rendering it a useful and ornamental institution. It is to be hoped that his exertions will be seconded by public aid; and that the state of New York, already eminently distinguished for its rapid progress in wealth and improvement, will not suffer the weight of supporting such an establishment to fall on an individual; who, after all his care to accomplish himself for this branch of instruction, in a foreign country, and his zeal in forming the best private botanical library in the United States, cannot be expected to devote all his resources to an object which ought to be fostered by public munificence, and cherished as one of the honours of the state. See *Additional Note.—(D D.)*

in superb magnificence and accuracy, without an equal on earth*.

SECTION III.

MINERALOGY.

This department of natural history has also, within the period under review, passed through various revolutions, and received numerous improvements equally fundamental and important. From the time of Aristotle, the first distinguished mineralogist, to that of Becher, a learned German, little had been done in this science, except bringing together, and gradually increasing, a wilderness of facts, without system or order. Becher, toward the latter end of the seventeenth century, turning his attention with zeal toward this subject, became the father of regular mineralogy. After him a number of adventurers in this field of inquiry appeared, but they did little more than make large collections of mineral substances, and class them according to the old rules. Among the principal of these were Hierne, a Swede, who gave an ample and very valuable account of the fossils of his own country; Woodward† and Charleton, English naturalists, who made curious collections and enu-

* This is the opinion of Dr. Darwin, whose taste or information on this subject will not be questioned.—*Phytologia.*

† Woodward instituted a professorship of mineralogy about the year 1720, in the university of Cambridge, to which he left his collection of minerals as a legacy.

merations of mineral specimens; and Brachmel, of Sweden, who threw much new light on this kingdom of nature, as it appeared in that part of Europe. To these succeeded Linnæus. This great man, about the year 1736, proposed a new classification of mineral bodies, and was the first who distributed them into *classes*, *orders*, *genera*, and *species*. But his arrangement was essentially defective. He divided substances wholly according to their external appearances, such as *figure*, *colour*, *hardness*, and other sensible qualities, and, of course, threw together the most heterogeneous and opposite kinds. He devised specific names, however, of great excellence; and he is entitled to much honour for his concise and elegant sketch of the *Saxa*, which had been little noticed before.

Linnæus was followed by his countryman Wallerius, who, in 1747, published an important mineralogical work, in which he adopted the Linnæan system, with considerable alterations and improvements, by himself and the learned Browal, bishop of Abo*. About the same time Vaugel, a respectable philosopher of Germany, presented to the public a new system of mineralogy, of considerable value. In 1748 appeared the voluminous work of Dr. Hill, under the title of *Systema Mineralogicum*, which was important, as it gave a general account of the fossils of England; but his perplexed and barbarous nomenclature rendered it much less useful than it might otherwise have

* See the Preface to Cronstedt's *Mineralogy*, by Magellan. The above-mentioned work of Wallerius was published about twenty-five years afterwards, with great and splendid improvements.

been *. Soon afterwards the inquirers and publications in mineralogy began greatly to multiply, especially in Germany and Sweden, which, from the abundance of their mineral riches, have long presented peculiar encouragements to the study of this kingdom of nature.

Hitherto little or nothing had been done in the investigation of minerals through the medium of *chemical analysis.* External characters continued to form almost the sole ground of distinction and arrangement. Hierne and Brachmel had, indeed, some time before, suggested the plan of forming a mineralogical system on chemical principles; but they did nothing more than suggest it. Margraaf and Pott, two illustrious mineralogists of Berlin, seem to have been the first who instituted, with any remarkable success, this kind of inquiry. Their numerous and well-directed experiments were generally made by means of *heat*, and, according to the language of chemistry, in the *dry way.* About the same time, Neumann, a philosopher of Germany, distinguished himself by investigating the nature of mineral substances by means of acid *menstrua*, or in the *moist way.* These inquiries opened a new and interesting field in this science, led to many important discoveries, and may be considered as one of the grand æras in natural history.

It was in this stage of mineralogical improvement that Frederic Cronstedt, a nobleman of Swe-

* Wallerius characterises this work, as "*Mirificis nominibus potius onustam quam ornatam.*" See his *Brevis Introductio in Historiam Literariam Mineralogicam*, 8vo, Upsal, 1779.

den, and superintendant of the mines of that country, published an incomparable work, exhibiting the elements of this science in a manner singularly clear, determinate, and perspicuous*. This distinguished mineralogist assumed Mr. Pott's facts, but improved much upon his labours. He adopted a method of arrangement chiefly chemical; and has the honour of being the first who introduced a *natural* classification. He appears to have derived a considerable portion of his knowledge from van Swab, one of the masters of the mines, whose name is little known in the scientific world, though he communicated much information to almost all the eminent naturalists of that country, who flourished during his time.

Though Pott and Margraaf did much in the chemical analysis of minerals, and shed new light on the science by this means, yet they left much still to be done. They were followed by Scheele and Bergman†, who, with great ingenuity, perseverance, and success, pursued the same course. In the hands of these great philosophers, mineralogy may be said to have first assumed that high rank which it now holds. They not only made large additions to the lists of mineral substances which had been before given, but they also pursued the analysis of these substances to a greater length than their predecessors, ascertained new and more clear distinctions, and gave the whole science a

* Wallerius pronounced this work *opus sine pari*. It has passed through many editions, has been translated into most of the European languages, and is still considered as one of the best elementary works on mineralogy extant.

† *Sciagraphia Mineralis.*

more simple, intelligible, and dignified aspect. As long as this branch of natural history shall be cultivated, a large share of gratitude and admiration will be due from its votaries to Scheele and Bergman.

Though the refinements of chemical analysis were carried to a great length by the celebrated mineralogists last mentioned, and entitle them to high honours, yet they were afterwards exceeded by Klaproth, of Berlin, who applied himself to the analysis of minerals with a degree of zeal and perseverance which no difficulties could discourage, and with an ingenuity and accuracy which enabled him to penetrate far beyond his predecessors. He corrected many errors, and supplied important defects in the analytic method. He invented new instruments of great value, and new processes, more easy and expeditious, and of more certain result, than those before in use. It is, perhaps, to his labours, as much as to those of any individual, that we are indebted for some of the most curious knowledge in mineralogy that we possess. The same course of refined and subtile chemical investigation, by which Klaproth was so much distinguished, was pursued further by succeeding chemists, and particularly by M. Vauquelin of France.

While this astonishing progress was making in mineralogy by means of chemical inquiry, the attention to *external characters*, which had been for some time out of vogue, began to be resumed, and led to considerable improvements in the diagnostic rules, and in the nomenclature of the science. For this we are chiefly indebted to the celebrated

Abraham G. Werner, of Freyberg, in Germany, who certainly holds a place among the most distinguished mineralogists of the age. His principal publication on this subject appeared in 1774, and has commanded an uncommon degree of attention among philosophers. Though he did not wholly neglect the chemical properties of fossils, he devoted his chief attention to their *external characters*, and made these the principal foundation of his arrangement. He and his disciples insisted, that the *colour, shape, lustre, transparency, texture, cohesion, density, feel,* and general *habitude* of mineral substances, furnish abundantly sufficient indications for distinguishing and arranging them*. And, indeed, the ingenuity and skill with which they selected these characters, the judgement and accuracy with which they learned to apply them, and their wonderful success in forming a luminous system on the principles which these sensible qualities afforded, must be considered as pointing out one of the most important periods in the history of mineralogy.

Before this period, the *nomenclature* of mineral bodies had been in a very perplexed and imperfect state; insomuch, that, while rich stores of knowledge respecting them were possessed by many, it was extremely difficult to communicate this knowledge, for want of precise definitions and descriptions. The same substance, from some slight variations in appearance, was often called by different names; and different substances, from some affinities of ex-

* See his Treatise on the *External Characters of Minerals*, Leipsic, 1774.

ternal character, by the same name. From these, and other causes, the language of mineralogy was long arbitrary, vague, and ambiguous; each author using that which his caprice or his convenience dictated. Many attempts were made to supply this defect, and to obviate these difficulties, by Linnæus, Peithner, and others, but without much effect. At length Werner undertook to make a radical reform in the descriptive language of this science, and published the result of his labours in 1774. This nomenclature proved more precise, accurate, and scientific, than mineralogists had ever before possessed; and its illustrious author, by afterwards uniting the descriptions of external characters (which he had formed with much taste and skill) with terms indicating the chemical properties of minerals, was enabled to publish, in 1780, the best system of mineralogical language that is now extant*.

Since the publication of Werner's system, almost all the distinguished writers on mineralogy have formed their arrangement and language on the *union* of *external characters* and *chemical properties.* This is the case with the learned and indefatigable Dr. Walker of Edinburgh, Messrs. Daubenton, Patrin, and Monge, of France, and Mr. Kirwan of Ireland. All these gentlemen have inquired much, and written with ability, on this branch of natural history. The last-named philosopher, in particular, has rendered very important services to mineralogical science, and, doubtless,

* This latter publication was in the form of *Notes on Cronstedt's Mineralogy.*

deserves to be ranked among the greatest of its benefactors now living*.

Beside the systematic writers just mentioned, several naturalists of great eminence have founded mineralogical distinctions on characters peculiar to themselves, and have pursued their inquiries, founded on these characters, to a very curious and instructive length. Rome de Lisle of France, in his *Crystallographie*, published a few years since, made a very ingenious application of *geometry* to the phenomena of minerals, and exhibited a work in which they were subjected to all the precise principles of mathematical calculation. M. Brisson, another distinguished mineralogist of the same country, proposed to found the leading character of mineral bodies on the *static principle*, or their relative *specific gravities*; and in the exhibition of his plan displayed much ingenuity and learning. Scarcely inferior to any that have been mentioned is the venerable M. Sage, also of France, who, in the art of *assaying*, in tracing the connexion between the mineral and the other kingdoms of nature, and by his experiments in chemical analysis, has contributed much to improve this department of natural history.

The subject of *Crystallisation* engaged much of the attention of chemists and mineralogists during the eighteenth century. The first attempt to account for this phenomenon, in any manner that deserves the name of philosophical, was by sir Isaac Newton. He supposed the aggregation which

* See *Elements of Mineralogy*, by Richard Kirwan, F. R. S. &c. 2 vols, 8vo, 1794.

takes place in this instance to be produced by the attraction which he had proved to exist between the particles of all bodies, and which acts as soon as these particles are brought within a certain distance of each other by the evaporation of the liquid in which they are dissolved. The regularity of their figure he explained, by supposing that, while in a state of solution, they were arranged in the liquid in regular rank and file; the consequence of which, as they are acted upon by a power which at equal distances is equal, and at unequal distances unequal, will be crystals of determinate figures.—This explanation, which is worthy of the luminous and acute mind of its author, is now generally admitted as the true one, and has contributed much towards the elucidation of the subject.

Still, however, there remained various phenomena respecting crystallisation, which required to be more fully explained. To effect this, many attempts have been made, and several theories formed.—Rome de Lisle professed to have determined the primitive form of every crystallised substance, and to have ascertained that all other forms are only modifications of this.—Gahn, of Sweden, went further. Having broken a calcareous spar of a particular kind (dog-tooth), he found that the crystal was entirely composed of small rhombs, like those of the primitive calcareous spar.—Bergman seized upon this idea of his pupil; and as he combined an attention to geometry with physical science, he demonstrated that every crystal is composed of other small crystals, variously piled, but, in each case, according to certain laws of decrement. These little elementary crystals are called by him *constituent parts of a crystal.* In this manner Bergman developed the mechanical structure of various crystals, and showed that the primitive form often lies concealed in those very crystals which appear to deviate farthest from it.

M. Hauy pursued the idea, and applied it to various crystallised minerals. He is supposed to have shown, not only that every particular species of crystal has a primitive figure, and that the variations are owing to the different ways in which the particles arrange themselves; but also to have determined the laws according to which the decrements take place, after certain data which he assumed. His theory of crystallisation has been much celebrated. It is generally considered as ingenious and plausible; and certainly manifests a degree of diligence, zeal, and mathematical skill, which entitle him to much commendation*.

In addition to the great systematic writers whose names have been mentioned, considerable service has been rendered to mineralogy, within the period under consideration, by many others, who have either collected, analysed, or discovered, mineral productions. Among these it is proper to enumerate, with some distinction, Lawson, Townson, Jamison, Whitehurst, Lewis, Anderson, Withering, and Garnet, of Great Britain; d'Argenville, Soulavie, Faujas, Macquart, Dolomieu, Monnet, Chaptal, Bomare, Fourcroy, Hassenfratz, and de la Metherie, of France; Ludwig, Woltersdorff, Cartheuser, baron Born, Debern, Voigt, Gellert, Woulfe, Raspe, and many more, of Germany; de

* See Tilloch's *Philosophical Magazine,* and Nicholson's *Journal.*

Saussure, jun., of Geneva; Rinman and Ferber, of Sweden; Pallas, of Russia; d'Acosta, of Spain; Camera, of Portugal; and Gioenni, Fabroni, and Spallanzani, of Italy.

The use of the *Blow-Pipe*, for the purpose of assaying mineral bodies in the *dry way*, was first introduced by van Swab, a little before the middle of the century. The importance of this apparatus in mineralogy, and the great ease with which it enables the experimenter to conduct his investigations, render its introduction by no means an inconsiderable æra in the history of the science. After van Swab, the *Blow-Pipe* was much improved, and more extensively applied, by Cronstedt, Bergman, Rinman, Berkenhout, Black, and several others. The great value of this invention, in chemical and mineralogical inquiries, will appear from considering that the most intense degree of heat may be obtained by it, with the utmost conveniency, in a few minutes, which can scarcely be obtained by means of a crucible in many hours.

While new systems of arrangement and of language in mineralogy, and new means of facilitating experiments in this science, have been proposed by different philosophers during the period under review, immense additions at the same time have been made to the old catalogues of mineral substances. Linnæus described about *five hundred* different species. Since that time so many discoveries of new substances have been made, that the number of species now known is between *seven* and *eight thousand.* Seven new kinds of *earth* have been discovered within the century under consideration. Among these are *Magnesia*, by Hoffman and Black; *Barytes*, by Scheele and Gahn; *Strontites*, by Hope; *Silica*, by Pott; *Alumina*, by Margraaf *; *Adamanta*, by Klaproth; and *Jargonia*, by the same great mineralogist. Within this time, also, *ten* new *metallic* substances have been discovered; viz. *Cobalt*, by Brandt, in 1733; *Nickel*, by Cronstedt, in 1751; *Platina*, by Schæffer, in 1752; *Manganese*, by Scheele and Gahn, in 1774; *Tungsten*, or *Wolfram*, by d'Elhuyart, in 1782; *Molybdenum*, by Hielm, about the same year; *Uranium*, by Klaproth, in 1789; *Titanium*, by the same philosopher, in 1795; *Tellurium*, or *Sylvanite*, also by the same, in 1797; and *Chromum*, by Vauquelin, in 1798.—Beside these, the discoveries belonging to almost every class, order, and genus, in mineralogy, have been more numerous than our limits admit of recounting.

It follows as a natural consequence, from what has been stated, that *collections of minerals* have been more numerous, and more complete, during the last century, than ever before. Among those who have formed these collections, it is not easy to select such as are most worthy of notice. In general, the great systematic writers, whose names have been mentioned, are entitled to the highest praise in this respect also. The best collection now on earth, if we may rely on the judgement of Mr. Kirwan, from which few will presume to dissent, is that made between the years 1782 and 1787,

* It is not meant to be asserted that *siliceous* and *argillaceous* earths were unknown previous to the time of Pott and Margraaf, but that the discovery of their characters and properties, as *pure* earths, is to be attributed to these mineralogists.

by professor Leske, of Leipsic, one of the earliest and most eminent of the disciples of Werner, by whose assistance it was arranged. After the death of Leske, it was revised, corrected, and enlarged, by Karsten, another disciple of Werner, and a mineralogist of great judgement and learning. This monument of skill and labour was, a few years since, transferred to Ireland, where it has been for some time receiving those additions and improvements from the hands of Mr. Kirwan, which his extensive acquaintance with the subject, together with his acuteness, zeal, and industry, render him so capable of conferring.

In describing the present state of mineralogical science, it is impossible to do better than to adopt the words of the illustrious Irish academician, whose name has been mentioned with so much respect in the preceding paragraphs. Within a few years, " precise lines of information have been traced, even in the minuter subdivisions of the science; the gross indications of the unassisted senses, freed from their attendant fallacies, have been pressed into its service; the more refined chemical tests, still further perfected, have been rendered more conclusive; many new species brought to light; the catalogue of the elementary substances nearly completed; and the great art of analysis, extended far beyond its former limits, now nearly approaches the precision of an algebraic formula *."

The progress which was made in the art of analysing minerals, in the course of the last thirty

* Kirwan's *Elements of Mineralogy.—Preface.*

years of the eighteenth century, cannot be contemplated without astonishment. To separate five or six substances intimately combined together; to exhibit each of them separately; to ascertain the precise quantity of each; and even to detect the presence and the weight of substances which do not approach $\frac{1}{500}$th part of the compound; would, at no very remote period, have been considered as a hopeless, if not an impossible task. Yet all this, by means of the wonderful discoveries and improvements of Margraff, Neumann, Scheele, Bergman, Klaproth, Vauquelin, and others, can now be done with the most rigid accuracy *.

This science, like almost every other cultivated in modern times, while its boundaries have been extended, and its principles greatly improved, has been rendered more subservient than formerly to various important purposes of economy and art. Instead of being considered, as it once was, a low and trifling object of study, it has lately begun to be viewed as dignified in its nature, and most interesting in its relations. It is now regarded as a valuable and indeed necessary handmaid to *Medicine*, *Agriculture*, and a large portion of the *manufactures*, which supply the conveniences, comforts, or luxuries, of human life. Mineralogy has, therefore, within a few years past, been cultivated with great diligence and success by almost all the nations in Europe, especially in *Germany* and *Sweden*, where splendid mineral riches particularly invited inquiry and application. Societies have been formed for extending and improving the

* Thomson's *Chemistry*.

science; travellers have explored foreign countries for the same purpose; distinguished eminence in this branch of knowledge has been rewarded by public esteem, and by civil honours; and the most effectual methods used to direct general attention to the subject.

The mineral treasures of America have been hitherto but little explored. It were to be wished that some of its natives, who have leisure and talents for the purpose, might be induced to undertake this interesting task. That the United States abound in *Coal, Gypsum, Marble, Metals*, and other mineral riches, which would abundantly reward the diligence of naturalists in seeking for them, we have already had satisfactory evidence. Professor Mitchill was commissioned, several years ago, by the Agricultural Society of New York, to travel through a considerable part of the state, with a particular view to mineralogical investigation. The result of his tour has been published*, and affords at once honourable testimony of his talents, and strong incitements to a further prosecution of the inquiries which he instituted. It would be happy for the interests of science in this new world, if similar undertakings, conducted with similar skill, could be multiplied and extended. It is, indeed, devoutly to be wished that a kind Providence may for ever conceal from our view all mines of the *precious metals*, if there be such in the country †; but

* See a *Sketch of the Mineralogical History of the State of New York* in the *Medical Repository*, vols. i and iii.

† The most considerable mine of either of the precious metals of which the author has heard in the United States, is the *silver*

so many mines of more real value to a nation have been discovered, and profitably wrought within the last age, in the United States, that we may safely wish for the extension and the more diligent improvement of these discoveries.

SECTION IV.

GEOLOGY.

In the investigation of the natural history of the *Earth*, little progress had been made prior to the commencement of the eighteenth century. Indeed, as Mineralogy is the alphabet, by the principles and combinations of which the great volume of geological science must be formed, it is plain, that, as long as the former remained in an uncultivated state, the latter would receive but little light or improvement. During the century under consideration, geology has become an object of the attention and inquiries of many distinguished philosophers. The discoveries of chemists and mineralogists, and the observations of intelligent travellers, have all tended to facilitate these inquiries,

mine in the town of Mount-Pleasant, Westchester county, state of New York. This mine is near the margin of the Hudson, thirty-six miles above the city of New York, and on land belonging to William Street, esq. It was discovered about forty years ago; and, for some years before the revolutionary war, was wrought to tolerable advantage. The convulsions and derangements attending that struggle suspended the operations of the company engaged in the business, and they have not since been resumed.

and to render them more enlightened and satisfactory: and, although modern times have produced many visionary theories, and crude conjectures on this subject, they have also given birth to some important acquisitions, and much correct philosophy, which will be highly prized by all who study the history and structure of our globe.

Towards the close of the seventeenth century, *three* different *Theories of the Earth* were proposed, by as many philosophers of Great Britain; of which, as they were among the first offered to the world, and bear a relation to several of the subsequent theories, it will be proper to take some notice.

The first was the *Telluris Theoria Sacra** of the rev. Dr. Thomas Burnet. This celebrated theorist was a man of genius and taste; and his work, if it do not command the assent of the philosophic mind, will be found to display much learning, and a very vigorous imagination. According to him, the earth was first a fluid heterogeneous mass. The heaviest parts descended and formed a solid body. The waters took their station round this body, and all lighter fluids rose above the water. Thus, between the coat of air, and that of water, a coat of oily matter was interposed. But as the air was then full of impurities, and contained great quantities of earthy particles, these gradually subsided and rested upon the stratum of oil, and composed a crust of earth, mixed with oleaginous matter.

* This work was first published, in 1680, in the Latin language. It was afterwards translated, by the author, and published in two parts, in 4to, in 1683 and 1690.

This crust was the first inhabitable part of the earth; and was level and uniform, without mountains, seas, or other inequalities. In this state it remained about sixteen centuries, when the heat of the sun, gradually drying the crust, produced, at first, superficial fissures or cracks; but, in process of time, these fissures became deeper, and increased so much in their dimensions, that at last they entirely penetrated the crust. Immediately the whole crust split in pieces, and fell into the abyss of waters which it had formerly surrounded. This wonderful event was the universal *Deluge*. These masses of indurated earthy and oily matter, in falling into the abyss, carried along with them vast quantities of air, by the force of which they dashed against each other, accumulated, and divided in so irregular a manner, that great cavities, filled with air, were left between them. The waters gradually opened passages into these cavities, and in proportion as the cavities were filled with water, parts of the crust began to discover themselves in the most elevated places. At last the waters appeared no where but in those extensive valleys which contain the ocean. Thus our ocean is a part of the ancient abyss; the rest of it remains in the internal cavities, with which the sea has still a communication. Islands and rocks are the small fragments, and continents the large masses, of the antediluvian crust: and as the rupture and fall of the mass were sudden and confused, the present surface of the earth is full of corresponding confusion and irregularity*.

* Sullivan's *View of Nature*, vol. i, letter 6.

This "elegant romance" of Burnet was succeeded by the work of his countryman, Mr. Woodward, who, in 1695, published *Essays towards a Natural History of the Earth*, and terrestrial bodies. Though he possessed much more knowledge of minerals than his predecessor, and on this account had greatly the advantage of him, he produced a work far less ingenious and interesting. He also proceeded on the supposition of the Mosaïc history being true, and ascribed the present aspect of our globe to the influence of the general deluge. He supposed that all the substances of which the earth is composed were once in a state of solution; that this solution took place at the flood; that on the gradual retiring of the waters the various substances held in solution, or suspended in them, subsided in distinct strata, according to their specific gravities; and that these are arranged horizontally, one over the other, like the coats of an onion. As this theory was soon found to contradict some of the plainest and most unquestionable facts which geologists observed, it has had few admirers, and its refutation has been usually considered as obvious and easy.

In 1696 Mr. William Whiston, a man of uncommon acuteness, and of still greater learning, published a *New Theory of the Earth*, from its original to the consummation of all things. He supposed the earth, in the beginning, to be an uninhabitable *Comet*, subject to such alternate extremes of heat and cold, that its matter, being sometimes liquefied, and sometimes frozen, was in the form of a *chaos*, or an abyss surrounded with utter darkness. This chaos was the atmosphere of the comet, composed of heterogeneous materials, having its centre occupied with a globular, hot, solid nucleus, of about two thousand leagues diameter. Such was the condition of the earth before the period described by Moses as the time of *creation*. The first day of the creation every material in this rude mass began to be arranged according to its specific gravity. The heavy fluids sank down, and left to the earthy, watery, and aërial substances, the superior regions. Round the solid nucleus is placed the heavy fluid, which descended first, and formed the great abyss upon which the earth floats, as a cork upon quicksilver. The great abyss is formed of two concentric circles; the interior being the heavy fluid; and the superior, water; upon which last, the earth, or the crust we inhabit, is immediately formed. So that, according to this theorist, the globe is composed of a number of coats or shells, one within the other, of different materials, and of different densities. The air, the lightest substance of all, surrounds the outer coat, and the rays of the sun, making their way through the atmosphere, produced the light which *Moses* tells us first obeyed the divine command. The hills and valleys are formed by the mass of which they consist pressing with greater or less weight upon the inner coat of the earth; those parts which are heaviest sinking lowest into the subjacent fluid, and making *valleys*, and those which are lightest rising higher and forming *mountains*.

Such Mr. Whiston supposed to be the state of the globe we inhabit before the *Deluge*. Owing to the superior heat, at that time, of the central parts, which have been ever since cooling, the earth was more fruitful and populous anterior to that event than since. The greater vigour of the genial principle was more friendly to animal and vegetable life. But as all the advantages of plenty and longevity which this circumstance produced, were productive only of moral evil, it pleased God to testify his displeasure against sin, by bringing a flood upon a guilty world. The flood was produced, as this theorist supposed, in the following manner. A *Comet*, descending in the plane of the ecliptic to its perihelion, made a near approach to the earth. The approximation of so large a body raised such a strong tide, and produced such powerful commotion in the abyss concealed under the external crust, that the latter was broken, and the waters which had been before pent up, burst forth with great violence, and were the principal means of producing the deluge. In aid of this, he had recourse to another supposition, which was, that the comet, while it passed so near the earth as to produce these effects by the force of attraction, also involved our globe in its atmosphere and tail for a considerable time, and deposited vast quantities of vapours on its surface, which produced violent and long-continued rains; and, finally, that this vast body of waters was removed by a mighty wind, which dried up a large portion, and forced the rest into the abyss from which it had been drawn, leaving only enough to form the ocean and rivers which we now behold.

The fanciful and untenable theories which have been briefly stated, served little other purpose than to amuse the curious, and excite to new, and, for the most part, unsuccessful modes of speculation on this interesting branch of natural history. Accordingly, the eighteenth century has teemed with plans almost numberless, for solving the phenomena, and elucidating the internal structure and history of the earth. These plans, to say nothing of the impious nature and tendency of some of them, have, generally, rather resembled philosophical dreams, than the conceptions of waking and sober reason. Their authors, in forming them, have been too often guided by imagination more than judgement; and have laboured rather to support a favourite hypothesis, than to consult the voice of authentic history, or patiently to examine the materials and structure of the fabric which they undertook to describe. It may not be improper to take a brief review of some of the more conspicuous, among the great number, which, at different periods of the century under consideration, and in different parts of the world, have been received by philosophers.

At an early period of the century, the celebrated John Hutchinson, whose principles of philosophy were mentioned in a preceding chapter, formed a theory of the earth, which he professed to derive from Scripture*. He supposed, that, when the earth was first created, the terrestrial matter was entirely dissolved in the aqueous, forming a thick, muddy, chaotic mass; that the figure of this mass was spherical, and on the outside of this sphere lay a body

* This theory was enlarged and commented upon by Mr. Catcot, a follower of Hutchinson, who, in 1768, published a volume on the subject.

of gross dark air; that within the sphere of earth and water was an immense cavity, called by Moses the deep; that this internal cavity was filled with air of a kind similar to that on the outside; that on the creation of light the internal air received elasticity sufficient to force its way through the external covering; that immediately on this, the water descended, filled up the void, and left the earth in a form similar to that which it bears at present; that when it pleased God to destroy mankind by a flood, he caused, by his own miraculous agency, such a pressure of the atmosphere on the surface of the earth, that a large portion of it was forced into the internal cavity which it had formerly occupied, and expelled the waters from it with great violence, spreading them over the surface; that the shell of the earth was by this means utterly dissolved, and reduced to its original state of fluidity; and that, after the divine purposes were answered by the deluge, the globe, by a process similar to that which at first took place, was restored to the form which it now bears.

In the year 1740 the abbé Moro, of Italy, published a theory of the earth, which he chiefly derived from the works of Ray, of the preceding century. He supposed that the surface of the earth, as we now behold it, and especially the mountainous parts, arose originally from the bottom of the ocean. At first, according to him, these mountains contained neither strata of shells, nor any organised fossils; but by means of subterranean conflagrations, earthquakes, and volcanoes, these substances were thrown up in confused heaps, after which they successively subsided according to their different specific gravities, and thereby necessarily disposed themselves in different strata. He also maintained that these submarine eruptions, while they threw up huge and irregular masses of matter, also ingulfed marine plants and animals of every kind, which subsided in like manner, and thus formed new mountains, and new beds of stones, sand, metals, and other minerals, intermingled with the remains of vegetable and animal bodies, all which remained under the sea till some new agitation threw them above its surface. He supposed that the waters by which the earth was originally overflown subsided by degrees, the dry land first appearing in places adjacent to that where the first man and animals were placed at the creation; that the land extended itself gradually, a considerable time elapsing before the waters had returned into their proper bed, during which time the shell-fish, multiplying in great abundance, were universally distributed by the waters of the sea; and that when the bottom of the ocean was raised up by the earthquakes that accompanied the deluge, and formed the mountains, whole beds of such shells were thrown up, and distributed as we now behold them.

About the year 1744 M. le Cat, a philosopher of France, proposed a theory of the earth differing from all which had preceded it. According to him, in the beginning, the substance whence metals, stones, earths, and other mineral bodies were to be formed, was a soft mass, consisting of a kind of mud. The earth was a globe, or regular spheroid, and its surface was uniform and free from hills and valleys. The sun and moon were afterwards created.

The fluid which covered the mud became agitated by the flux and reflux to which it was subjected by attraction, and the mud was variously and violently moved. This agitation increasing, part of the mud became exposed, and dried. Continents were thus formed. The materials of the earth being compact and solid, the sea continually excavated its bed; and from the continual retreat of the sea, and the excavation of the earth, this globe is doomed to be at last so perfectly undermined as to produce a confluence of the sea from hemisphere to hemisphere. The earth becoming thus hollow, and its shell being gradually extenuated, will at length fall to pieces; a new chaos will be formed, the fabric will be again revived, as at first; and a periodical dissolution and renovation will take place. —Le Cat professed to believe the sacred scriptures, and discovered an anxious desire to show that his theory was consistent with them; but the best judges among his contemporaries, and since that period, have pronounced it equally inconsistent with the structure and phenomena of our globe, and with the Mosaïc history.

About the year 1750 appeared the *Telliamed* of M. Maillet, a French writer of some note. He taught, that the earth was once wholly covered with water, which, by means of strong currents, raised in its bosom all those mountains which different countries bear on their surface; that this water has been ever since gradually diminishing, and will continue to diminish until it shall be quite absorbed; that our globe, being then set on fire, will become a sun, and have various planets revolving in its vortex, till its igneous particles being consumed, it will be extinguished; that then it will roll through the immensity of space, without any regular motion, till it is again covered with watery particles, collected from other planets, when it will fix in the vortex of a new sun, and again go through the same course of motions and changes, being supplied with fresh inhabitants, resembling those by which it is tenanted at present; that the earth has probably been undergoing revolutions of this kind from all eternity, and will continue to go through a succession of them without end.—This atheistical and absurd theory, if it deserve the name, not more hostile to revelation than to all sound philosophy, seems to have gained but few adherents, and but little celebrity.

After M. Maillet, his countryman, the count de Buffon, formed a new theory of the earth, which has been much celebrated, and, notwithstanding its inconsistency with revelation, and the visionary absurdities which it involves, has gained many advocates and admirers.—According to this ingenious theorist, a comet falling into the body of the sun with great force, struck from its surface a large mass of liquid fire. The comet communicated to this fragment, thus driven off from the sun, a violent impulsive force, which it still retains. This fragment forms the globe we inhabit. It assumed its present figure when in a fluid state. As the heated mass gradually cooled, the vapours which surrounded it condensed, fell down in the form of water upon the surface, depositing at the same time a slimy substance, mixed with sulphur and salts, part of which was carried by the waters into the perpendicular fissures of the strata, and produced metals; the rest remaining on the surface, and giving rise to vegetable mould, with more or less of animal and vegetable particles. Thus the interior parts of the globe were originally composed of vitrified matter, and they continue so at present. Above these were placed those bodies which the fire had reduced to the smallest particles, as sands, which are only portions of glass, and above these pumice stones, and the dross of melted matter, which gave rise to different clays. The whole was covered with water to the depth of five or six hundred feet. This water deposited a stratum of mud, mixed with all those materials which are capable of being sublimed or exhaled by fire, and the air was formed of the most subtile vapours, which, from their levity, rose above the waters.

Such was the condition of the earth, as Buffon supposes, when the tides, the winds, and the heat of the sun, began to introduce changes on its surface. The diurnal motion of the earth, and that of the tides, elevated the waters in the equatorial regions, and necessarily transported thither great quantities of slime, clay, and sand; and by thus elevating these parts of the earth, sunk those under the poles about two leagues. The great inequalities of the globe took place when it assumed its form and consistence; swellings and blisters arising, as in the case of a block of glass or melted matter. In the act of cooling, it became furrowed, and variously irregular. The vitrescent matter of which the rock of the globe is composed, and all the nuclei of mountains were produced by the primitive fire. The waters have only formed the accessory strata, which surround the nuclei horizontally, and in which are the relics of shells, and other productions of the ocean. The whole surface of the earth, therefore, as we now behold it, was, at a period long subsequent to its separation from the sun, covered by an ocean; and the waters forming this ocean probably remained for a succession of ages on what are now inhabited continents. Hence the remains of marine plants and animals to be found in almost every part of the globe, on or near its surface. M. Buffon supposes, further, that, since the period when the primitive waters encircled the earth, there have been repeated partial inundations, in different places; and, in others, instances of land formerly covered with the ocean being elevated above it, and becoming inhabitable; and similar events, he seems to suppose, may in future occur. According to him, also, the earth, for many ages, too intensely heated to admit the existence of animal life on its surface, first acquired at the poles a more genial temperature. There, consequently, must we look for the first abodes of man. To *Greenland* or *Iceland*, to *Spitzbergen* or *Nova-Zembla*, we must have recourse for the verdant bowers of Eden. And, finally, he contends that all the other planets belonging to our system were stricken off from the sun in the same manner with that which we inhabit, and have probably undergone similar changes, so far as their respective circumstances admitted.

Such are the outlines of a theory bold and plausible, as might have been expected from the mind of its author, but unsubstantial and deceptive. Its manifest object is to exclude the agency of a Divine Architect, and to represent a world begun and perfected merely by the operation of natural undesigning causes. That it cannot be reconciled with the sacred history, will appear evident on the slightest inspection; and that it involves the grossest philosophical absurdities has been clearly shown by succeeding geologists. It was embraced, however, by M. Bailly, of France, by the celebrated Hollmann, of Goettingen, and others; and continues to be respected and adopted by many to the present time.

M. de Buffon's theory was warmly opposed, soon after its publication, by Raspe, a geologist of Germany*. He also opposed the theory of Moro, before mentioned, though he considered it as approaching much nearer the truth than the ingenious fable of the French naturalist. He insisted, that the opinion of continents and mountains having been thrown up from the bottom of the ocean, solely by submarine conflagrations and volcanoes, was abundantly refuted by close observation. He contended, likewise, that in veins of sand, marble, chalk, and slate, there are found no indications of a burning soil, but rather of a sediment disposed by the agitation of the sea. Accordingly, he maintained, that the strata, of which the shell or surface of the earth is composed, were originally formed at the bottom of the sea, by the constant agitation of the waters, and the continual production of plants and shells; that the subterraneous explosions and earthquakes, breaking through the bottom of the sea, not only formed banks, hills, and submarine mountains, of its broken parts, but also

* *Specimen Historiæ Naturalis Globi Terraquei.—Autore* Rudolpho Erico Raspe. 8vo, *Leipsic,* 1763.

frequently raised up such large portions of the bed of the ocean, with its incumbent strata, as to form islands and dry mountains. At some times, as he supposed, the presence of so large a body of water caused it to break through the cavities made by previous eruptions, and at other times the violence of the subterraneous explosions was so great as to remove mountains from one place to another; while the heat of the internal fires causing these explosions was so intense as to melt, calcine, or vitrify, all adjacent substances.

In 1773, Dr. William Worthington, of Great Britain, published a theory*, in which great learning and piety, and a considerable share of ingenuity, are combined. He maintained that the earth, in its primitive state, was plain and uniform; and that all mountains, and every thing irregular and rugged in the surface of it, are the result of the curse pronounced on the ground after the fall; that the melancholy lapse of our first parents was immediately followed by earthquakes, and every species of convulsion, which produced these dreadful effects in the surface of our earth; that the antediluvian earth greatly abounded with water, much more than at present, and that the greatest quantity of it was collected about the poles; that at first the poles of the earth were erect, and at right angles with the plane of the equator; that the centre of the earth was then the centre of gravity; that the deluge was produced by the centre of gravity being removed twenty-three degrees and a half nearer to one of the poles, which led to a corre-

* *Scripture Theory of the Earth*, 8vo. 1773.

sponding deviation of the poles from their former position, and thus threw the great body of water accumulated round them on those parts of the earth where little had existed before, and by these means drowned them. This event, he supposed, increased the irregularity of the earth's surface, and produced many of those phenomena, which so plainly establish the reality of the general deluge.

Another British theorist, of still more celebrated name, published a new system of geology in 1778. This was Mr. Whitehurst, a gentleman of respectable talents and information, and whose theory has attracted considerable attention*. Mr. Whitehurst supposes, that not only this globe but the whole of the planetary system was once in a state of fluidity, and that the earth acquired its oblate spheroidical form by revolving round its axis in that state. In this fluid state, the component parts of the earth were suspended in one general undivided mass, "without form and void." These parts were endued with a variety of principles or laws of elective attraction, though equally and universally governed by the same law of gravitation. They were heterogeneous; and by their attraction progressively formed a habitable world. As the component parts of the chaos successively separated, the sea universally prevailed over the earth; and this would have continued to be the case had it not been for the sun and moon, which were coëval with the earth, and by their attractive influence interfered with the regular subsiding of the solid matter, which was going on. As the sepa-

* *An Inquiry into the Original State and Formation of the Earth*, &c., by John Whitehurst, F.R.S. 1778.

ration of the solids and fluids increased, the former were moved from place to place, without regularity; and hence the sea became unequally deep. These inequalities daily becoming greater, in process of time dry land was formed, and divided the sea; islands gradually appeared, like sand-banks above the water, and at length became firm, dry, and fit for the reception of the animal and vegetable kingdoms. He supposed that mountains and continents were not primary productions of nature, but of a very distant period from the creation; that they are the effects of subterranean fires and commotions, and were produced when the strata of the earth had acquired their greatest degree of firmness and cohesion, and when the testaceous matter had assumed a stony hardness. And, finally, that the *marine shells* found in various places, on and below the surface of the earth, were for the most part generated, lived and died in the places in which they are found; that they were not brought from distant regions as some have supposed; and, consequently, that these beds of shells, &c. were originally the bottom of the ocean.

Two or three years after the appearance of Mr. Whitehurst's publication, M. de Luc, of Geneva, dissatisfied with all the numerous theories which had been proposed, offered another, which has occupied considerable attention in the scientific world*. He supposes that the ocean once covered

* *Lettres Physiques et Morales sur l'Histoire de la Terre et de l'Homme*, &c., by J. A. de Luc, 8vo. 5 tom. 1780. This theory, as to its principal outlines, was first suggested by Mr. Edward King; but was afterwards much extended and improved by M. de Luc.

our continents; that the bottom of the old ocean was full of mountains, which neither the waters, nor any other cause known to us, formed, and which he therefore calls *primordial.* These mountains rose above the surface of the waters, and formed islands. These islands, and the ancient continents, were fruitful and well peopled, and the ancient sea had tides, currents, and tempests, as the present ocean. These powers acting upon the soft matters which are known to have formed the bottom of the ancient ocean, produced accumulations of calcareous substances, which, in process of time, became more or less mixed with marine bodies. The rivers, in the mean while, carried from the land into the sea scattered remains of animal and vegetable productions; the sea itself washed them from its coasts into its bosom; and these materials, transported by currents, became a secondary soil upon its primordial bottom. Fires and elastic fluids, formed by fermentations, made various openings in the bottom of the ocean, whence proceeded torrents of liquid substances and lava, which gave rise to the volcanic mountains observable on the surface of our continents. The continents which existed in a state of population and fertility, while the sea covered those which we now inhabit, though they did not form a solid mass, but were, properly speaking, vaults, which covered immense caverns, maintained their elevation above the level of the ocean by the strength of their pillars, which, being of primordial matter, were solid and stable. But the changes which the subterranean fires produced at the bottom of the ancient sea opened passages for its waters into the interior of the earth; the fermentation produced by this irruption shook the pillars of the primitive earth, which sinking into its caverns, the old continents disappeared, and their surface descending below the level of the waters, a general inundation ensued. This was the general deluge. The sea now covered all the globe, except the islands of its ancient bottom, which increased in number and magnitude, until the weight of the water, added to that of the superior vaults, crushed the inferior ones, and deepened more and more the new bed of the ocean; so that, at last, by a motion rapid, but not violent, all the waters retired from their former bed, and left our continents dry. Secondary mountains, and other irregularities, were afterwards formed by volcanic commotions and maritime currents and convulsions.

This learned and ingenious theorist professes a firm belief in revelation; and insists that all the principal lines in the Mosaïc history are confirmed, and none of them contradicted, by the most attentive survey of the globe. It may well be questioned, however, whether some parts of his theory can be reconciled with the sacred records; and they are precisely those parts which it is most difficult to reconcile with reason and sound philosophy.

Next to the theory of M. de Luc appears that of Mr. Milne, of Great Britain, which, though less celebrated, is by no means unworthy of notice *. This gentleman declares himself a warm friend to revelation, and professes to have formed a system in strict conformity with the sacred history. In

* *A Course of Physico-Theological Lectures on the State of the World, from the Creation to the Deluge*, by Robert Milne, A. M. 8vo. 1786.

some respects he agrees with Mr. Whitehurst; in others, he adopts the opinions of M. de Luc; while, with regard to a third class of his doctrines, he claims to be original. He supposes that the earth, immediately after the fall, and in consequence of the divine curse pronounced against it, underwent a total change, by means of the elementary fire lodged at that time near its centre; and that hence arose the irregularities which now appear in the earth's surface.

The theory of Milne was followed by that of Dr. James Hutton, of Edinburgh, which has been much more distinguished, and excited incomparably more attention. Dr. Hutton thinks*, that all our rocks and strata have been formed by subsidence under the waters of a former ocean, from the decay of a former earth, carried down to the sea by land floods; that the strata at the bottom of the ocean were brought into fusion by subterraneous fires, and consolidated by subsequent congelation; that these strata were forced up, and made to form islands and continents by similar agency; that the shells and other exuviæ of animals, gradually collected and incorporated with these strata, make about a fourth part of our solid ground; and that the foregoing operations, *viz.* the waste of old land, the formation of new under the ocean, and the elevation of the strata now forming there into future dry land, are a progressive work of nature,

* *Theory of the Earth; or, an Investigation of the Laws observable in the Composition, Dissolution, and Restoration, of Land upon the Earth,* by James Hutton, M.D. F.R.S.E. This memoir is contained in the *Transactions of the Royal Society of Edinburgh*, vol. i.

which always did, and always will go on, forming world after world in perpetual succession. Consequently, according to this theory, the continents which we now inhabit must, in process of time, be worn away and destroyed, and others be forced up to supply their place. The length of time to be allowed for this successive destruction and re production, Dr. Hutton supposes to be far greater than is generally imagined. His system, therefore, is to be arranged, of course, among those which are hostile to the sacred history; and the best judges have pronounced it equally hostile to the principles of probability, to the results of the ablest observations on the mineral kingdom, and to the dictates of rational philosophy.

It has been suggested, that this doctrine of the *igniform* origin of our globe appears to be drawn from the theory of M. Buffon, with the difference of perpetually renovating powers, having no determinate commencement, instead of a once slowly forming and now gradually decaying principle. Dr. Hutton, indeed, does not attribute the fusion of terrestrial substances to the state in which this planet issued from the sun, but to subterraneous fires and furnaces, coeval with it, and still existing undiminished*.

In 1790 appeared a new theory of the earth, by Mr. John Williams, an English mineralogist of respectable character, which, though it has not acquired much celebrity, is entitled to a transient notice in the present sketch†.

* Howard's *Thoughts on the Globe*, &c.

† *Natural History of the Mineral Kingdom*, &c., by John Williams, 2 vols 8vo, 1790.

Mr. Williams supposes, that the superficial parts of the earth were originally mixed with water into a fluid or chaotic mass. All the regular strata were formed by the flow of the tides successively spreading out the deposited matters on a large horizontal plane. The granites and other stones, which he does not consider as stratified, subsided when the water was in some degree of rest, as at the highest of the tides, or where local obstructions produced stagnation. When the whole surface was in a fluid state, the tides necessarily rose to a prodigious height, several miles higher than the tops of any of our mountains. The mountains of granite, which are uniform throughout, must have subsided in one tide. The tides were highest, and had their resting places on the two opposite parts of the globe, which are now the continents; and their direction, on different parts of the globe, was such as we now find that of the strata to be. He maintained, further, that the interior body of the earth was formed in the same manner, prior to the superficial parts. From various causes, it was full of inequalities. It contained much water, both in the composition of the not yet consolidated strata, and in separate cavities; so that when the superficial strata were laid between the tides, and the ocean began to retreat into its present bed, the weight of these superincumbent strata forced out the water imprisoned below them. These strata themselves, as yet soft and flexible, were, in many cases, bent and broken; cracks were occasioned by their contraction in drying, which cracks were increased by the inclination of the strata in different ways, and were widest at the top; and the whole solid matter diminishing in bulk, as it became dry, high tides still overflowed it, and poured extraneous stony matter into the fissures. On these principles he explains all the declivities, ruptures, interruptions, and irregularities, which we now behold. The larger grains and fragments found in the composition of our rocks, and all those bodies which are of a similar structure, and not crystallised, were once in distinct strata, though not now to be found in that state. This he considers as one of the many evidences which our earth every where affords of the general deluge. By the high tides, and violent agitation of the diluvian waters, the primitive strata, which had never before felt any rain, were loosened, torn asunder, and ground down by attrition against each other, and all the superficial parts of the earth reduced again to a chaos. When the waters began to abate, the larger stony particles and fragments subsided first, and formed the compound rocks, and beds of sand; and the finer and lighter sediment was spread, by the tides, into strata of different consistency.

The next theory entitled to notice is that of M. Delamétherie, of France, which has been, of late, very fashionable in that country, and produced considerable discussion among naturalists*. He supposes that the external crust of our globe was formed in the bosom of the waters, from which it emerged in a state not very different from its present appearance. The crust, after its formation, underwent a variety of small alterations, from local

* *Théorie de la Terre*, 8vo, 5 tom. Paris, 1797. This large work embraces much extraneous matter. The fourth and fifth volumes contain the author's theory.

causes. The waters surpassed the highest mountains; in other words, they were at least three thousand toises above their present level. All mountains, valleys, and plains, were formed by *crystallisation* amidst the waters. The materials which formed them were truly dissolved; but as they would require much more water for solution than is now to be found, it is evident that most of the waters of the primitive seas have disappeared. He thinks, that these have chiefly retreated into the bowels of the earth: that cavities were formed there at the time of the crystallisation of the globe, which were at first filled with elastic fluids; but the water afterwards finding its way into them, became lodged there: that some caverns have been formed by subterraneous fires, but that the most powerful cause of them has been the refrigeration of our globe: and that, though the surface of the earth has been brought to its present state by the action of water, it may, at the first moment of its formation, have undergone a very great degree of heat, as happens to a comet passing near the sun.

In the formation of this theory, M. Delamétherie discovered considerable ingenuity and great learning. He can scarcely, however, be called an original writer: Voigt had held the doctrine of the aqueous *crystallisation* of strata before him; and, indeed, the greater part of his system is made up of parts collected from different theorists. This is generally considered as one of those theories which are hostile to revelation.

Of a very different character is the theory of Mr. Howard, a British geologist, who, about the same time published his opinions on this subject *. This gentleman is a firm believer in revelation, and his theory is intended to be perfectly consistent with the sacred history.

He supposes that the elements of all material substances were originally in a confused mass, called the abyss, without motion or animation; and that the present order of things was gradually, and at different intervals, drawn from it, by means of laws impressed by the power of the Creator. The earth, of which we now behold the ruins, was originally constructed with its poles perpendicular to the equator; the centre of gravity was the centre of the globe; and the year consisted of three hundred and sixty days. At that time, the irregularities of the earth's surface being less considerable, and the distribution of land and sea being more equal, the atmosphere was more temperate and salubrious, and, of course, the life of man was prolonged greatly beyond its present limits. The termination of this "golden age" might have been effected by the proximity of a *Comet* condensing the vapours of the atmosphere and attracting the subterraneous waters, which, bursting through the exterior surface, precipitated indiscriminate portions of the primitive earth into the cavities below. The more perfect consolidation of the globe in the southern hemisphere changed the centre of gravity, which produced a proportionate deviation from the plane of the equator. The ocean did not, at once, however, sink to its present level. The posterior ac-

* *Thoughts on the Structure of the Globe, and the Scriptural History of the Earth, and of Mankind,* &c., by Philip Howard, esq. 4to, London, 1797.

cession of waters from seas hitherto inland, may have crushed down other inferior vaults, and finally settled its lowest degradations. As the land became thus elevated above the bed of the ocean, the cold became more intense, the vicissitudes of climate were more severely felt, and the life of man suffered a proportionate abbreviation.

Mr. Howard was succeeded by M. P. Bertrand, of France, who next proposed a theory, much less philosophical, and in every respect unworthy of a sober mind *. This wild and impious theorist contends that water was the original substance of our earth, but that this water, before motion and heat were communicated to it, was a solid mass of ice. Such was the condition of the globe we inhabit, when one of the larger order of comets, after long wandering about, finally ended its career, and fulfilled its destination, by striking this frozen mass, breaking it in pieces, and mixing its own materials with those of the till then lethargic body. These fragments acquired by this impulsion a common projectile motion, in the same plane, and in the same direction. The light, heat, and life, brought by this energetic comet, mixing with the original ice, formed new combinations, afforded causes of internal motion, and began, by these means, a new order of things, which M. Bertrand calls vital and organic constitution, and which he supposes to be different in every planet, since the density is different. The ice, by means of heat as a solvent, being reduced to primordial matter, all ancient combina-

* *Nouveaux Principes de Géologie*, par P. Bertrand, &c. 8vo. Paris, 1798.

tions were destroyed, and room was given for new combinations of a different kind. The first result of this regeneration was the production of calcareous earth, from which species every other kind of earth is formed. This deposition of calcareous matter being equal every where, produced a regular nucleus in our globe, equally covered with water, and free from valleys and mountains. In this situation, according to our theorist, a new comet of high degree approached near enough to our globe to influence its destinies. By the force of its attraction it changed and slackened both the annual and diurnal motions of the planet, displaced the axis and the equator, altered likewise the points at which the spheroid was compressed or elevated; and by these means displacing the waters, caused the emersion of the first continents. The surfaces of these continents became unequal, from the change of level, and from the sudden retreat of the waters. The whole mass, however, was yet composed of calcareous matter. The first action of atmospherical powers, and of solar rays, occasioned a sudden irruption of all the vital forces, so long suspended and concentred. In this explosion of life every particle of native soil was *vivified*, and numerous races of vegetables and animals were produced, in such numbers, and of such sizes, that putrefaction and fermentation ensued. Some meteoric phenomena having set fire to this monstrous heap of putrefied bodies, the horrid conflagration extended every where, even under the sea, and was the cause of most tremendous earthquakes, that broke all the strata (which, till then, had been horizontal), and threw them in every direction. The ashes of this almost universal conflagration being the most saline of the then existing substances, formed a *lixivium*, which, filtering through the interstices of the broken strata, produced the *quartz* and other similar substances which now compose them. Wherever this lixivium and quartzeous flux deposed large quantities of matter, *granite* was formed; and, by a different modification of the same materials, other mineral bodies were composed. This great conflagration occasioned hollows and cavities of incalculable dimensions; which, being laid open by some violent shock, were filled by waters of the ocean; by which sudden retreat of the watery element, large portions of the globe were left dry, and formed new continents, while parts of the old continents fell into hollows and disappeared. Beside our earth, which has undergone this series of revolutions, an indefinite number of like cold lifeless masses exist, resting invisible in darkness and inactivity, waiting for some favourable circumstance, which may bring them to light, life, and motion.

Such are the outlines of a theory which, though exhibited and defended with some talents, may be considered as the most wild, and as involving the most palpable opposition to every received principle, that has yet been presented to the public. Indeed, its unreasonableness and extravagance are so great, that it seems to have attracted but little respectful attention among any class of philosophers.

This theorist was succeeded by another of the same name, but a much more sober and rational inquirer. In 1799 M. L. Bertrand of Geneva, published a work* which was intended to account for the phenomena of the globe we inhabit. This gentleman supposes, with Dr. Halley, that there is a magnetic nucleus enclosed and suspended in a hollow space in the centre of the earth. This has a rotatory motion of its own, and an inclination of its magnetic axis to the axis of rotation, thus causing an oscillatory motion in the magnetic poles. While things were in this situation, he supposes that a *Comet* of ordinary size and character approached our earth, displaced the nucleus from the centre, removed it toward one side, and changed the centre of gravity of the earth. These circumstances occasioned the derangement of the seas, their removal to other parts of the globe, the immersion of old and the emersion of new continents. This theorist is a disciple of M. de Saussure †; and the principal design of his work seems to have been to show the possibility of that sudden retreat of the ocean which his master believed and taught, and to account for that event and the subsequent elevation of the land which before formed its bottom.

The last person to be mentioned, as having adventured in this ample field of speculation and

* *Renouvellemens Périodiques*, &c., par L. Bertrand, &c., 8vo, 1799.

† M. de Saussure had promised to give a geological system at the end of his *Travels* over the *Alps*; but, after many years, he contented himself with informing the public, that the result of his investigations induced him to believe, that the whole of our continents had been formed under the sea, had been arranged by its action, and were left dry by a precipitate retreat of its waters.

inquiry, is Mr. Kirwan, whose name has been so frequently and so respectfully mentioned in the foregoing pages. This gentleman, with that learning which has enabled him to prosecute his numerous investigations in so enlightened a manner, with that judgement and penetration which render his inquiries so valuable, and with that spirit of patient and accurate observation which is so indispensably necessary to a successful developement of this subject, has framed a theory of the earth, which is perhaps the most rational and probable extant *.

Mr. Kirwan believes that the superficial parts of the globe were originally in a soft liquid state, proceeding from solution in water heated at least to 33°, and possibly much higher; that this menstruum held in solution all the different earths,—the metallic, the semimetallic, the saline, and the inflammable substances; that in this fluid its solid contents coalesced and crystallised, according to the laws of elective attraction; that these were deposited in strata according to the predominant proportion of the ingredients; that by this crystallisation of these immense masses a prodigious quantity of heat must have been generated, and increased by the decomposition of the water intercepted in the precipitated ferruginous particles, and by the disengagement of inflammable air, even to incandescence,—the oxygen uniting with the inflammable air, and bursting into flame; that this stupendous conflagration must have rent and split,

* *Geological Essays*, by Richard Kirwan, esq. F.R.S. &c. 8vo. 1799.

to an unknown extent, the solid basis on which the chaotic fluid rested; that from the heated chaotic fluid must have been extricated the *oxygen* and *mephitic* airs, which gradually formed the atmosphere; that from the union of oxygen with ignited carbon proceeded the *carbonic acid*, the absorption of which, as the chaotic fluid cooled, occasioned the crystallisation and deposition of *calcareous earth*. Mr. Kirwan also believes, that the immense masses thus crystallised and deposited formed the primitive *mountains;* that the formation of *plains* took place from the subsequent deposition of matters less disposed to crystallise in the intervals of distant mountains; that the level of the ocean gradually subsided, leaving large and elevated tracts of land uncovered; that the *creation of fishes* was subsequent to the emersion of the land; that after this retreat of the sea, the earth soon became covered with vegetables, and peopled with animals, being in every respect fitted to receive them; that the gradual retreat of the waters continued until a few centuries before the general deluge; that this event was occasioned by a miraculous effusion of water both from the clouds and from the great abyss,—the latter originating in and proceeding from the great southern ocean below the equator, and thence rushing on to the northern hemisphere, spreading over the arctic region, and descending again southward; that during this elemental conflict, the carbonic and bituminous matter ran into masses no longer suspensible in water, and formed *strata of coal;* and that other substances, by the combination or decomposition of their respective materials, formed various other kinds of mineral bodies, as *basaltic masses, calcedonies, spars, &c.*

That the *inequality of declivity* exhibited by the sides or flanks of mountains, in every part of the globe, had any regard to the *points of the compass*, seems to have been first remarked by the celebrated Swedish geologist, Tilas*: but he seems rather to have directed his views to the elevation or depression of the surface of Sweden, than to the bearings of the declivities of mountains in general. Bergman first discovered, that the declivities of the flanks of mountains bear an invariable relation to their different aspects. He found that, in mountains extending from north to south, the western flank is the steepest, and the eastern the gentlest; and that, in mountains which run east and west, the southern declivity is the steepest, and the northern the gentlest. After Bergman, Buffon took notice of the generality of this phenomenon; but his remark was confined to the eastern and western sides of mountains extending from north to south, having no reference to the north and south sides of those which run east and west. The same fact was afterwards observed, in a general or more partial manner, by Hermann, Delamétherie, Forster, Pallas, and several others.

Towards the close of the century, Mr. Kirwan directed his attention to this subject, and endeavoured to assign the cause of this almost universal allotment of unequal declivities to opposite points, and why the greatest are directed to the west and south, and the gentlest to the east and north. He

* See *Memoirs of Stockholm* for 1760.

supposes that this fact is connected with the original structure of our globe; that it proves that mountains are not mere fortuitous eruptions (as some, within a few years past, have confidently advanced); and that it furnishes a powerful argument in favour of the Mosaïc account of the creation, deluge, &c*.

Beside the *Theories* of which an attempt has been made to give a brief view, many others, less distinguished, have been offered to the world, during the period under review. Among these it would be improper to pass in silence the geological systems of Scheuchzer, Pluche, Engel, Lulolff, Pye†, Wallerius‡, Bailly, Franklin§, Darwin‖, and several others no less eminent. Some of these gentlemen have adopted theories nearly agreeing in their outlines with several of those which have been stated; and to attempt a further detail of such as have any considerable claims to originality, would be to present the reader with new vagaries of imagination, rather than with sober inquiries of philosophy.

But, although there has been in modern times (as appears from the foregoing pages) a wonderful variety of fanciful productions, under the name of

* See *Transactions of the Royal Irish Academy*, vol. vii.

† *The Mosaïc Theory of the Solar System*, by Samuel Pye, M. D. 4to. 1765.

‡ *Meditationes Physico-chemicæ de Origine Mundi*, 8vo. Stockholm, 1779.

§ *Conjectures concerning the Formation of the Earth*, in a letter to the abbé Soulavie. See *Americ. Philos. Trans.* vol. iii.

‖ See the *Botanic Garden: Additional Notes* to part i.

geological theories, we are by no means to imagine that little has been usefully done in this department of natural history. Amidst all the splendid rubbish with which it has been incumbered, some precious treasures have been brought to light. Amidst the speculations which have *darkened counsel*, large additions have been made to our knowledge of this important subject. These may be briefly summed up in the following particulars.

The *materials* for the formation of a correct and rational theory of the earth have been greatly augmented during the last age. Enlightened mineralogists, practical miners, and patient chemical experimenters, have been engaged, throughout the century, in making accurate observations; in visiting foreign countries; in exploring the bowels of the earth; in comparing the strata of every portion of the globe; in examining their form, direction, extension, and connexion; in analysing their component parts; and in collecting a multitude of facts, which have all tended to throw light on the origin and history of our planet. By means of the useful discoveries which these inquirers have made, we are furnished with weapons for beating down false theories, and with information enabling us to pursue our investigations further, and with more advantage. "In this magnificent display of the internal arrangement of the globe," says Mr. Kirwan, "many philosophical observers acquired distinguished eminence from tedious, laborious, painful, but successful exertions. Tilas, Gmelin, Cronstedt, Ferber, Pallas, Charpentier, Born, Werner, Arduino, de Luc, Saussure, and Dolomieu, are names consecrated to immortality *."

"So numerous, indeed," says the same respectable writer, "have been the more modern geological researches, that, since the obscuration or obliteration of the primitive traditions, strange as it may appear, no period has occurred so favourable to the illustration of the original state of the globe, as the present, though so far removed from it. At no period has its surface been traversed in so many different directions, or its shape and extent, under its different modifications of earth and water, been so nearly ascertained, and the relative density of the whole so accurately determined; its solid constituent parts so exactly distinguished; their mutual relation, both as to position and composition, so clearly traced, or pursued to such considerable depths; as within these last twenty-five years. Neither have the testimonies that relate to it been ever so critically examined and carefully weighed, nor, consequently, so well understood, as within the latter half of the past century †."

Difficulties have been lately removed which were once supposed, by some, to militate strongly against the *possibility* of a *general Deluge*. Early geologists, for want of accurate information, supposed that all the waters of the globe were not sufficient to cover the whole earth to such a depth

* *Geological Essays. Preface.* It is a curious fact, that, while some of these celebrated inquirers embraced geological principles unfriendly to revelation, they have all brought to light facts, and given views of the subject, which remarkably confirm the sacred history.

† *Geological Essays.* pp. 3, 4.

as the sacred historian describes. It was asserted that the mean depth of the ocean did not exceed a quarter of a mile, and that only half of the surface of the globe was covered by it. On these data Dr. Keil computed, that *twenty-eight* oceans would be requisite to cover the whole earth to the height of *four miles*, which he judged to be that of the highest mountains; a quantity, which, at that time, was utterly denied to exist. But further progress in mathematical and physical knowledge has since shown, that the different seas and oceans contain at least *forty-eight* times as much water as they were supposed to do, and much more than enough for the extent ascribed to the deluge in the sacred history*.

While difficulties which were supposed to render the deluge *impossible* have been removed by the investigations of modern philosophers, many facts have been, at the same time, brought to light, showing the *probability*, and even *certainty*, of that mighty inundation. In every valley and mountain,

* M. de la Place (whose mathematical and astronomical skill will not be questioned, and whom none will suspect of a disposition to press facts unduly into the support of revelation) has demonstrated, by a strict application of the theory of tides, to the height to which they are known to rise in the main ocean, that a depth of water reaching only to *half a league*, or even to *two* or *three leagues*, is utterly incompatible with the Newtonian theory, and that no depth less than *four leagues* can possibly be reconciled with the phenomena. It will be readily perceived that this is much more than the Mosaïc history requires. The extent of that part of our globe which is covered by water is now known to be far greater than Keil supposed it; it being ascertained that nearly two thirds of the surface of the earth are in this situation.—Kirwan's *Geological Essays*, pp 66, 67.

support for revelation has been found. *Marine shells* have been discovered in situations so elevated, and under circumstances so remarkable, as to prove that they were left there by a flood extending over the whole globe; and what confirms this conclusion is, that shells peculiar to different shores and climates very distant from each other have been found in promiscuous heaps, plainly showing that they could have been brought together only by an extensive inundation. The bones of *elephants* and of *rhinoceroses* have been found, in a multitude of instances, far distant from the regions in which they are found to live, and where, from the nature of the climate, they could never exist in the living state: and between the climates which they might have inhabited, and the places in which they are now found, too many mountains intervene to suppose them carried thither by any other means than a *general deluge**. The most patient and accurate examinations of detached mineral substances, and of the strata of the globe, which late inquirers have made, afford every reason to believe that the earth was for a considerable time wholly overflowed with water. And, to crown all, as voyagers and travellers have explored new regions of the earth, they have found, every where, the indications of geological phenomena confirmed and supported by the notices of tradition. Accordingly, it is very remarkable that a great majority of modern theorists have embraced the *Neptunian* doctrines; and even such of them as rejected the Mosaïc account of the deluge have

* Kirwan's *Geological Essays*, p. 54, *et seq.*

been compelled to seek for other means of immerging the present continents in the ocean*.

Finally, the researches of modern geologists have given abundant confirmation to the sacred history, not only with respect to the general *deluge*, but also with regard to the *age* of the earth†.

* M. Bailly of France at first embraced the theory of the earth proposed by Buffon; but finding the evidence arising from the investigations of natural history, and from universal tradition, so strongly to attest the reality of the general deluge, he abandoned that delusive theory, and took refuge in another system, in which he recognises the deluge, and only contends for placing it as far back as three thousand five hundred years before Christ.

† Sir William Hamilton and Mr. Ferber particularly applied themselves to the study of *volcanoes*, without giving general systems. They affirmed that the indications furnished by subterraneous and volcanic phenomena, and particularly by the beds of lava, announce the antiquity of the earth to be far greater than the sacred history represents it. But they did not advert to the fact, that all lavas are not composed of the same substance. All have not undergone the same degree of vitrification, and of course are more or less susceptible of decomposition. And even when their composition is the same, much depends on the state in which they are emitted. When poured from the crater in the fermentation of boiling liquefaction, a *scoria* (or dross) rises, like broken waves, on the surface, and is easily pulverised by the air and weather. When the heat is less violent, or when the torrent is cooled in its course, an even and almost impenetrable surface defies the influence of the atmosphere. These philosophers do not recollect that *Herculaneum*, the date of the destruction of which is well known, is covered by nearly *seventy* feet of lava, interspersed with *seven* distinct seams of friable earth; and the whole covered with good soil; yet all this has been the undoubted production of less than *eighteen hundred years*.—Howard's *Thoughts on the Globe*.

In like manner, count Borch, in his *Letters on Sicily and Malta*, professes to believe that *Ætna* is at least eight thousand years old, which he infers from the beds of vegetable earth which he discovered between different beds of lava. Yet M. Dolomieu, who

Early in the century, and indeed until within a few years, several geological phenomena were considered, by superficial inquirers, as indicating that the creation of the globe we inhabit was an event much more remote than the sacred history represents it; and some theorists even went so far as to profess a belief that it existed from eternity. These opinions were kept in countenance only as long as geology was in its infancy. Every successive step which has been lately taken in the improvement of this science has served to show their fallacy. The investigations of the latest and most accurate philosophers have afforded proof little short of demonstration, that the earth, at least in its present form, cannot have existed longer than appears from the Mosaïc account; the absolute falsehood of many positive assertions, and specious inferences, hostile to the scripture chronology, has been evinced; and thence has arisen a new presumptive argument in support of the authenticity of that volume, which contains the most ancient and the most precious of all records.

has greatly distinguished himself by the acuteness and success of his geological inquiries, expressly tells us that such earth *does not exist* between the beds of lava of which the count speaks, and thus destroys the foundation of his whole argument. But even if vegetable earth were found in the circumstances supposed, no conclusion relative to its age could fairly be deduced from this fact, as some lavas become fertile much sooner than others. The chevalier Gioanni, in 1787, found lavas projected in 1766 in a state of vegetation; while other lavas, known to be much more ancient, still remained barren.—Kirwan's *Geological Essays*, pp. 104, 105.

SECTION V.

METEOROLOGY.

The natural history of the *atmosphere* began to be cultivated as a science in the seventeenth century. The ancients, for want of the necessary instruments, were almost wholly unacquainted with it: but soon after the invention of the *thermometer* and the *barometer*, the learned men of Europe began to avail themselves of the manifest advantages which these instruments gave them, in studying the origin, nature, and effects, of those changes which take place in the atmosphere; especially with respect to heat and cold, motion and rest, moisture and gravity. Still, however, from the small number of the meteorological observations made by accurate philosophers; from the want of an extensive comparison of the results of different observations; and especially from the low state of those sciences most intimately connected with meteorology; little progress had been made in this department of knowledge prior to the commencement of the century under review. And though it must be acknowledged that this subject is one of those which are still far from being satisfactorily developed, yet so much has been done, during the period under consideration, to throw light upon it, and so many observations and discoveries have been made either directly or remotely relating to it, that it has, within a few years, assumed an aspect more interesting, practical, and approaching to the form of a system, than ever before.

The eighteenth century is distinguished by the numerous and enlightened experiments which were made during this period to ascertain the *weight* of the atmosphere in different latitudes and situations. For these we are principally indebted to M. Bouguer, M. Cassan, and M. Cotte, of France; and to sir George Shuckburgh, lord Mulgrave, and Mr. Kirwan, of Great Britain and Ireland.

Though the experiments on the *eudiometer* were mentioned under the head of *Chemistry*, and in some respects belong to that department of science, yet they also belong to *Meteorology*, and have contributed to throw some light on this obscure subject. These experiments, and the inquiries connected with them, belong exclusively to the eighteenth century.

At the commencement of the eighteenth century, the *ascent of water* in the atmosphere, in the form of *vapour*, had been but little investigated, and was very imperfectly understood. Nieuentyt and others had taught that the particles of fire, by adhering to those of water, made up *moleculæ*, or small bodies specifically lighter than air. Dr. Halley supposed that by the action of heat the particles of water are formed into hollow *spherules*, filled with a finer air, highly rarefied, of less specific gravity than the atmosphere, and, of course, disposed to rise in it. While Dr. Desaguliers thought that the ascent of aqueous particles was owing to their being converted into an *elastic steam*.

Such was the state of opinions with regard to this fact, when Dr. Hamilton undertook the investigation of the subject, and proposed a new theory. He held that evaporation is the gradual *solution of water in air*, and that the former is suspended in the latter in the same manner as salts, or other soluble substances, are suspended in aqueous fluids*. The same doctrine, in substance, had been suggested before by several philosophers; particularly by M. le Roy, in 1751; by Dr. Franklin, in 1756; and by Muschenbroeck, in 1769†. But though these, and some others, had spoken of the solubility of water in air, before Dr. Hamilton, yet he was the first who treated the subject with precision, or who applied it systematically to the explanation of meteorological phenomena. This opinion was afterwards adopted by Dr. Hutton, and exhibited in his ingenious *Theory of Rain*‡, and continued for a number of years to be the popular doctrine.

In 1786, M. de Luc, of Geneva, published a new theory on this subject§, which has been since generally considered as superseding the doctrine of Hamilton and Hutton. Observing that evaporation takes place in *vacuo*, as well as in the open air, M. de Luc rejected the opinion that vapour is

* *Essay on the Ascent of Vapours*, &c. This essay was first read before the Royal Society in 1765, and was afterwards published, with others, under the title of *Philosophical Essays*, by Hugh Hamilton, D.D. F.R.S.

† Bishop Watson's *Chemical Essays*, vol. i, p. 317.

‡ *Transactions of the Royal Society of Edinburgh*, vol. i.

§ See *Recherches sur les Modifications de l'Atmosphère*, par J. A. de Luc, 8vo, 2 vols, Geneva, 1772; and also *Idées sur la Météorologie*, a more full and satisfactory work, by the same author, 1786.

the solution of water in air, and taught that this effect is produced by the chemical *combination*, or *union*, of the particles of *heat* with those of water. Hence he accounted for the great loss of sensible heat in every process of evaporation, according to the celebrated doctrine of *latent heat* taught by professor Black. He made a number of curious observations and experiments on this subject; by which he ascertained that water, after its ascent into the atmosphere, does not exist in a sensibly *humid* form; whence he concluded that it passes into a form entirely different from itself, and probably becomes air. This doctrine is evidently founded on the mutual convertibility of water into air, and the reverse, discovered by Cavendish and some later chemists. The same theory, of the combination of water with heat, was also embraced by M. Lavoisier, and appears to be now the most popular mode of interpreting the phenomenon in question.

Beside forming and giving to the world this ingenious theory of evaporation, M. de Luc has also rendered essential service to the science of meteorology by his patient and persevering observations on the comparative degrees of moisture in the atmosphere in different situations. On this subject he has brought to light a number of facts equally new and interesting. His countryman, M. de Saussure, has also laboured very successfully in the same field of inquiry*; and though not always with an entire coincidence of opinion and result, yet with sufficient agreement on most im-

* *Essai sur l'Hygromètrie*, 4to. 1783.

portant points. There are, probably, no two individuals to whom the scientific world is more indebted for the minuteness, the accuracy, and the success, of their meteorological investigations, than to these philosophers of Geneva.

All our knowledge of *Atmospherical Electricity* is the product of the eighteenth century. To this subject the attention of philosophers has been particularly drawn since the time of Dr. Franklin's discovery that lightning and thunder are occasioned by the agency of electricity.

The most complete set of experiments on this part of meteorology were made by professor Beccaria, of Turin. He found that the air is almost always positively electrical, especially in the daytime, and in dry weather; that when dark or wet weather clears up, the electricity is always negative; and that low thick fogs, rising into dry air, carry up a great deal of electric matter. He ascertained that the mid-day electricity of days equally dry is always proportional to the heat; that winds lessen the electricity of a clear day, especially if damp; and that, for the most part, when there is a clear sky, and little wind, a considerable quantity of electricity arises after sun-set, at dew-falling. Considerable light has been thrown on the sources of atmospherical electricity, by the experiments of M. de Saussure and other mineralogists. Air is not only electrified by friction, like other electric bodies, but the state of its electricity is changed by various chemical operations which often go on in the atmosphere. Evaporation seems in all cases to convey electric matter into the atmosphere; and de Saussure has ascertained, that the quantity of electricity is as much increased when water is decomposed as when water is dropped on red-hot iron. On the other hand, when steam is condensed into vesicular vapour, or into water, the air becomes negatively electric. Mr. Canton has ascertained that dry air, when heated, becomes negatively electric, and positively when cooled, even when it is not permitted to expand or contract; and the contraction and expansion of air also occasion changes in its electric state. It is discovered, therefore, by these experiments, that there are four sources of atmospheric electricity known; *viz.* 1. Friction; 2. Evaporation; 3. Heat and Cold; 4. Expansion and Contraction; not to mention the electricity evolved by the melting, freezing, solution, &c., of various bodies in contact with the air*.

Closely connected with the doctrines which have been taught on the subject of evaporation, are the several theories of *Rain* to which modern times have given birth. The phenomenon of vapour becoming condensed, or of air in any manner producing water, and falling in the form of *rain, hail,* and *snow,* has long been considered a point of difficult solution among meteorologists. All the suppositions to account for this fact were for a considerable time insufficient and unsatisfactory; and even now the subject is far from being fully unfolded. At one time, the condensation and fall of vapour in different forms has been accounted for by referring to the influence of *electricity;* at another, by considering water as held in solution in air, and *precipitated* by streams of air of different tem-

* Thomson's *Chemistry*.

peratures being brought into contact or a state of mixture; and, at a third, by supposing this event to be produced by the conversion of oxygen and hydrogen gases into water, according to the experiments of Cavendish, Lavoisier, and others. These several opinions have been successively popular in the course of the century, and will be found amply detailed in the writings of Hamilton, Hutton, de Saussure, and de Luc, on this subject. But, after all, it must be acknowledged that great difficulties attend every theory hitherto formed with a view to solve this question: insomuch that the greatest meteorologist of the age, M. de Luc, after making a more patient, accurate, and thorough inquiry into the subject than was ever accomplished by any other man, seems to be at a loss to furnish a satisfactory account of the matter. He therefore contents himself with concluding, that the air formed by the decomposition and ascent of water becomes reconverted into that fluid by some unknown cause, or by a combination of causes, and falls in the form of rain, hail, or snow, according to the circumstances in which the reconversion takes place, or the state of the regions through which it passes in its descent.

Much light has been thrown, in the course of the last century, on the varieties of *temperature* in different seasons and latitudes. On this subject Dr. Halley made some instructive observations. A few years afterwards, M. de Mairan, an ingenious French meteorologist, by a series of observations and experiments, discovered that the rigour of the winter's cold is tempered by the heat imparted to the atmosphere by the earth itself; and thus explained by what means the winter's cold is rendered so moderate as to make the colder climates inhabitable. On the ground of this discovery he calculated, with great sagacity, the *maximum* and *minimum* of heat, in every latitude, for the summer and winter solstices; and though his calculations are not always found to coincide with facts, yet they have proved highly instructive and useful to subsequent inquirers. De Mairan was followed by Mayer, the celebrated astronomer of Goëttingen, who, in a few pages, did more to solve the difficulties that occurred on this subject than any of his predecessors. He first pointed out to meteorologists the necessity of following the method long used by astronomers; namely, of first finding the mean of certain large periods, as years and months (gradually correcting the errours that may be discovered), and afterwards finding an equation whereby to correct aberrations arising from height and situation. He even proceeded so far as to give an equation to correct the effects of height, which in many cases approximates very nearly to the truth: but the equation by which (knowing the mean annual temperature of two latitudes) the mean annual temperature of every other latitude, and even of the pole itself, may be found, has been pronounced his most important discovery *.

Mr. Kirwan has carried the discoveries and improvements of Mayer considerably further. By

* See *An Estimate of the Temperature of different Latitudes*, by Richard Kirwan, esq. F.R.S., &c.

means of the equation formed by the philosopher of Goëttingen, but rendered much plainer and more simple, he has calculated the mean *annual* temperature of every degree of latitude between the equator and the pole. He has also calculated the mean *monthly* temperature of that part of the ocean which lies between the eightieth degree of northern and the forty-fifth of southern latitude, extending westward as far as the *Gulf Stream*, and to within a few leagues of the coast of America; and for all that part of the Pacific Ocean reaching from 45° north to 40° south latitude, and from 20° to 275° east longitude. This immense tract of ocean he calls the *standard*. From these calculations he has deduced a number of important principles of great practical utility, and which place him among the most distinguished meteorologists of the eighteenth century.

The origin, qualities, and laws of *Winds* have been diligently studied during the period under consideration, but not with the same success that has attended inquiries into other branches of meteorology. No satisfactory theory has yet been formed on this subject; owing to the want of observations, sufficiently numerous, of the exact times and places where they begin and cease to blow, but chiefly to our imperfect knowledge of the means by which great regions of air are either suddenly produced or destroyed. The discoveries of modern chemists evince that air is perpetually subject to increase and diminution, from its combination with other bodies or its evolution from them: and, therefore, that a just theory of winds, whenever it shall be formed, will be found to rest upon chemical principles, there is much reason to believe. But though little has been done in anemology, in the way of scientific reasoning, much has been accomplished, during the period under review, in the way of patient observation, and the establishment of numerous important facts. For these we are chiefly indebted to Dr. Halley, M. de la Caille, M. Prevost*, M. de la Cotte, Mr. Dalton†, and several of the distinguished meteorologists before mentioned,—especially M. de Luc and Mr. Kirwan. To these may be added Dr. Franklin, Dr. Madison, Dr. Cutler, and several other American gentlemen, who have made and recorded valuable observations on the winds in America‡; and a long catalogue of modern navigators and travellers, who have contributed rich materials, brought from the most distant parts of the globe, toward forming a systematic view of anemology§.

Beside the great meteorologists whose names have been already mentioned, very important services have been rendered to this branch of natural history by Bouguer, du Carla, Hales, Wargentin, Mariotte, Reyer, Toaldo, Priestley, and many

* *Sur les Limites des Vents-Alizés.*

† *Meteorological Observations,* 8vo, 1793.

‡ For the observations of the above-named American gentlemen, and several others, see Franklin's *Philosophical Letters,* and the volumes of *Transactions* which have been published by the *American Philosophical Society* and the *American Academy of Arts and Sciences.*

§ For some ingenious remarks on anemology, see *Botanic Garden,* Additional Notes.

others, to whom due honour is given by various writers on the subject. The volumes of *memoirs* published by the scientific academies, in different parts of Europe, during the century under review, contain rich treasures of meteorological information, contributed by numerous hands.

Modern times have given birth to various inventions for measuring the force and velocity of winds. Among these, the most remarkable are the *Wind-gage*, the *Anemoscope*, and the *Anemometer;* in the construction and improvement of which Dr. Linn, Mr. Pickering, and others, have rendered important service to meteorology. Numerous attempts have also been made, during the period under review, to construct *hygrometers*, or instruments for indicating the comparative states of the atmosphere with respect to *moisture* and *dryness*. And though much imperfection is found to attend every instrument hitherto devised for this purpose, yet gradual approximations have been made toward those of a more perfect and useful kind. Among these, Mr. Smeaton's *hygrometer*, formed of a *hempen cord* boiled in salt water; M. de Saussure's, made of *human hair* prepared by maceration in alkaline ley; Mr. Coventry's, consisting of *dried paper;* and M. de Luc's, of *ivory* and *whalebone;* deserve to be distinguished: especially that formed of *whalebone* by M. de Luc, which is generally considered as the most accurate and convenient hygrometer now in use.

That remarkable meteorological phenomenon usually called the *Aurora Borealis* appeared with peculiar frequency in the course of the eighteenth century. Dr. Halley tells us* that it was seen but once in the seventeenth century,—*viz.* in 1621—when it attracted considerable attention, particularly in France, where the celebrated Gassendi observed it, and gave it the name which it now bears. After this there is no record of any such appearance until 1707, when a small one was seen. But in 1716 an uncommonly brilliant one appeared, which commanded universal attention, and was considered by the vulgar as a very portentous circumstance. Since that time these meteoric phenomena have been so frequent and familiar, that they have in a great measure ceased to attract attention or to be recorded as remarkable events.

Modern philosophers have ascertained many facts, with respect to the *Aurora Borealis*, which were of course unknown to those who lived in the seventeenth century, and probably to all who lived before them. It seems now to be generally considered either as an *electrical* phenomenon, or as produced by the *combustion of inflammable air* either with or without the intervention of the electric spark. For the observations which have been made upon this kind of meteor, and the principles with respect to it which appear to be established, we are under particular obligations to Dr. Halley, M. Mairan, signor Beccaria, Dr. Franklin, Dr. Forster, M. Gmelin, M. Æpinus, Dr. Hamilton of Dublin, Mr. Canton, Dr. Blagden, Mr. Dalton, and others. The last-named gentleman is supposed to have given the most satisfactory account of the subject.

* *Philosophical Transactions*, No. 347.

SECTION VI.

HYDROLOGY.

The natural history of *Waters* holds so important a place among the objects of human knowledge, that it has, in almost every age, attracted the attention of those who loved to study nature: but it is only within the century under review that any thing on this subject deserving the name of science, or a correct acquaintance with principles, could be said to exist. The accessions to Hydrology in modern times have been very great. The improvements in Chemistry, in Mineralogy, and in many other sciences, have contributed much to enlarge our knowledge in this department of philosophy.

The comparative qualities of *common waters*, whether falling in *rain*, or found in *springs*, *wells*, or *lakes*, were observed and ascertained, during the eighteenth century, with a degree of intelligence and accuracy never before known. For the experiments and inquiries which have led to our knowledge on this subject, we are chiefly indebted to Bergman, Scheele, Carradori, Hassenfratz, and Guyton-Morveau.

The taste, specific gravity, and other properties of *sea water*, were also examined with new accuracy, and with new results. For many enlightened experiments in this branch of hydrology, we owe much to Sparrman, Bergman, lord Mulgrave, M. Pages, Mr. Bladh, Dr. Watson, and Mr. Kirwan.

But among the discoveries and improvements of the last age, which belong to this head, the most important are the numerous and very useful investigations of *Mineral Waters*, which were pursued with great success during that period. It is evident that our knowledge of the properties and effects of mineral waters must in general keep pace with the progress of chemical science; for which reason the early writers on this subject were in a great measure destitute of the best means of pursuing their inquiries.

Mr. Boyle may be considered as the first person who pointed out the method of examining mineral waters. He first ascertained the existence of air in water, and directed to a number of tests by means of which conjectures might be made concerning the saline bodies which the water examined held in solution. He was soon followed by du Clos of France, by Hierne of Sweden, and by several other philosophers in different parts of Europe, who made considerable additions to the tests employed and the facts ascertained by Boyle. In 1726 Boulduc pointed out a method of precipitating several of the saline contents of water by means of alcohol. But it was not till after the discovery of *carbonic acid* by Dr. Black, that any great progress was made in ascertaining the composition of mineral waters. That subtile acid, which is so often contained in them, and which serves as a very powerful solvent to many of the earths, and even of metallic bodies, had thwarted all the attempts of former chemists to detect the composition of these liquids. Since the discovery of that acid, the analysis of mineral waters has advanced with great rapidity; so that, at the present period, this may be considered as one of the parts of chemical philosophy best understood.

The Dissertation on the Analysis of Mineral Waters published by Bergman, in 1778, was considered as the first great work on this subject. No general mode of analysing mineral waters was known prior to this publication. The author, in this admirable work, not only shed much new light on the subject, but he also carried the investigation of it at once to a very high and honourable degree of perfection. His method, with many additions and improvements, has been generally adopted by succeeding hydrologists.

About the same time with the publication of Bergman's work, Messrs. Monnet and Cornette of France, and Gioannetti of Italy, displayed in their respective works considerable talents as hydro-analysts, and gave much valuable information to the world. These were followed by the excellent treatises of Fourcroy on the waters of *Enghien*, of Klaproth on the waters of *Carlsbad*, and of Black on those of *Iceland*. In the experiments of these distinguished philosophers new and more accurate tests are exhibited, several improvements in the application of those before known are communicated, and methods unfolded of determining with precision the separate quantities of inseparable substances.

Next appeared the publications of Dr. Pearson on the waters of *Buxton*, of Dr. Garnett on the waters of *Harrowgate*, of Mr. Lambe on those of *Lemington Priors*, of M. Breze on those of *Pu*, and of M. Hassenfratz on those of *Pougues*.—To these may be added the hydrological inquiries of Gren, Westrumb, and Kirwan, which are highly valuable,—especially those of the last named gentleman, who, in a tract singularly comprehensive, and abounding with instruction, has given a rich amount of principle, experiment, and authority, on this interesting subject*. By the labours of these and many other philosophers, discoveries have been made concerning the composition and medical powers of mineral waters, in almost every part of the world, extremely useful to the interests both of science and humanity.

* *Essay on the Analysis of Mineral Waters,* by Richard Kirwan, esq. F.R.S. &c. 8vo. 1799.

CHAPTER IV.

MEDICINE.

THE profession, whose department of knowledge now comes under consideration, occupies an immense field of science, and by its number constitutes a large class of the learned world. In addition to the incentives of philanthropy and fame, which equally actuate the exertions of others, physicians are combined into a corps of observers and practical inquirers by the nature of the employment and duties they assume, and by the connexion which the usages of society establish between their duties and emolument. In discharging their professional labours, they incessantly find observations and facts obtruded on their attention; and by combining these into hypotheses, theories, and systems, they only indulge a favourite and almost irresistible propensity of the human mind. Hence arises the vast mass of writings which fill medical libraries, constantly accumulating, and too numerous, extensive, and diversified, to come within the comprehension of an individual inquirer. Whoever duly considers these things will perceive the necessity of resting satisfied on this occasion with a transient retrospect. To attempt any minuteness of detail would be to travel far beyond the limits assigned to this work, and to engross the pages which are destined to the examination of other subjects. All that can be aimed at is briefly to notice some of the more important revolutions and improvements which distinguish the last age and to commemorate a few of the illustrious names to whom the praise of them is chiefly due*.

Within the period assigned for this review, the state of medicine has been essentially changed, and has acquired a degree of extent, popular dissemination, and practical usefulness, unknown to preceding ages. The improvements in natural history and chemistry, mentioned in the preceding chapters, have greatly contributed to this extension, and may be considered as inexhaustible sources of materials calculated for a similar extension in future times. The more enlarged intercourse of mankind, the greater facility of communicating opinions and discoveries from one region to another, and the progress of commercial arrangements, by which the choicest productions of one country become the property of every other, may also be enumerated among the causes of this advancement.

In no period so much as in the last century, and in no science more than that which now engages the reader's attention, have the advantages been exhibited which arise from lord Bacon's plan of pursuing knowledge by observation, experiment, analysis, and induction. Every department of medicine bears witness of the efficacy of this process to remove the rubbish of prejudice and errour, to present truth in a simple form, and to establish it upon a legitimate foundation. A more precise, rigid, and logical mode of philosophising has been generally substituted for the wild and visionary hypotheses which disgraced the science of the preceding centuries.

* For many of the names, facts, and details, included in this chapter, the author is indebted to a medical friend.

To understand the history of medicine at any period, it is necessary to trace the progress and mark the affinities of all the sciences which are contemporarily cultivated. Not only the reign of fashion, but the peculiar acquirements and taste of individuals are often to be considered in an estimate of their medical principles. "La Philosophie," says M. d'Alembert, "La Philosophie prend, pour ainsi dire, "la teinture des esprits où elle se trouve. Chez un "métaphysicien, elle est ordinairement toute systé-"matique; chez un géomètre, elle est souvent toute "de calcul." The application of this remark, if possible, is more eminently verified in respect to medicine than to philosophy in general. This propensity of the human mind is productive both of good and ill effects. If it be easy to show examples of injury sustained by the precipitancy of mathematicians, chemists, and metaphysicians, in applying their doctrines to medical science, which cannot indeed be reasonably doubted; it is equally easy to prove that great benefit has arisen from such applications.

But notwithstanding the advantages and improvements which the eighteenth century has bestowed upon medicine, it must still be admitted that its progress has never equalled the sanguine expectations formed by many. Although nearly coeval with the existence of mankind, and demanding attention in every stage and condition of human life, the art of healing maintains a struggle with difficulties at every step. Like all other knowledge derived from observation and experience, that of medicine, though continually progressive, is subject to perpetual revolution. This tardiness, therefore, in the career of improvement, which all must admit and deplore, will excite no surprise in such as consider the mystery which still envelopes the principle of life, the labour of watching the operations of nature, the numberless fallacies which attend the endeavour to discriminate truth from falsehood, and the smallness of the stock of genuine and undisputed facts which all the observation and wisdom of ages have been able hitherto to collect.

There is no species of knowledge, relating to affairs merely human, which more indispensably requires steadiness of principles and harmony of opinion than that now under consideration. There is none in which speculation and action are more intimately related, where errour is of more immediate and fatal consequence, or where a fluctuation of the mind between opposite decisions is attended with more embarrassment and distress. Yet medicine abounds with schisms and controversies; and, in the present imperfect state of knowledge, to hold doctrines and adopt practices beset with the fewest errours, constitutes the highest attainment within the reach of the human mind.

SECTION I.

ANATOMY.

This subject was pursued with so much diligence soon after the restoration of learning in the fifteenth and through the two succeeding centuries, as to leave less than might be expected for the investigation of modern anatomists. Leonardo da Vinci made great progress in anatomical studies towards the close of the fifteenth century*. In the sixteenth century flourished the immortal Vesalius, the founder of rational and systematic anatomy, whose works afford surprising proofs of laborious and successful dissection. After him appeared Sylvius in France; Columbus, Fallopius, and Eustachius, in Italy; whose discoveries and improvements were so numerous as to give a deep impression of the zeal and enthusiasm with which the knowledge of the structure of the human body was cultivated at that early period.

Soon after the time of the last mentioned writers, the study of anatomy was gradually diffused over all Europe. The principal impediment to its progress, in that age, was the difficulty of obtaining human subjects for dissection; the want of which frequently made it necessary to dissect the bodies of brutes.

With the dawn of the seventeenth century new lights were shed upon anatomical inquiries from every quarter. At this time Fabricius ab Aquapendente, an eminent Italian teacher, published his account of the valves in the veins; which evidently affected the established doctrine of all former ages, that the veins carried the blood from the liver for nourishment to all parts of the body. The detection of these valves may also justly be supposed to have laid the foundation of the discovery of the circulation of the blood.

For Dr. Harvey, the pupil of Fabricius, was reserved the noble discovery of the *circulation of the blood* soon afterwards. This was by far a more

* This was the first man who introduced the practice of making anatomical *drawings*. These drawings, preserved in a British collection, excite astonishment at the depth and accuracy of his knowledge.

important step in the knowledge of animal bodies than had ever been made before, and gave a new spring to anatomical inquiries. In a few years after Harvey's discovery, Asellius, an Italian physician, found out the lacteals, or vessels which carry the chyle from the intestines. And about the middle of the seventeenth century, Pecquet, in France, was so fortunate as to discover the *thoracic duct*, or common trunk of all the lacteals, which conveys the chyle into the subclavian vein. At nearly the same period, the practice of dissecting living animals furnished the occasion of discovering the lymphatic vessels. Rudbec, a young Swedish anatomist, was the first to detect them; and, after him, Thomas Bartholine, an anatomist of Denmark, who first appeared as a writer on the subject.

Malpighi, an eminent Italian, made great progress in anatomy soon after the period last mentioned. He was the first who used magnifying glasses with address to trace the early appearances in the formation of animals. He likewise improved anatomy by many other observations on minute parts of the body, by his microscopical labours, and by the dissection of animals. Between the middle and end of the seventeenth century, anatomy was much improved by the diligence of Swammerdam, Van Horn, Steno, and de Graaf. Professor Diemerbroeck, of Utrecht, without much originality, compiled a work which for many years was regarded among students as a standard authority.

Towards the close of the same century, Lewenhoeck obtained great celebrity by his improvement on Malpighi's use of microscopes. Though many of the supposed discoveries of this anatomist (parti cularly his account of the composition of the red globules of the blood, and of animalcula observed in the semen) are now discredited, it must still be admitted that he advanced many steps in bringing to light the more minute parts of the animal structure. Nuck likewise soon afterwards added to the stock of knowledge by his injections of the lymphatic glands. The anatomical plates of Bidloo and Cowper, published about this time, are also entitled to respectful notice.

In the latter part of the seventeenth century anatomy was greatly advanced by the invention of injections, and the method of making what are commonly called *preparations*. These two modern arts have been of great advantage in this science: they have introduced not only an unexpected degree of correctness, but an elegance in demonstrations which formerly could not have been supposed to be possible. They began in Holland under Swammerdam and Ruysch, and were afterwards employed in England by Cowper, St. Andre, and others. Ruysch possessed a singular excellence in injections, which has been supposed by many not to have been equalled since, and which certainly has not been surpassed. The anatomists of former ages had no other knowledge of the blood-vessels than such as they were able to obtain by laborious dissections, and by pursuing the smaller branches of them, upon favourable occasions, when they happened to be more than commonly loaded with red blood: but filling the vascular system with a bright-coloured wax presents a distinct view of the large vessels, renders the smaller much more conspicuous, and makes thousands of the very minute ones visible, which, from their capillary size, their delicacy, and the transparency of their contents, would be otherwise imperceptible.

In this high state of advancement, anatomy stood at the beginning of the century the progress and improvements of which it is the object of this work more particularly to explore. At that period, the Italian and Dutch schools held an undoubted superiority. This superiority, however, has been since much more equally divided among the British, French, and German anatomists.

Early in the eighteenth century, anatomy was improved by the writings of Ruysch in Holland, and of Cowper, Keil, Douglas, Cheselden, and others, in Great Britain. The works of Albinus, Winslow, and the first Monro*, greatly contributed to the same end, and are familiarly known to all the cultivators of this science.

But the most memorable discovery that anatomy can boast in the eighteenth century, is that of the *absorbent system*. It has been mentioned that Rudbec and Bartholine became acquainted with the lymphatic vessels about the middle of the preceding century. When they were first seen, and traced into the thoracic duct, it might have been supposed natural for anatomists to suspect, that, as the lacteals absorbed from the cavity of the intestines, the lymphatics, similar in figure and structure, might possibly perform

* The family of Monro, in Edinburgh, has been long and eminently distinguished in the annals of anatomy. Three persons, of the name of Alexander Monro, have in succession adorned the medical school of that city since the year 1720; of these, the last is yet alive, and ably supports the reputation of his illustrious predecessors.

the same office with respect to other parts of the body. Notwithstanding this, anatomists in general, from repeated experiments, particularly such as were made by injections, were persuaded that these lymphatic vessels did not arise from cavities, and did not absorb, but were merely continuations of the small arteries. It had indeed been supposed by Dr. Glisson, who wrote in 1654, that they arose from cavities, and that their use was to absorb. Dr. Frederick Hoffman had also very explicitly laid down the doctrine of the lymphatic vessels being a system of absorbents. These suggestions, however, produced little effect. And it was reserved for Dr. Hunter * of London, and Dr. Monro, the present professor at Edinburgh, to prove that the lymphatics are absorbing vessels throughout the whole body; that they are similar to the lacteals; that all these, collectively taken, together with the thoracic duct, constitute *one great and general system*, dispersed through the whole body for the purpose of absorption; that their sole office is absorption; and, finally, that they serve to take up and convey whatever is *to enter the composition of the blood*, or *to be again mixed with the blood*, from the intestinal canal, from the skin, and from all the internal cavities and surfaces †.

* William and John Hunter, also natives of North Britain, and afterwards residents in London, hold a high place in the anatomical history of the eighteenth century. The former was born in 1718, and died in 1783; the latter was born in 1728, and died in 1793.

† A warm controversy, concerning the discovery of the true use of the lymphatics, was carried on between Dr. Hunter and Dr. Monro. The former asserts that he taught it in his lectures so early as 1746, and appeals to his pupils for the truth of the asser-

The discovery of the absorbent system is justly considered as the greatest that anatomy has suggested since that of the circulation of the blood. The advantages which arise from the knowledge of the structure and office of this system of vessels, in establishing physiological principles, and in ascertaining the nature and treatment of diseases, are universally admitted. Before the discovery of the lymphatics being a system of absorbents, it was impossible to give a clear and consistent account of a great number of phenomena which are now satisfactorily unfolded. From this source much knowledge has been obtained concerning the introduction and effects of poisons; and, aided by this light, physicians are enabled to trace many diseases directly to their causes, to explain the assemblage and succession of symptoms, and to apply remedies with more prompt and appropriate efficacy. On this account physicians of learning and judgement have not been wanting, who pronounce the solid and practical usefulness of this discovery even to exceed that of the circulation of the blood.

But whatever may be the comparative estimate of the two discoveries in relation to one another, it is plain that they are both the most memorable

tion. The latter seems to have made the discovery in 1753; and in 1755 published an account of it in a thesis *De Testibus in Variis Animalibus.* Before the publication of this thesis, Dr. Black is said to have informed the author that the same opinions concerning the valvular lymphatics had been long entertained by Dr. Hunter. In 1756 Dr. Monro attended Dr. Hunter's lectures in London; heard the whole doctrine of the lymphatics very amply explained; and in 1757 reprinted his opinion at Berlin, without taking notice of Dr. Hunter's, who, in consequence, charges him with plagiarism; and the charge is retorted by Dr. Monro.

that the annals of anatomy can boast. Under the influence of this impression, Dr. Hunter declared, in one of his lectures, that "in looking over the whole progress of anatomy, from the time of Aristotle to the present day, there have been only *two grand discoveries* with regard to the physiology of our bodies,—to wit, the *vascular system, or circulation of the blood*, and the *absorbent system*;—the *brain* and *nervous system* having been known long before."

Notwithstanding, however, the weight of the arguments adduced by Dr. Hunter, Dr. Monro, and others, in support of this doctrine of the absorbent system, it has been opposed by writers of great authority. The old opinion, that the veins perform the office of absorbents, was held by Haller* and Meckel. Within a few years, Mr. Humpage, in a work entitled "Physiological Researches into the most important Parts of the Animal Economy, &c.," undertook to controvert the prevailing doctrine on this subject. He endeavours to prove, conformably to the opinion of the old anatomists, that the lacteals and the lymphatics constitute systems of vessels entirely separate and distinct. He admits that the lacteals arise from the internal surface of the alimentary canal, terminate in the thoracic duct, and convey the chyle into the blood: but he denies that the lymphatics arise from cavities and surfaces, or that they terminate in the thoracic duct; and maintains, on the contrary, that they originate from the heart and arteries, that they serve to convey lymph from the

***Element. Physiolog. Corp. Human.* l. 24, § 2, 3.

blood, and that they terminate on all surfaces and cavities. He contends that the use of the lymphatic glands is for the separation of the lymph from the blood; and that the lymphatic vessels are excretory ducts to the lymphatic glands. For the important function of absorption he provides in the following manner: he supposes that, although the lymphatic vessels convey fluids from the blood, they also occasionally possess the power of absorption. This office, he imagines, they perform after accomplishing their first purpose—that is to say, after conveying the lymph to the various parts of the body, they become mere empty tubes, and absorb whatever is applied to any surface. According, therefore, to the degree of inanition or repletion of the lymphatic vessels, in his opinion, will the body be more or less susceptible of the absorption of any fluid applied to the skin or any other surface or cavity.

These, however, and many other objections to the generally received doctrine of the absorbent system, have gained little credit among the most respectable anatomists. The arguments by which they are attempted to be supported have been shown to be founded on injections unskilfully made, on observations inaccurate, and conclusions altogether illogical.

In the early part of the controversy on this subject, it was urged, that, before the doctrine of the lymphatics being a system of absorbents could be established, it was necessary first to determine whether this system is to be found in other animals beside man and quadrupeds. Mr. Hewson claimed the merit of having proved the affirmative of this question, by discovering the lymphatic system in birds, fishes, and amphibious animals *.

Since the time of Mr. Hewson, the anatomy of the absorbent system has been greatly extended and improved. The ramifications of it, in almost every part of the body, have been traced by Mr. Cruikshank, with great accuracy; and from his dissections, figures have been made and published which are deservedly held in high estimation. To Mr. Sheldon, also, anatomists are much indebted, for his illustration of this system. And Mascagni, of Italy, has likewise bestowed great pains on this subject †.

As a general system of anatomy, the "Anatomical Exposition of the Structure of the Human Body," by professor Winslow, of the university of Paris, though compiled and published early in the eighteenth century, was, till near the close of it, regarded as a standard work. This has, of late, given place to a more comprehensive and accurate compilation, in three volumes, executed by Mr. Fyfe of Edinburgh, under the direction of professor Monro. Heister's compendium, during a great portion of the century, was held in high esteem. Dr. Simmons, of London, has also lately obliged the world with an excellent system of anatomy, in which the subject is treated with uncommon perspicuity and elegance. Among treatises on anatomy in general,

* *Philos. Trans.* vols. lxviii and lxix.

† The work of Mascagni on the *Lymphatics* is considered by good judges, as by far the greatest work that has been published on this subject, as one of the most valuable anatomical productions of the age, and as a work that must immortalise the reputation of the author.

those presented to the world by Sabatier and Plenck, within a few years, deserve to be particularly mentioned. Mr. John Bell, of Edinburgh, has published two volumes of a system of anatomy, which is considered as a very able work, so far as it goes, and will probably be completed in a short time. Mr. Charles Bell, of the same city, in a work entitled "A System of Dissections," has done much towards facilitating and familiarising the study of anatomy, and displaying the appearances of morbid parts of the body. And a very recent "Compendium of Anatomy," by Mr. Fyfe above-mentioned, illustrated by a large number of engravings, is supposed to contain improvements, of more or less value, on every preceding work of that kind.

To the above may be added a variety of valuable publications by professor Scarpa, of Pavia, who has well supported the reputation of the former Italian schools of anatomy.

In particular departments of anatomy, much has been done within the century to enrich the science, which ought not to be passed without special notice.

The *gravid uterus* is a subject which has attracted much attention, and received considerable improvement within this period. The works of Albinus, Roederer, and Jenty, have greatly enlarged the knowledge of former anatomists on this point. But Dr. Hunter's publication on the gravid uterus, to which he had devoted a long time and uncommon pains, far excelled every preceding work. Meckel, and the second Monro, have treated on the *nerves* to considerable extent; Weitbrecht and Leber on the *joints* and *fresh bones*; Soemmering and Monro on the *brain**; Porterfield, Haller, Zinn, and Wrisberg, on the *eye*; Cotunnius, Meckel, jun., Camper, Scarpa †, and many others, on the *ear*. Walter is celebrated for his description of the *veins of the head and neck*, as well as very elegant plates of the *nerves of the thorax and abdomen*. Trew has ably treated of the *differences between the fœtal and adult vessels*: Dr. Monro, jun., on the *Bursæ Mucosæ*, &c.

The anatomists of the eighteenth century have effected great improvements in the science, and facilitated the communication of it to students, by the number and correctness of their *engravings*. Figures of the *bones*, in folio, have been published by Cheselden, Albinus, Sue, and Trew. The *muscles*

* Mr. Soemmering thinks it probable that the *soul* is seated in the fluid of the ventricles of the brain. He infers this from the fact of the nerves of vision, hearing, taste, and smell, being all at their origin in contact with and exposed to the action of the fluid in the ventricles; from the same taking place with regard to the nerves of touch, originating from the fifth pair, the glosso-pharyngeal, those belonging to the organ of voice and the motions of the eyes; from the impossibility of finding a solid part of the brain into which the terminations of all the nerves can be traced; from the nerves of the finest senses—*viz.* hearing and seeing—being most extensively expanded and most directly in contact with this fluid; from the preternatural increase of this fluid in the ventricles of ricketty children, which perhaps may be the cause of their uncommon acuteness of mind; and, finally, from the fact, that no animal possesses so capacious and so perfectly organised ventricles as man,—they being in the other mammalia much smaller than in man, still less in birds, least of all in fishes, and absolutely wanting in insects.

† This great anatomist wrote ably, not only on the *ear*, but also on the *nerves of the heart*. His work on this subject is said to be highly meritorious.

are exhibited by Cowper and Albinus with great accuracy; by the latter particularly, in a style of elegance which cannot easily be surpassed. Haller's *Icones*, especially of the *arteries*, are much admired. Anatomical figures of particular and smaller parts of the body are without number, and many of them possess great excellence. It will be sufficient to mention a few; such as those by Morgagni, Ruysch, Valsalva, Sanctorini, Heister, Vater, Cant, Zimmermann, Walter, &c.

The vast work projected by Vicq-d'-Azyr, of France, was soon terminated by his premature death. He conceived the idea of representing anatomically the whole animal kingdom, from man down to the simplest hydra, of giving exact figures of every form of living matter, and of consolidating the immense plan into one great whole. Upon the *brain* alone nineteen folio plates are employed, of which several are coloured; these are executed with admirable elegance. This universal system of anatomy and physiology, both human and comparative, was proposed to be executed in the same splendid style. But he lived only to finish five numbers. The design is apparently too extensive to be accomplished within the period of a single life.

In Great Britain, likewise, an extensive anatomical work has been undertaken by Mr. Andrew Bell, entitled *Anatomia Britannica*, under the inspection of Mr. Fyfe and Dr. Monro. It is designed to compose a complete illustration, both general and particular, of the human body, by a selection from the best plates of all the greatest anatomists, as well foreign as British, exhibiting the latest discoveries, and accompanied with copious explanations. The whole number of plates is to be upwards of three hundred, in royal folio; of which a large proportion is already published.

The art of *injection* and of making *preparations*, which was before stated to have reached such a point of excellence towards the close of the seventeenth century, has been very extensively and successfully exercised during the eighteenth. The modern practice of corroding the fleshy parts and leaving the moulded wax entire, is so useful as well as ornamental, that it reflects great credit on Dr. Nicholls, the ingenious inventor. In the injection of the lacteals and lymphatics, the late century may justly claim the credit of having made very considerable progress.

Morbid dissections form a new and interesting æra in anatomy and medicine. Bonetus, near the end of the seventeenth century, had published his *Sepulchretum Anatomicum.* Morgagni, in his inestimable work, "*De Causis et Sedibus Morborum,*" has enriched morbid dissections with many valuable additions, and has rendered them highly instructive to the medical practitioner. Lieutaud and Haller also greatly increased the stock of knowledge on this point. Most of the distinguished anatomists, indeed, have contributed their exertions to improve the principles of medicine, by directing their dissections to this object. Lately Dr. Baillie's publications on morbid anatomy, illustrated by correspondent engravings, do the highest honour to his diligence, learning, and judgement.

Beside the discoveries and improvements obtained from the dissection of human bodies, *Compa-*

rative Anatomy or *Zoötomy* has made great progress in the course of the eighteenth century. Many advantages have arisen, and may be expected hereafter to arise, from this source. In addition to the benefits resulting from a more enlarged acquaintance with the properties and functions of animated nature, which often reflect light on the human economy, and are founded on the knowledge of comparative anatomy, the *veterinary* art has lately become so extensive and respectable as to require, on its own account, a more minute examination of the structure of many animals.

The most illustrious names among such as have distinguished themselves in human anatomy are in general precisely those who have done the most to extend the limits of comparative anatomy in the eighteenth century. To prove this, it will be sufficient to recall the reader's attention to the writings of Haller, Dr. and Mr. Hunter, the first and second Monro, &c. The *Essay on Comparative Anatomy* by the first Monro affords proof of the diligence he exercised on the subject. The thesis of the second Monro, "*De Testibus in variis Animalibus*," abounds with evidence of deep, laborious, and successful researches. And his work on *Fishes*, mentioned in the preceding chapter, has greatly contributed to enlarge our acquaintance with the structure and functions of that large class of animals. Every anatomist is informed of the discoveries and improvements made by Dr. and Mr. Hunter in their numerous dissections of animals, and of the principles and doctrines which these dissections enabled them to establish. They were followed by Mr. Hewson, Mr. Cruikshank, and many others of distinguished reputation, who were employed in the investigation of the absorbent system. Daubenton and Vicq-d'-Azyr, the dissections made under the orders of the Royal Academy of Sciences of Paris, Spallanzani of Italy, Camper of Holland, the late extensive and systematic work of Mons. Cuvier, which exhibits the dawn of an improved arrangement, and a great number of the most eminent zoölogists of the age, have strong claims to be commemorated in a review of the comparative anatomists of the eighteenth century*.

In concluding this brief survey of the subject, it may not be improper to remark, that far less remained to be done in anatomy, at the commencement of the late century, than in any of the other branches of medicine. The leading principles of the science had been chiefly ascertained and settled by the industry and perseverance of preceding ages. And the greater part of what was left to be accomplished consisted in a superior fulness, accuracy, and minuteness of description, more elegance of delineation, more neatness and variety of preparations, and a progressive improvement in the arts of dissection and demonstration. It is evident, that, in all these respects, a considerable progress has been made within the period under review.

* In addition to the above-mentioned works and names, it may not be improper to subjoin the following comparative anatomists, selected from a great number. Fragments of the *Curieux de la Nature;* the collections of Blasius and Valentini; du Verney, Collins, Stubbs, Coleman, and Home, on *quadrupeds and birds;* Charas, Roesel, and Fontana, on *reptiles;* Artedi, the Gouans, and Broussonet, on *fishes;* Réaumur, the Geoffroys, Bonnet, and Lyonet, on *insects;* and Ellis, Donati, Trembley, Baker, Baster, Bohadsch, Forskal, Adanson, Mueller, Pallas, and Dicquemare, on *worms, zoöphytes,* and *polypes.*

SECTION II.

PHYSIOLOGY.

That department of physical science which treats of the various properties and functions of living bodies must be allowed to possess great importance; and the review of its progress during a hundred years of more industry and enterprise in the pursuit of natural knowledge than the world ever witnessed before, will be supposed to present difficulties proportioned to the extent and complexity of the subject.

To such as feel a genuine attachment to the science of nature, few subjects present inquiries of a more interesting and instructive kind. When improved as far as the state of the other contemporary sciences will admit, it will be found to exhibit a systematic result of all the experiments and observations, facts and principles, which serve to explain and illustrate the phenomena of animated nature. And when it shall reach that point of advancement to which a cautious estimate of the powers of the human mind may suppose it to proceed, it will probably be enabled to diffuse lights and suggest improvements far beyond the most sanguine expectations of the naturalists of the present day. In zoölogy, botany, anatomy, and the theory and practice of physic, these good effects may be confidently anticipated.

As all living bodies are subjects of physiological inquiry, and as by living bodies are here meant all those which are enabled, by a certain organised structure, to grow and to propagate their kind, it is plain that physiology must extend to the whole of that organical economy in animals and plants which the Author of Nature has contrived for the preservation of the individual, and the continuance and propagation of the species. But although it is not intended, in this brief retrospect, wholly to overlook the history of the doctrines of general physiology for the late century, it may be proper to apprise the reader that the objects of human physiology will chiefly claim attention. This restricted view of the subject is preferred on the present occasion, not only on account of the requisite brevity, but because the chief design of introducing this sketch of the progress of physiology is to consider it in subserviency to medical science, and as preparatory to the remarks which are to follow concerning the theory and practice of physic.

At the close of the seventeenth century, physiology presented a chaos of the wildest and most discordant principles. The extravagant notions of the Galenists and chemists had indeed ceased to be generally defended; but they were succeeded by those of the mathematicians, which were nearly as far removed from truth and nature. The discovery of the circulation of the blood, in the beginning of the seventeenth century, had given rise to the introduction of mechanics into medical doctrines. And as that system of philosophy was founded upon the general laws of nature, the ablest physiologists of the day were easily induced to apply it to the human body; which was supposed to differ only from the rest of the universe in the variety and complexness of its machinery.

Bellini, of Florence, was the first who attracted much attention by the introduction of mathematics into physiology. Professor Borelli pursued the same course of reasoning, and soon became one of its most enthusiastic admirers. He employed it so well in showing how the muscles act as cords, and the bones as levers, that he thence undertook to explain, with happy effect, the phenomena of standing, walking, leaping, flying, and swimming, in different animals *. Emboldened by the success of his first attempt, he afterwards ventured to explain on the principles of mechanism all the internal motions and their proximate causes. On the same ground he gave a minute account of the pulsation of the heart, of the circulation of the blood, of the office of the lungs, the kidneys and the liver, of the nervous fluid and the semen, of vegetation, generation, nutrition, hunger, thirst, pain, lassitude, and febrile heat. By this ardent speculatist all nature was interpreted on mathematical principles; for, except the mechanical, he was willing to admit no other secondary powers in nature. He thought, with Plato, that the Deity himself was always *geometrising;* and was fully persuaded that physical knowledge could only be acquired through the medium of geometrical demonstrations and forms.

With what eagerness and zeal Dr. Pitcairn adopted mechanical physiology, and to what unreasonable extremes he was disposed to carry it, is

* See his work, *De Motu Animalium.*

sufficiently known. So attached was he to the geometrical mode of demonstration, that he appeared to consider it as the only species of evidence, excepting the senses, that deserved any reliance.

These opinions were warmly adopted and supported by the illustrious Boerhaave, who first appeared as a public teacher about the beginning of the eighteenth century. He exhibited the first successful example of combining physiology with anatomy, reduced the former from a rude and chaotic into a regular state, and conferred upon it that systematic and elegant form which so greatly recommended it to the notice and admiration of the world. But a more particular account of the opinions of this distinguished physician will be given under a succeeding head.

Baron Haller, the disciple of Boerhaave, pursued the steps of his master, and far surpassed him in his physiological career. He made a universal collection of preceding discoveries in anatomy and physiology, and digested them into order and method. He surveyed every part of the human body, explained the various functions according to the best lights which the state of science at that time afforded, corrected the errours of preceding writers, and, by a series of indefatigable labours, was enabled to make very important additions to the existing stock of knowledge. In his great work, entitled *Elementa Physiologiæ Corporis Humani*, he examined the opinions which had been recommended, or at least advanced, by all the most celebrated authors. Nothing of importance, that had been previously published, escaped his notice. The most rapid sketch of the errours in physiology which he detected, of the new facts which he added, of the ingenious and profound views which he opened, of the doubts he removed, and of the theories he reformed and improved, would exceed the limits assigned to this work *.

But the greatest of Haller's discoveries, and that which forms an æra in the progress of physiology, is the *irritability* of the animal fibre. This *irritable* or *contractile* power is that property by which muscles recede from stimuli, and become shorter on being touched by them. It is a power inherent in the muscular fibre, and essential to life. It is so far independent of nerves, and so little connected with feeling, which is the leading property of nerves, that, upon stimulating any muscle by touching it with caustic, or irritating it with a sharp point, or directing the electric spark through it,

* Baron Albert von Haller was born at Berne, October 18, 1708, and died in 1777. He was unquestionably one of the greatest men of the age in which he lived; being equally distinguished for the extent and variety of his learning, the vigour and comprehensiveness of his mind, the purity of his taste, and the excellence of his moral and religious character. His great attainments, and the uncommon powers which he displayed in almost every kind of knowledge, and particularly in anatomy, physiology, medicine, botany, and various branches of Natural History, and also in classical and polite literature, are generally known. He was not less distinguished as a friend to the religion of Christ. He not only professed to believe in revelation, and to cherish a warm attachment to the Gospel, but, amidst his multiplied avocations, he spent much time in studying the Scriptures, and the evidences of their divine origin; and entered the lists as their avowed advocate and defender. His excellent *Letters to his Daughter* will long remain a monument at once of his regard to religion, and of his paternal fidelity. See Henry's *Memoirs of Haller*.

the muscle instantly contracts; although the nerve of that muscle be tied; although the nerve be cut so as to separate the muscle entirely from all connexion with the nervous system; although the muscle itself be separated from the body; and although the animal upon which it is performed have lost all sense of feeling, and have been long to all appearance dead. It is by this irritable principle that an incised muscle contracts so powerfully, and that a divided artery shrinks and retires into the flesh.

This important *principle of irritability*, which Haller denominated *Vis Insita*, from its being an inherent, independent, and permanent property of the living fibre, was in a great measure unknown to preceding physiologists. Boerhaave acknowledged an active power in the heart, and a latent principle of motion in the parts of it when divided; but, nevertheless, he attributed this to the nerves, though the communication with the brain had been entirely cut off. The celebrated Dr. Whytt, of Edinburgh, followed nearly the same path, with only some difference in point of expression. About the middle of the century now under consideration, this physician was engaged in a controversy with Haller on this subject. Whytt contended that all the phenomena of irritability might be referred to nervous influence, and rejected his antagonist's principle of muscular action, as founded in errour, and unnecessary to explain the phenomena. On the contrary, to this *Vis Nervosa* of Whytt, though maintained with all the aid of ingenuity and learning, Haller, with much greater force and conclusiveness of reasoning, persisted in opposing his doctrine of *Vis*

Insita, as a primary, essential, and inherent quality of the living fibre, dependent on its original structure and organisation, and entirely independent of the nerves. Not many years ago, professor Monro, of Edinburgh, in his *Observations on the Structure and Functions of the Nervous System*, renewed the attempt, though it is conceived without success, to invalidate the doctrine of Haller.

In pursuance of this interesting doctrine, Haller contemplates the living body under a fourfold division, into parts, 1. Irritable; 2. Inirritable; 3. Sensible; 4. Insensible. Among *irritable* parts he ranks the heart, the muscles generally, the diaphragm, the œsophagus, the stomach, the intestines, the gall-duct, the arteries, the absorbents, and the bladder. Among *inirritable* parts he reckons the lungs, the liver, the kidneys, the spleen, and the nerves. Among *sensible* parts he enumerates the brain, the spinal marrow, the nerves, the skin, the internal membranes of the stomach, intestines, and bladder, the ureters, the muscular flesh, and the breasts. Among *insensible* parts he considers the dura mater, the pia mater, the periosteum, the peritonæum, the pleura, the pericardium, the omentum, the cellular texture, the cuticle, the rete mucosum, the fat, the tendons, the capsules and ligaments of the joints, the bones, the marrow, the teeth, and the gums.

From this account, given by Haller, of the various parts which are united to form an animal system, it results that the *irritable* and *sensible* portions are comparatively few and small; that the great mass of the body consists of *inirritable* and *insensible* parts, which serve to combine, envelope, and defend the former, and thereby to constitute a moving perfect whole, adapted to assume the actions of life, and to sustain the impression of surrounding objects.

In this arduous inquiry, which so long engaged the mind of Haller, and which led to so many interesting results, he was not condemned to the necessity of labouring alone. The example of the preceptor inspired many of his pupils with the same spirit of exertion and enterprise. Zinn, Zimmerman, Caldani, and several others, animated by a liberal emulation, laboured with indefatigable diligence to extend and improve the discoveries of their illustrious master. Thus, by the combined exertions of the teacher and his students, was the philosophy of animal life more deeply investigated than ever before, and eventually placed on a basis almost entirely new.

The effects of Haller's doctrine of *irritability* in improving physiological and medical principles must be obvious to the most superficial observer. It will not be thought extravagant to say that he seems to have laid the true foundation of the science of medicine, if indeed such a foundation can be said to be yet laid. From Haller, more than from any single writer, Dr. Brown, and other modern systematic reformers, who have done most to improve medical principles, seem to have borrowed the torch by which they were enabled to direct their progress, and to explore the obscurities of their route.

But notwithstanding Haller's felicity in accomplishing so much to aid the progress of physiology, he did not live to witness two of the most signal improvements in that science which the eighteenth century can boast. He died in the year 1777, just about the time when a new and unexpected light began to be shed upon the functions of *respiration* and *digestion*.

The office of the *Lungs*, which is now of all the animal functions the best understood and the most susceptible of scientific illustration, was unknown to Haller. He supposed that the principal object of respiration was to form the voice. That such a man, possessed of all the knowledge of preceding and contemporary physiologists on this subject, should have acquiesced in this conclusion, is indeed matter of surprise; but at the same time it serves to fix the source, and to enhance the value of this great discovery.

To modern chemistry the praise of unfolding the mystery of respiration is certainly due. The establishment of this truth alone is almost sufficient to subvert the old and to erect a new system of physiology. And if no other benefit than this had arisen from all the brilliant discoveries which chemistry offers to the world, it would have sufficed to rescue that science from neglect, and to assign it an elevated rank among the objects of human knowledge.

It is often asserted, that much of the true office of the lungs was known to the physiologists of the seventeenth century. Even from much more ancient writers expressions sometimes escape which show a tendency to just views of the subject; as, for example, when air received in respiration is supposed to afford the *pabulum vitæ, spiritus alimentum,*

&c. But in the century just mentioned a much nearer approximation to the truth was undoubtedly made. Verheyen observed that those animals which respire most have the warmest blood*. Lower demonstrated that the blood receives a new and a brighter colour in passing through the lungs†. Verheyen and Borelli both proved that the air lost something by coming into contact with that organ‡. And the former remarked that this *something* is absorbed by the lungs; and is probably that which maintains combustion, which qualifies the air to support animal life, and imparts to the blood the vermilion colour§. Towards the latter part of the same century Dr. Hook and Dr. Mayow published opinions concerning respiration, which approach more nearly to the doctrine now generally received than could be readily believed, if their writings themselves did not bear witness. The former seems to have been obscurely acquainted with oxygen and its absorption in breathing. The latter, according to the opinion of Dr. Beddoes‖, "was acquainted with the composition of the atmosphere, and perceived the action of *vital air* in almost all the wide extent of its influence. He carried on his investigation of respiration from the diminution of the air by the breathing of animals, to the change it produces in the blood during its passage through the lungs. The office of the lungs, says Dr. Mayow, is to separate from the air, and convey to the blood one of its constituent parts."

* *Tract. De usu Respirationis.* † *Ibid.* ‡ *Ibid.* § *Ibid.*
‖ See Dr. Beddoes's *Analysis of Dr. Mayow's Work.*

It is astonishing that such suggestions should have been so little known and so little attended to by succeeding physiologists. They seem to have attracted but slight regard at the time of their publication, and very soon afterwards to have been completely forgotten. But after all it must be admitted, that the superior light of modern discoveries, reflected on organs of eager discernment, is alone sufficient to enable the reader of these antiquated writings to perceive, in the few truths they contain, blended and buried under so much obscurity, mistake, and errour, the true principles of respiration.

There cannot be stronger proof of the fact, that these obscure hints of the real use of respiration were unknown or forgotten by succeeding physiologists, than may be found in the works of Haller and Dr. William Hunter. The opinion of the former of those great physiologists, concerning the subserviency of respiration chiefly to the formation of the voice has been already mentioned. The latter, in his introductory lecture, published in 1784, expresses himself as follows:—" Respiration we cannot explain; we only know that it is *in fact* essential and necessary to life. Notwithstanding this, when we see all the other parts of the body, and their functions so well accounted for, we cannot doubt but that respiration will be so likewise. And *if ever* we should be happy enough to find out clearly the object of this function, we shall, doubtless, as clearly see, that *this organ* is as wisely contrived for an important office, as we now see the purpose and importance of the heart and vascular system; which, till the circulation of the blood was discovered, was wholly concealed from us."

It will scarcely be necessary to add to what is already stated concerning Hook and Mayow, that Mr. Boyle and Dr. Hales were much engaged on the same subject, and that the latter particularly was greatly useful by his experiments and researches in pneumatic philosophy, which paved the way for the brilliant improvements of his successors in that inquiry.

The splendid progress of pneumatic chemistry which ennobles the last twenty-six years of the eighteenth century, has been detailed in another place. The discovery of *oxygen*, and the analysis of the atmosphere, are prominent points in that progress; and they likewise constitute the basis of the principles which were afterwards so successfully applied to explain the nature and objects of the function of respiration.

It is universally known, that the merit of taking the lead in the application of the principles of pneumatic chemistry to explain the function of the lungs is due to Dr. Priestley*. In the year 1774 he discovered the existence, and many of the properties, of *oxygen*. Mr. Scheele made the same discovery nearly at the same time. Not long afterwards these two philosophers demonstrated that the quantity of oxygenous gas is diminished in respiration. In 1776 Lavoisier proved that atmospheric air is compounded of oxygen and azote,

* For a considerable portion of the facts detailed in several of the following paragraphs on the subject of *respiration,* the author is indebted to a very respectable work, entitled *A System of Chemistry,* by Thomas Thomson, M. D. 4 vols, 8vo, 1802.

brought by means of caloric to the state of elastic fluids. In the following year that eminent philosopher discovered that a quantity of carbonic acid gas is found in air after it has been respired for some time, which did not previously exist in it. Some time afterwards he found, by a variety of experiments, that no animal can live in air totally deprived of oxygen. This fact was soon confirmed and extended by the experiments of many other philosophers, who proved that even fishes, which do not perceptibly respire, and frogs, which can suspend their respiration at pleasure, speedily die if the water in which they are placed become destitute of oxygenous gas*.

By a further prosecution of observations and experiments on this subject, it was not long afterwards satisfactorily established, that certain remarkable changes are produced by respiration not only upon the air respired, but likewise upon the blood exposed to this air. The most noted changes observed to take place, in the air itself subjected to respiration, are the following:—a part of the air respired entirely disappears; the rest becomes impregnated with carbonic acid, and is loaded with water in the state of vapour. For the knowledge of these changes effected in the air respired, and for the numerous and laborious experiments from which these conclusions were inferred, the world is chiefly indebted to Priestley, Cigna, Lavoisier, Menzies, Seguin, and Davy.

Changes no less remarkable are found to be produced in the blood exposed to the air in the

* Carradori, *Ann. de Chim.* xxix, 171.

lungs. The principal of these are as follow: the blood absorbs air; it acquires a florid red colour, and the chyle mixed with it undergoes such alteration as to lose its colour and disappear; it emits carbonic acid, and perhaps carbon itself; and it emits water, and perhaps hydrogen. The writers who have principally signalised themselves in tracing and making known these changes in the blood, are Priestley, Cigna, Fourcroy, Hassenfratz, Beddoes, Watt, and, very lately, Mr. Davy.

The theories of this function, as deduced from facts successively discovered, have varied according to the number of such facts, and the impressions which they made on different minds. Dr. Priestley, the first of the modern chemical philosophers, as was before remarked, who attempted to investigate the use of respiration, seems to have considered it, from some of his earliest experiments, chiefly as an excretory process. He believed that the blood, in passing through the lungs, gives out *phlogiston* to the air, which, when expired, he supposed to be loaded with that substance, and, consequently, that the main purpose of respiration is to discharge phlogiston from the blood.

Soon after these conclusions had been formed by Dr. Priestley, M. Lavoisier directed his efforts to ascertain, with as much precision as possible, the changes which the air undergoes in the process of respiration. In order to explain this function he framed a theory, which assumed, as its basis, that all the changes produced on the air inspired are produced in the lungs; and, of consequence, that all the new compounds and substances detected in the air expired, are formed in the lungs. It was a principle of this theory, that the blood absorbs no air in the lungs; but that it discharges hydrogen and carbon, which, combining with the oxygen of the air inspired, form water and carbonic acid. This theory was adopted by la Place, Crawford, Gren, and Girtanner, with some small modifications, which it is unnecessary here to particularise. Upon close inspection, it appears that this theory of Lavoisier does not materially differ from the original hypothesis of Dr. Priestley, *viz.* that the object of respiration is to free the blood of *phlogiston.* The difference consists chiefly in terms and in detail. For if carbon and hydrogen be substituted for phlogiston, which is often necessary in reconciling the statement of facts delivered by the *phlogistians* and *antiphlogistians,* the two theories will be found entirely to agree. M. Lavoisier did little to establish his theory by proof. He only attempted to prove that the amount of oxygen absorbed in respiration exactly corresponds with the quantity of it contained in the carbonic acid and the water emitted. But as this coincidence of quantities cannot be proved, his theory is unsupported, so far as the establishment of it depends upon such coincidence.

Afterwards, when a greater number of facts and illustrations of this subject had been collected, a different theory was offered by la Grange. According to him, the *oxygen* which disappears in respiration combines with the blood in its passage through the lungs, and at the moment of this combination there is set loose from the blood a quantity of carbonic acid gas and water in the form of vapour, which are thrown out with the air expired. This theory was adopted and illustrated by M. Hassenfratz, who succeeded in proving its superiority to that of Lavoisier and his associates. The establishment of this theory depended upon proving that the oxygenous portion of the atmosphere alone is absorbed from the inspired air. This was indeed the generally received opinion of chemical philosophers for some time; but as it has lately been brought into question, and the contrary asserted, it is proper to notice the variation of theory which has thence been attempted to be made.

Mr. Davy has endeavoured to prove that azote, as well as oxygen, is partly absorbed by the lungs in respiration. As the azote which disappears in breathing is not to be found in the products of respiration, it has been thence concluded that it is absorbed by the blood. The experiments of Mr. Davy led him to believe that atmospheric air is absorbed by the blood in an undecomposed and unaltered state; that it is afterwards decomposed in that fluid by the affinity of the red particles for its oxygen; that the greater part of the azote is liberated without undergoing any change, and again given out and mixed with the air in expiration; but that a minute portion of it remains condensed in the serum and coagulable lymph, and passes with them to the left ventricle of the heart. A minute examination and decision as to the correctness of these facts, will not be attempted in this place. But admitting the facts to be justly stated, the following changes will appear to be produced by respiration. The blood in passing through the lungs absorbs a portion of air, and carries it along with it through the blood vessels. In the course of the circulation, this air is gradually decomposed by the blood, the oxygen and part of the azote entering into new combinations, while at the same time a portion of azote, of carbonic acid and water, is evolved. On returning to the lungs, the blood receives a fresh quantity of air, and at the same time discharges the azotic gas, carbonic acid gas, and watery vapour which had been formed during the circulation. This theory of respiration by Mr. Davy is believed to be the latest of those deserving especial notice which belong to the eighteenth century*.

Beside the general theories of respiration which have been just stated, it will be proper to mention a few of the leading discoveries on this subject, and the authors to whom they respectively belong.

It was not till Dr. Priestley had discovered that venous blood acquires a scarlet colour when brought into contact with oxygen gas, and arterial blood a purplish red colour when put in contact with hydrogen gas; or, in other words, that oxygen gas instantly gives venous blood the colour of arterial, and that hydrogen, on the contrary, gives arterial blood the colour of venous;—it was not till the accomplishment of this discovery that philosophers began to attempt any explanation of the phenomena of respiration.

To Dr. Priestley likewise belongs the merit of that instructive experiment of enclosing blood in a bladder, and exhibiting the passage of oxygen

* *Researches Chemical and Philosophical*, by Humphry Davy, 8vo, 1800, p. 477, &c.

through its moistened coats, by the florid colour thence imparted to the blood, in order to demonstrate the mode in which oxygen finds its way through the coats of the blood-vessels in the lungs.

Dr. Goodwin was the author of the celebrated experiment, in which the action of the lungs is exhibited by opening the chest of a living dog, and exposing to view the motion of the lungs and heart. In this experiment, the blood driven from the right ventricle of the heart into the pulmonary artery appears of a dark venous complexion; but on its return from the lungs, by the pulmonary veins, it is changed to a bright vermilion colour. He also demonstrated that the bright florid appearance of the blood, derived from oxygen received in the lungs, is absolutely necessary to enable it to stimulate the left ventricle of the heart, in order to produce the contraction which propels the blood into the aorta. For whenever an intermission in the motion of the lungs denied the access of air, the blood in the pulmonary veins returning to the heart was of a dark purple colour, and was no longer sufficient to excite the due contraction of that organ.

That respiration is the source of the *temperature* of animals, or of what is commonly called *animal heat*, is one of the results of the light recently thrown on that function. Physiologists long ago observed that animals which do not breathe have a temperature little higher than the medium in which they live. This is the case with fishes and many insects. Man, quadrupeds, and birds, on the contrary, have a temperature considerably higher than the ordinary states of the atmosphere. It may be proved that the heat of all animals is proportional to the quantity of air they breathe in a given time. These circumstances are sufficient to establish the fact, that the heat of animals depends upon respiration. On this subject the philosophical world are under strong obligations to Dr. Black, whose doctrine of *latent heat* offered the first hints towards an explanation of the cause of temperature in breathing animals. It was observed, in a preceding chapter, that the discoveries of this eminent chemist place him in a high rank, and constitute much of the foundation of that chemical philosophy which is the boast of modern times, and the source of numberless improvements in the arts and sciences. He early perceived the light which his doctrine of latent heat was calculated to shed on the temperature of animals, and with great sagacity availed himself of the advantage.

Dr. Black formed the following theory of animal heat. He supposed part of the latent heat of the air received into the lungs to become sensible; that the temperature of that organ and of the blood passing through it is consequently raised; and that the blood thus heated communicates its temperature to the whole body. This opinion was plausible, but by no means free from objections; for, admitting the truth of it, the heat of the body ought to be highest in the lungs, and thence gradually to abate in proceeding to the extremities; which is not the fact. The author's attempts to support this theory were so feeble as to induce the belief that he himself considered it as untenable.

Lavoisier first announced, in 1777, that animal heat was owing to the caloric disengaged from oxygen gas during its decomposition and condensation in the lungs. Dr. Crawford, in 1779, adopted this opinion, and supported it by experiments. They both believed that all the changes produced by respiration are performed in the lungs; and their theory differs but little in reality from that of Dr. Black. They supposed the oxygen gas of the atmosphere to combine in the lungs with the hydrogen and carbon emitted by the blood; that, during this combination, the oxygen gas sets free a great quantity of caloric; and that this caloric is not only sufficient to maintain the temperature of the body, but also to carry off the new formed water in the state of vapour, as well as the carbonic acid, and to raise considerably the temperature of the air expired. According to the opinion, therefore, of these philosophers, the whole of the caloric which supports the heat of the body is extricated in the lungs. But on this hypothesis the question will arise, how it happens that the heat of each individual is maintained nearly the same in every part of his body? To explain this, Dr. Crawford endeavoured to prove, by well devised experiments, that the capacities for containing caloric in arterial and venous blood are nearly as 11.5 to 10; that is to say, if it require a quantity of caloric, represented by 11.5, to heat a pound of arterial blood from zero to 30°, it will only require a quantity as 10 to heat a pound of venous blood from zero to 30°.

On these experiments the following conclusions were formed. Oxygen gas is decomposed in the lungs in consequence of the affinity of the carbon and hydrogen of the blood for oxygen being greater than that of oxygen for caloric, or of the carbon and hydrogen for the blood. In proportion as the oxygen unites with the hydrogen and carbon, water and carbonic acid are formed; the caloric combines with the venous blood, which, in losing its carbon and hydrogen, becomes arterial, and has its capacity for containing caloric immediately augmented. The blood, now become arterial, in its circulation through the body, gradually absorbs carbon and hydrogen, repasses to the venous state, and sets free a portion of caloric in proportion as its capacity for containing it is diminished. According to this doctrine, therefore, the almost uniform temperature in all parts of the body is owing to the gradual and successive changes of arterial blood to venous throughout the body, and of venous to arterial in the lungs. It is also agreeable to this doctrine to suppose that the higher temperature of some parts of the body may be caused by arterial blood absorbing more carbon and hydrogen, or, in other words, becoming more rapidly venous.

However ingenious this explanation deserves to be regarded, it has not been deemed satisfactory. The difference in specific caloric, admitting the calculation to be accurate, is justly thought too small to account for the great quantity of heat which must be evolved. And if the opinion of some be true, that the carbonic acid gas and water emitted in expiration are not formed in the lungs, but during the circulation, this doctrine must be altogether untenable.

This defect in Dr. Crawford's hypothesis might perhaps be remedied, if Mr. Davy's supposition of air entering the blood and combining with it in the state of gas should be admitted. In this case it is evident that the air at first would only set free part of its caloric, and that the remainder must gradually escape in the successive stages of the circulation. In another mode, likewise, that defect has been attempted to be remedied. It has been alleged, that the evolution of caloric attends almost all chemical combinations; that all animal fluids which pass through capillary vessels and glands, for the purposes of secretion, are subjected to such new chemical combinations, as must incessantly give out heat; and that this glandular action thus accounts for the more general and copious source of animal temperature.

From the view of respiration now given, it results that the final causes of that function are these: 1. To complete the assimilation of the blood: 2. To produce and support animal heat: 3. To impart a quality to the circulating fluid which enables it to stimulate the left side of the heart.

After this account of respiration, which, from its great importance in the animal economy, has been treated of more at large than was at first intended, it is proper to proceed to the consideration of *Digestion.* This function in its full extent includes all the changes which aliment undergoes for the formation of chyle, whether such changes are effected in the mouth, stomach, or small intestines. But as it is the knowledge of the office of the stomach which has received the most important improvement within the period assigned for this retrospect, and as the other parts of the process, such as mastication, deglutition, the admixture of saliva, &c., were tolerably well understood before, it is obviously expedient to direct the chief attention to the former branch of the subject.

Galen supposed *heat* to be the principal cause of digestion, and this opinion so generally prevailed for a long time that the term *coction* was used by the greater part of physiologists instead of *digestion.* But, though the effect of heat in assisting and expediting digestion is universally admitted, no person will now contend that it is the sole cause.

During the eighteenth century, the theorists of digestion have ascribed it either, singly, to *fermentation, mechanical action,* or the *operation of a solvent* in the stomach; or to the combined effects of two or all of these agents.

Dr. Boerhaave, dissatisfied with the opinions of all who had gone before him on this subject, and leaning strongly to mechanical theory, admitted *fermentation* as one cause of digestion, but principally ascribed to it *trituration, pressure,* and powerful *quassation.* The analogy of digestion, as performed in certain birds, seems to have led him into this doctrine. He had observed the *ostrich* to swallow pieces of iron and glass, evidently for the purpose of trituration, because the sound of *grinding* was perceptible to those who listened. In the *granivorous birds* he had noticed, in addition to the crop furnished with salivary glands to macerate and soften their food, a gizzard, or second stomach, provided with strong muscles to triturate the grain, and the eagerness with which they swallow gravel to assist the operation. Considering the predominance of mathematical doctrines at that period, it is not wonderful that this great mechanic in medical science was desirous to explain digestion on mechanical principles.

Early in the eighteenth century Mr. Cheselden appears to have imbibed some correct notions on this subject. He remarked, that in serpents, some birds, and several kinds of fishes, digestion seemed to be performed by *some unknown menstruum;* as he frequently found in their stomachs animals so totally digested, *before their form was destroyed*, that their very *bones* were rendered soft.

About the same time M. Réaumur instituted a set of experiments concerning this function; and, by a number of clear and decisive facts, exhibited in his excellent memoirs on this subject, proved the existence and agency of a solvent in the stomach.

About the year 1777, the abbé Spallanzani, professor of natural history in the university of Pavia*, began, by his numerous experiments and diversified inquiries, to throw new light upon the function of digestion. Having directed his inquiries to a great number of animals, man, quadrupeds, birds, fishes, and amphibia, he was led to divide an extensive variety of stomachs, differing from one another in many important points of structure and functions, into three classes, the *muscular*, *intermediate*, and *membranous* †.

* The abbé Lazarus Spallanzani, of Italy, was born in the year 1729, and died in 1800. His researches and publications in several branches of natural history, especially in animal and vegetable physiology, place him among the most distinguished men of his age. On the subject of *Digestion*, he is, perhaps, the highest authority.

† *Dissertations relative to the Natural History of Animals and Vegetables*, vol. i.

Among such as have *muscular* stomachs, he particularly examined common fowls, turkeys, ducks, geese, pigeons, &c. In these, that organ is provided with very large and powerful muscles, capable of grinding down to powder the grains and other aliment which they receive. He proved by his experiments, that such muscular stomachs can pulverise pieces of glass, and abrade and smooth the rugged edges of the hardest substances, even of granite, without any injury to the animal. He resorted to experiments to illustrate the force of trituration in these stomachs, which a person of less ardour in this kind of investigation, and more tenderness for the animal creation, would certainly have spared. He caused a leaden ball, beset with needles fixed in it, with the points outwards, to be forced down the throat of a turkey. He contrived to make another swallow a ball of a still more formidable construction; for it was armed with small lancets, sharp at the points and edges, instead of needles: both balls were covered with paper to prevent the throat of the animal from being hurt as they descended, but fixed so loosely as to fall off in the stomach. The consequences proved the force and ruggedness of these muscular stomachs; the needles and lancets were broken to pieces and voided without wounding or injuring the animal.

But notwithstanding such proofs of the strength and activity of this kind of stomach, he ascertained that the solvent powers of a *gastric liquor* are combined even in these animals with the operation of gastric muscles to effect the process of digestion, and that they mutually assist each other.

Spallanzani's next experiments were directed to animals possessing what he called *intermediate* stomachs; such as are endowed with muscles less thick and strong than the former, but more so than the *membranous* stomachs. Among these he examined and made experiments upon the raven, the crow, the heron, and many other birds, which have this intermediate structure of the organ in question. It was found in these birds, as might be expected, that digestion is performed by a more equal combination, than in the former cases, of the forces of muscular action and a gastric menstruum secreted for the purpose.

These interesting experiments on digestion were finished with those animals which have thin *membranous* stomachs. This class comprehends an immense number of species, as man, quadrupeds, fishes, reptiles, &c. No triturating power is possessed by the stomachs of this description; for their muscular fibres seem to exert little other effect than that of propelling their contents through the pylorus. In proof of this is alleged the well known fact, that cherries and grapes are often received and voided entire from the human alimentary canal. The solvent power of the gastric liquor in these animals was found almost solely to effect the dissolution of food, after the preparatory treatment of mastication, and the admixture of saliva. To prove the efficacy of this powerful agent in the process of digestion, Spallanzani enclosed different kinds of animal and vegetable food in linen bags, and in wooden tubes, perforated in such a manner as to admit the entrance of the gastric juice; these he swallowed himself, and, after a short interval, the contents of them were found to be dissolved and discharged. He satisfied himself that no trituration could take place by employing tubes so thin and weak that the slightest pressure would have crushed them to pieces; yet not one was ever broken, nor could he ever perceive the smallest depression or fissure. Of the active solvent powers of this gastric fluid he gives many remarkable proofs. In a dog it not only dissolved bones, but was found to corrode the enamel of two *dentes incisores* taken from the jaw of a sheep. And, from some experiments on himself, he observed it to be sufficiently powerful to digest not only muscular fibres and membranes, but tendon, cartilage, and even bone itself, when not of the hardest kind.

The conclusions arising from these experiments of the professor of Pavia were, about the same time, confirmed and illustrated by others equally ingenious and interesting, undertaken by Dr. Edward Stevens*. He prevailed on a person to swallow little hollow spheres of silver, filled with food of different kinds; the sides of the spheres being perforated in various places, the gastric juice had access to, and, of course, could act upon their contents; and when voided, the food within them was found to be dissolved, either partially or entirely, according to the nature of it, and the time allowed for its remaining in the stomach.

* See his *Inaugural Dissertation*, published at Edinburgh, in the year 1777.

The celebrated Mr. John Hunter is to be always enumerated among those who have improved our knowledge on the subject of digestion. In addition to many other improvements, he endeavoured to solve the question, how the stomach itself can remain unhurt, while it encloses so penetrating and active a solvent as the gastric juice, seeing that it consists of materials similar to a large proportion of our food? He ascribes to the *living principle* in animals the power which the stomach possesses to resist that action of its gastric fluid which penetrates and dissolves the aliment. In confirmation of this, he observes that intestinal worms can remain a considerable time unhurt in the stomach, while they retain the principle of life; but as soon as they lose this, they are dissolved and digested, like other substances. In like manner he asserts, that while the stomach itself retains this living principle, the gastric fluid cannot exert its solvent powers on it; but when the person dies, particularly in cases of violent and sudden death, that fluid immediately begins to corrode it, and sometimes is found to have made its way entirely through the coats of the stomach into the cavity of the abdomen *.

It seems therefore to result, from all the most successful inquiries concerning digestion made during the eighteenth century, that this function is variously performed by *mechanical action*, or *chemical solution* in different animals, according to the structure of the stomach, and the nature of the gastric secretion; and that in man, and many

* *Phil. Trans.* vol. lxii, p. 447.

other tribes of animals which possess a similar organization of this viscus, it is effected by the solvent operation of the gastric fluid independently of trituration.

Beside the points in physiology already noticed, many others might be mentioned which have undoubtedly received much elucidation and improvement in the course of the late century. The senses of *Vision* and *Hearing*, which had previously derived a great deal of light from the endeavours used to investigate them, have been examined with still more minuteness and success within the last hundred years, and many new facts and principles concerning them have been satisfactorily ascertained. But the doctrines of *Secretion* and *Nutrition*, though so fundamental in a thorough acquaintance with the animal economy, notwithstanding all the diligence and ingenuity bestowed on them by a multitude of physiologists, have not been cultivated with equal success, and indeed can scarcely be said to be better understood at this time than they were at the close of the seventeenth century.

The celebrated doctrine of the *vitality of the blood,* which was first distinctly taught in modern times by Harvey, found a new and able advocate in Mr. John Hunter, who maintained, in his lectures, that the *fluids* as well as the *solids* were possessed of the principle of life. The arguments by which he endeavoured to support this doctrine are not only ingenious and forcible in themselves, but they derive additional strength from the theory of respiration, and the principles of pneumatic chemistry, which are now generally received.

Within the period assigned to this retrospect, the functions and laws of the *Nervous System* have been investigated with the greatest zeal. Willis, in the seventeenth century, had laid the foundation of this improvement, by his accurate description of the brain and nerves. Vieussens, in his *Neurographia*, pursued the subject with much discernment. Early in the eighteenth century Hoffmann still further prosecuted this inquiry; and, at a more advanced period of it, Dr. Cullen exerted all his powers in the same course. The use made by the two latter of the knowledge gained on this subject, in constructing their medical theories, will be mentioned more particularly under the succeeding head.

Comparative physiology has been cultivated with great ardour and success in the course of the century now under contemplation. Haller, though chiefly devoted to human physiology, did not neglect the instruction which may be derived from a comparative view of the functions of man and other animals. The Hunters, the Monroes, and most of the other distinguished anatomists of the late century, laboured in this field with the utmost zeal and assiduity. The great anatomical work planned by Vicq-d'-Azyr, that was mentioned under the preceding head, was principally designed to deduce a body of physiological principles, which, by comparison, might illustrate the functions of the whole animal kingdom. The numerous comparative inquiries concerning animals of warm and cold blood, and those which, in respect of the function of generation, are distinguished into viviparous and oviparous, have already thrown much new and important light on this branch of knowledge, and opened a train of investigation which hereafter will probably lead to still more interesting results. Mr. Blumenbach of Goettingen, whose physiological labours deserve very high praise, has greatly distinguished himself by his *Specimen Physiologiæ comparatæ inter Animantia calidi Sanguinis Vivipara et Ovipara**. The recent work of M. Cuvier, on comparative anatomy, furnishes an abundance of the materials requisite for the extension and the improvement of this part of science.

Within a few years the irritability of vegetables has attracted much of the attention of physiologists; and the interesting facts which it offers have been naturally combined with the great body of corresponding facts presented by the animal kingdom. Such general views penetrate deeply into the economy of nature; and the light they afford may be clearly discerned in an estimate of the progress and present state of medical opinions. To the account before given of the labours of Haller, in the former part of the century, to ascertain the fundamental laws of the animal economy, it would be improper not to add those lately undertaken for the same purpose by the abbé Fontana. By a series of experiments, in which accuracy and industry are eminently conspicuous, the abbé has proved, beyond the possibility of doubt, the existence of a principle in the animal fibre, independent of nervous energy, from which result, on the application of certain exciting powers, the various actions suited to the support of animal life. This principle, which with Haller he

* Vide *Comment. Soc. Reg. Scient. Gotting.* vol. ix.

denominates *irritability*, has been since proved by a great variety of facts to be susceptible of two remarkable changes in the living fibre, *viz.* increase and diminution, depending upon the abstraction or accumulation of stimulant powers. In support of this general principle, which is supposed universally to belong to animated nature, the aid of many facts, derived from the vegetable kingdom, has been recently added. As the functions of the animal economy, *viz.* sensation and voluntary motion, to which the nerves seem alone to be necessary, are never satisfactorily observed in the vegetable kingdom, it is presumed that the absence of nerves in this kingdom can in no degree diminish the analogy which is attempted to be established between these two grand divisions of created nature. It is contended by these physiologists, that there is a principle of action common to both kingdoms, upon which their respective functions chiefly depend, and which is believed to be governed by the same laws as are laid down for the regulation of the irritability of the animal fibre. By the term *irritability*, nothing more is here meant than merely to express a act; which fact is this, that certain parts of animals and vegetables are possessed of a property, by which, upon the application of a stimulus, the ends of a straight fibre approach nearer to each other, and the diameter or area of a curved or circular one is diminished.

For the facts respecting the functions of vegetables from which the above-mentioned principles have been drawn, the world is indebted, among many others, to Hales, Grew, Duhamel, Bonnet, Buffon, Spallanzani, des Fontaines, Gmelin, Ingenhousz, Hunter, Broussonet, Darwin, and many of the most distinguished disciples of the *Linnæan* school. And when the progress made by them in vegetable physiology is considered in relation to the discoveries obtained by Haller and Fontana in animal physiology, it will not appear surprising that inferences and doctrines of the greatest interest have recently been thence deduced. The physiological principles of Brown and Darwin, which now occupy the attention of so large a portion of the medical world, are conclusions resulting from that great body of facts. But of these more particular notice will be taken under the next head.

Theories of *Generation* have engaged much attention during the last century. Towards the close of the preceding one, Leuwenhoeck attracted notice by his microscopical inquiries concerning the *semen masculinum,* in which he believed that he saw numerous animalcula, one of which was destined to form the rudiments of the future embryo. This supposed discovery gave rise to a theory not yet altogether exploded, according to which the womb of the female only affords to the embryo a lodging, and the requisite supplies of nourishment.

M. Buffon endeavoured to prove that the female holds a more important share in the process of generation. He asserts that animalcula, or organic particles, are to be found in the semen of both sexes; and he derives that of the female from the ovaria, denying, at the same time, that any ovum exists in those parts. But in this he is commonly supposed to be mistaken.

The opinion more generally adopted within a few years is, that an impregnation of the ovum by the influence of the semen masculinum is essential to conception. The abbé Spallanzani has thrown much light on this obscure subject; he labours to prove, by a variety of experiments, that the animalcule exists entire in the female ovum, and that the male semen is only necessary to vivify and put it in motion.

This part of physiology furnishes one among numerous instances, in which modern improvements in science serve to support and confirm religious faith. It was mentioned, in the last chapter, that toward the close of the seventeenth century, the doctrine of *equivocal generation* began to be discarded by the ablest physiologists; still, however, it continued to find some advocates long after the beginning of the eighteenth. The *atheistical* tendency of this doctrine is obvious; for, if a single animal could be produced in this manner, what should prevent the universe from having come into existence without an intelligent author? Accordingly, this mode of accounting for the production of animals was, in general, fondly embraced by those who wished to exclude God from the creation and government of the world. But all the experiments and discoveries which were made on the subject of generation, in the course of the century under review, have served to discredit this doctrine; so that it is now considered, by the most eminent naturalists, as exploded. It is true, difficulties, or rather darkness and doubt, still exist, particularly with respect to the generation of one class of animals; but all modern experiments seem to concur with analogy in showing, that the doctrine in question is unphilosophical and untenable. Indeed it may be asserted that every successive step which has been taken in developing the structure and functions of the animal frame, and every new ray of light that has been shed upon this interesting subject, in modern times, have made more apparent the absurdity of atheism, and furnished new demonstration of the existence and wisdom of the Great First Cause.

SECTION III.

THEORY AND PRACTICE OF PHYSIC.

At the period of the revival of learning in the fifteenth century the medical system of Galen was restored, and began generally to prevail. Early in the sixteenth century the famous Paracelsus laid the foundation of a chemical system, which attracted much notice, and excited a violent contest with the followers of Galen. The efficacy of the remedies employed by Paracelsus and his disciples, and the bold and confident terms in which their virtues were extolled, procured, with many, the reception of his system, and for a long time supported its popularity and fame. But the regular and systematic physicians still generally maintained the doctrines of Galen, and, by their superior learning, were enabled to keep possession of the schools of physic till the middle of the seventeenth century.

About this time the discovery of the *circulation of the blood* began to be generally received, which, together with that of the *receptacle of the chyle*, and the *thoracic duct*, gave a heavy blow to the Galenic theory. In the destruction of this theory, the operation of the revolution in philosophy, effected by lord Bacon, deserves likewise to be particularly mentioned. His method of philosophising exhibited the futility of the numberless hypotheses which are found in the system of Galen, and excited a disposition to observe facts and make experiments.

At the beginning of the seventeenth century the contest between the Galenical and chemical physicians was carried on with the utmost animosity and indecorum. The influence of the writings of Galileo, aided by the discovery of the circulation of the blood, introduced mathematical reasoning into the doctrines of medicine. The progress made about this time in the knowledge of the organic structure of animals, which was greatly facilitated by an acquaintance with the circulation of the blood, had extended the application of mechanical philosophy in order to explain the phenomena of the animal economy. The agency of the nerves or moving powers of animals was at that time so little understood, that physicians universally, whether Galenists, chemists, or mathematicians, considered the state and condition of the fluids as the cause of diseases, and the medium of the operation of remedies. Hence arose the *Humoral Pathology*, which then predominated in every system of opinions, however diversified in other respects. While the followers of Galen were daily losing ground from the circumstances which have just been stated, the chemists gained some accession of strength from the doctrines of the humoral pathology. Chemical reasoning was readily adopted to explain the various acrimonies which were supposed to infest the circulating mass, and thereby to give origin to diseases. On this ground the use of stimulating, cordial, and sudorific remedies became fashionable throughout Europe in the latter half of the seventeenth century. This doctrine, which exhibits the last glimmering of the chemical sect, attained its utmost height, and was taught and practised with the greatest applause, by the celebrated Francis du Bois, more known by his Latin name of Sylvius, professor of medicine in the university of Leyden, who continued for many years the medical oracle of Europe, and gave an eminent degree of *éclat* to the seminary to which he belonged. With this physician *acidity* formed the principal source of morbid affections; and he extended and supported his doctrine by every analogy that the learning of that period and the utmost ingenuity could devise. Agents adapted to correct or expel this acrimony were exalted into universal remedies, and supplied every intention of cure.

To oppose the *cardiac* and *alexipharmic* doctrines of the *Sylvian* school, which often consisted in doing violence to nature, and could not fail, when carried to extremes, of increasing the mischiefs it was intended to remove, required the powers of a great and original mind. For this purpose the illustrious Sydenham was eminently suited. The sagacity of this physician led him, by an almost seeming intuition, to discern and obey the dictates of nature, and to afford every proper assistance without urging her to useless and hazardous efforts. The effects of this revolution were immediately seen in the improved treatment of acute diseases of every class, when, instead of the fashionable alexipharmic remedies, intended to promote imaginary depurations, by additional heat and increased stimulus, a safer *antiphlogistic* or cooling plan was adopted, with a view to unload the oppressed habit, to reduce excessive action, and to preserve the strength of the system for the subsequent conflict.

Towards the close of the seventeenth century, the application of mathematical reasoning to medical theory had attained its greatest height. The mathematicians were alike hostile to the Galenists and chemists. With equal aversion they discarded the *qualities*, *elements*, *temperaments*, *concoctions*, and *crises* of the Galenist; and the *Archæus* of Van Helmont, the *salts*, the *sulphur*, the *mercury*, the *acids*, *alkalies*, *effervescences*, *fermentations*, *ebullitions*, and *deflagrations* of the chemist. Instead of such objects as these, the mathematical pathologists endeavoured to direct the public attention to *mechanical tension* and *relaxation*, to *true* and *spurious plethora*, to *obstruction* and *error loci*, to *excessive* or *deficient motion of the fluids*, and to their *lentor*, *tenuity*, or *dissolution*. Flushed with their success in astronomical inquiries, and with their dominion over the globe we inhabit, the mathematicians confidently imagined they should find no difficulty in subjecting the province of medicine to their extensive empire. The chemists of that day had little to urge against the claims of these invaders. Their loose, visionary, and capricious doctrines (for such was undoubtedly much of the chemistry of that period) could make no successful opposition to the *axioms*, *postulates*, *propositions*, *lemmas*, *problems*, *theorems*, *demonstrations*, *corollaries*, and *calculations*, with which the mathematicians were constantly armed when they entered into controversy. Bellini, of Florence, as was formerly observed, was among the first medical writers who introduced mechanical reasoning; and soon afterwards the application of it was extended still further by professor Borelli, who prosecuted the subject with great learning and zeal. The laborious calculations made by these mathematicians of the force exerted by the heart in propelling the blood*, and by the stomach in the digestion of food, are signal examples of the delusion which then occupied the most respectable minds. But no person at this period seems to have proceeded farther in this course than the celebrated Dr. Pitcairn, who, during some of the last years of the seventeenth century, held a medical professorship in the university of Leyden. He flattered himself that medical principles might be supported by a clear train of mathematical reasoning, which would defy the attacks of the sophist, and which would be exempt from the fluctuations of opinion and prejudice. His works are full of postulates, data, and demonstrations. And, after a long parade of geometrical forms, he supposes himself to have arrived at the *ne plus ultra* of the science of medicine†.

* Borelli believed that he made it clearly to appear, that the force of the heart is equal to 180000 *pounds* weight; while Dr. Keil's calculation reduces the power of the left ventricle to *five ounces*.

† Pictairn concludes his chapter, *De divisione Morborum*, thus triumphantly: "*Quapropter non dubito me solvisse nobile problema, quod est, dato morbo, invenire remedium. Jamque opus exegi.*" Vide *Elementa Medicinæ Physico-Mathematica*, p. 177. The annals of science can scarcely furnish a more striking example of the delusion of enthusiasm, or the blindness of prejudice.

The mechanic theory of medicine is now so obsolete that even the most illiterate affect to smile at the absurdities of that kind, which were often uttered by learned men. But it should be remembered, that, amidst all its extravagance, it was an important step towards improvement; and it will certainly be rescued from contempt by the recollection that it was once honoured with the great names of Borelli, Boerhaave, and Newton.

The Italian and Dutch schools, though hurried into wild extremes by the rage of mathematical reasoning which then prevailed, possessed an unrivalled celebrity at the end of the seventeenth century. The history of medicine at that period particularly dwells on the merits and services of many of their physicians, and abundantly justifies their claim to distinction.

Thus stood the theory of medicine at the beginning of the eighteenth century. At that auspicious period, every part of science began to assume a more correct and improved aspect; and, from the vast and diversified labours of the preceding age, it had become more practicable to select and combine the materials necessary to construct the theories of medicine which were speedily to appear. Accordingly, very early in the century three new and considerably different systems were presented to the world in the writings of Stahl, Hoffmann, and Boerhaave. And they are the more worthy of examination at the present time, as they not only engrossed the attention of physicians during a great part of the century, but as even now they are not without influence upon principles and practice.

Notwithstanding the seniority of Stahl and Hoffmann by a few years, they were, as theorists of medicine, strictly the contemporaries of Boerhaave. It is judged expedient to begin with the latter in this place, not only on account of the great importance and celebrity of his system, but because his doctrines held a closer alliance with the predominant philosophy of that period, and those of the two others with the succeeding theories.

Hermann Boerhaave began his career as a teacher and a writer about the commencement of the eighteenth century. In all respects he deserves to be considered as one of the greatest men that ever adorned the medical profession. He possessed a vast range of erudition, and had cultivated the auxiliary branches of medicine with such assiduity, that he particularly excelled in anatomy, chemistry, and botany. No physician, since Galen, has so authoritatively swayed the empire of opinion, nor been more universally obeyed in the schools of physic. Endowed by nature with a powerful, logical, and systematic mind, he seemed to be designed to clear away the rubbish of errour and prejudice, with which he found medical learning overgrown; to collect knowledge from every source; and to present it to the world embodied in that clear, consistent, elegant, and luminous state of arrangement, which constitutes him the parent of medical theory *.

* This great man was born at a village near Leyden, in the year 1668, and died in 1738. The space which he filled in the scientific world, for upwards of forty years, was so great, that no one acquainted with the history of the period in which he lived is ignorant of his immense learning, his singular talents, or his numerous and inestimable works. His moral and religious character is as worthy of commemoration as his intellectual endowments,

In framing his system of physic, Boerhaave seems diligently to have studied the writings of both ancient and modern physicians, from Hippocrates down to Sydenham. Though extremely partial to the mechanical principles of Bellini and Pictairn, he appears to have endeavoured, as much as possible, to divest himself of prejudice in favour of former systems, and to make a candid and genuine selection of truth from every source. Beside availing himself of the experience of Hippocrates, and other observers of nature in every age, he drew many of his doctrines from the chemical as well as mathematical philosophy of the period in which he lived.

Boerhaave's *Institutes*, which is his *theoretical* work, contain all the discoveries in anatomy and physiology known at that time; and that system likewise of pathology and therapeutics which he thought proper to adopt. His *Aphorisms*, or *prac-*

" Some, though few," (says his great disciple Haller) "will rival him in erudition; his divine temper, kind to all, beneficent to foes and adversaries, detracting from no man's merits, and binding by favours his daily opponents, may perhaps never be paralleled." He was at once a practical philosopher and an eminent Christian. No one was ever less moved by the attacks of envy and malice; no one ever bore with more firmness and resignation the evils of life. Simplicity was the characteristic of his manners. He was easy and familiar in his converse; perfectly free from parade of every kind; grave and sober in demeanour, and yet disposed to pleasantry, and occasionally indulging in good-humoured raillery. He was almost adored by his pupils, whose interests he regarded with the kindness of a parent, and whom, when sick, he attended preferably to any other patients. Piety of the most amiable cast was wrought in the very habit of his soul; the perusal of the scriptures was one of his habitual and stated employments; and the business of every day was preceded by the devotional exercises of the closet.— *General Biography* by John Aikin, M. D. and others, vol. ii.

tical work, with all their imperfections, contain perhaps more medical learning than any book extant of the same size.

The most prominent feature in the *Boerhaavian* system is the attempt to explain the phenomena of the animal economy, whether in health or disease, upon mechanical principles. Under the impression of such opinions he considered the body chiefly as an hydraulic machine, composed of a conic, elastic, inflected canal, divided into similar less canals, all proceeding fron the same trunk; which, being at last collected into a retiform contexture, mutually open into each other, and send off two orders of vessels, lymphatics and veins, the former terminating in different cavities, the latter in the heart; that these tubes are destined for the conveyance of the animal fluids, in the circulation of which he supposed life to consist, and on the free and undisturbed motion of which he judged health to depend. He therefore believed *obstruction* to be the proximate cause of most diseases; and this obstruction he supposed to be produced either by a constriction of the vessels, or by a *lentor* in the blood.

In Boerhaave's doctrine of *obstruction*, which is fundamental in his system, he makes an important use of Leuwenhoeck's supposed discoveries concerning the blood. That eminent microscopical investigator had imagined that he found each globule of red blood composed of six serous globules, the serous of six lymphatic globules, the lymphatic of six other globules still finer, and so on in a similar progression till these particles were diminished down to the finest and most subtile of all, namely, the nervous fluid. According to Boerhaave's opinion, the diameters of the vessels also decreased in the same regular series, perfectly corresponding with the size of the globules. This explains his frequent introduction of *error loci* in his account of obstruction and inflammation. But as the notions of Leuwenhoeck on this subject are now generally exploded, so likewise must be the inferences and doctrines grounded upon them.

It was taken for granted by Boerhaave and by almost all preceding medical writers, that diseases always arise either from some depravity of the fluids, or some fault in the composition or cohesion of the simple solids; and that wherever such disorders exist, they are always susceptible of a definite character, and placed within the reach of the senses. He believed the fluids to be liable to contamination by acid and alkaline acrimony, and by other morbific matters variously constituted, and to be disordered by lentor and excessive tenuity. The simple solid, according to his doctrine, is subject to very frequent changes of condition, from weakness and excessive stiffness or elasticity, and from laxity and rigidity.

Boerhaave supposed the *proximate cause of fever* to consist in a lentor or viscidity prevailing in the mass of blood, and stagnating in the extreme vessels. To this he attributed the cold stage of fevers, and all its consequences. It is true that he afterwards introduced, though with some doubt and hesitation, as an additional part of the proximate cause, an *inertia* of that portion of the nervous fluid which is destined to the heart. It was one of his positions, that the morbid heat in fever, being a symptom only, might therefore be disregarded.

His doctrines of *acid* and *alkaline acrimony*, of *fermentation*, and of *morbific matter* in the blood, were evidently derived from the chemical theories which then prevailed. And from the mechanical philosophy he borrowed his opinions concerning the diseases of the simple solid; concerning deficient or excessive circulatory motion; concerning obstruction and *error loci**; and concerning the *lentor* and morbid tenuity of the fluids.

The objections which have been made to this system are numerous and important. Though it was exhibited by the illustrious author in a very attractive and elegant form, and long possessed an unrivalled degree of reputation, yet it appears that time and the great mass of improvements since made in every department of medical knowledge have effected its entire overthrow.

The leading defects in the Boerhaavian system are too close an adherence to the humoral pathology, and a constant neglect of the moving powers of the animal body. In his notions of various acrimonies, and of lentor, he yielded almost entirely to a hypothetical mode of reasoning. In his consideration of the diseases of the solids, he dwelt too much on the changes of the simple inanimate solid, and too little on those of the living or vital solid. Most of the faults, however, of his theory are chargeable rather on the time in which he lived, and on the general imperfection of knowledge at that period, compared with the present, than on any defects in himself. It is surprising that he considered his system as having advanced so near to perfection; for,

* By this phrase is meant the entrance of particles of the blood into vessels the capacity of which is too small to transmit them.

though he lived almost forty years after he had formed it, he seems to have made in all that time but few corrections or additions which can be thought to be of any moment.

The next medical theorist whose system demands notice is George Ernest Stahl, professor of medicine at Halle, in Saxony, who was so illustriously distinguished for his improvements in chemistry, mentioned in a former part of this work. For a long time his was the prevailing system in Germany; and the traces of it may be discerned in many modern writings, which still maintain a high degree of authority.

The fundamental principle of this system is, that the *rational soul* of man presides over and governs the whole economy of his body both in health and sickness. In all ages physicians have supposed the existence of a power or faculty in the animal economy, by which it is enabled to resist injuries, and to correct and remove the diseases to which it is exposed. This power by many of the ancients was vaguely termed *nature*, and, under the denomination of *vis conservatrix et medicatrix naturæ*, has been long celebrated in the schools of medicine.

Stahl explicitly founds his system on the principle that this *power of nature*, so much spoken of, is nothing else than a faculty of the rational soul *. On

* It appears that physicians are by no means unanimous in their mode of understanding the *Stahlian* theory. In proof of this the following quotation is offered from a writer of high reputation. "Stahl has been reproached for having ascribed too much to the soul; but they who have done this, either have never read his works, or did not understand them. The soul, according to Stahl, is a being purely material; or rather he admitted no soul,

many occasions he imagines the soul to act independently of the state of the body; and that, without any physical necessity arising from a particular state, the soul, merely in consequence of its intelligence, perceiving the application of noxious powers, or the approach of disease from any cause, immediately excites such motions in the body as are suited to obviate the hurtful or pernicious effects which might otherwise take place. He sometimes mentions two opposite principles or propensities in the human frame; one constantly and uniformly tending to corruption and decay, the other to life and health; the former founded on the elementary composition of the body, the latter depending immediately on the energy of the mind or soul. By means of the nerves, the influence of the soul is extended to every part of the system; and if their action be impeded or deranged, disease is the unavoidable consequence. A plethora and lentor of the blood are therefore the proximate causes of disease, as the energy of the mind is thereby diminished, and its action on the body obstructed. Hence, to lessen the quantity, and to break down the *lentor* of the blood, the soul exerts all its powers, and excites hæmorrhages, sweats, diarrhœas, fevers, and the like. These efforts are sometimes happy and successful; at other times they fail to answer the purpose, and may occasionally even do mischief, especially when opposed by the improper interference of physicians, or by some internal, accidental, or organic, impediment.

only the vital principle of an organised body." Zimmermann on *Experience*, vol. i, p. 98.

Such is the theory of health and disease which Stahl delivered to his pupils and readers, and which he endeavoured to recommend and support by all his great powers of learning and ingenuity. But, in his ponderous volume on this subject, entitled *Theoria Medica Vera*, we look in vain for the logical arrangement, the elegance and perspicuity, which are constantly displayed in the writings of Boerhaave. There were not wanting, however, in various parts of Europe, especially in Germany, many followers of Stahl, who thoroughly imbibed his principles, and pursued his practice in the treatment of diseases. Among these, Juncker and Carl, particularly the former, in his work entitled *Conspectus Therapeiæ Specialis*, have given a much better account of the doctrines and opinions of their preceptor than himself.

To many the *Stahlian* theory appears so fanciful and absurd, that they can scarcely think it deserving of a serious refutation. But still, it has been often thought there are such appearances of intelligence and design in the operations of the animal economy, that many eminent physicians have been induced to countenance similar opinions. Among these may be mentioned Nichols and Mead, in England; Porterfield and Simson, in Scotland; Gaubius *, in Holland; and perhaps Whytt, of the university of Edinburgh †.

* Doubts have been suggested whether Gaubius was really a follower of Stahl. Dr. Haller represents him as *cautus vir, et in recipiendis opinionibus difficilis*. He is said, at any rate, never to have openly avowed his adherence to the *Stahlian* system.

† Among those who embraced either the whole or a part of the Stahlian doctrine, Paul Joseph Barthez is entitled to respectful no-

Of the writers who adopt the opinions of Stahl, in a greater or less degree, Nichols and Gaubius may be considered as two of those who deserve the highest consideration *. The consequences result-

tice. His work *De Principio Vitali Hominis*, published in 1773, and his *Nova Doctrina de Functionibus Naturæ Humanæ*, published in 1774, both deserve to be commended as indications of acuteness and ingenuity.

* In an elegant prelection by Dr. Nichols, which he published under the title of *Oratio de Anima Medica*, we find the following visionary excesses of *Stahlianism*. According to him, the soul at first forms the body, and governs it ever afterwards. He ascribes it to the prudence of the soul, that the *semen* is not perfected in males, till the strength and vigour of the system are prepared for generation, and he sees her sagacity in the slow and gradual eruption of the small-pox, thereby dividing the force of the disease and greatly lessening the danger. After violent pain or exhaustion by fatigue, the soul hides herself in sleep, in order to recruit the body or to rectify any disorder; hence the inclination to sleep after child-birth; hence also the frequent sleeping of infants, whose *anima* is so engrossed with attention to the vital motions as to mind little else. When too much distracted and perplexed with external things, she often neglects her internal duties; and hence health is so much impaired by fear, grief, love, and other violent passions. He also accuses the soul of occasional fits of caprice and ill-humour, by which she is led to disregard her office, and indulge herself in freaks of petulance and perverseness. In fevers, the sudden failing of the strength and pulse ought to be regarded, he tells us, as signs of the soul's abandoning the body in despair, and intending soon to relinquish it. Nay, he sometimes imputes to her cowardice and folly in suffering the body to sink under diseases by no means deadly in their own nature; in falling into undue alarm and trepidation, thereby becoming unfit to discharge her office, and being often precipitated into mischief and injury; and in deserting her post in a moment of peril, when, were she always wise enough to neglect things of inferior moment, and to attend solely to the preservation of the body, she might not only prevent diseases, so far at least as they proceed from internal causes, but might protract the life of man to an indefinite period, it may be to a thousand years!—Vide *Oratio de Anima Medica*, passim.

ing from such doctrines may be discovered from what appears in their writings. If it be thought proper to admit such a capricious government of the animal economy as these writers in some instances maintain, it will follow that a rejection of all the physical and mechanical reasoning which is employed concerning the human body must take place.

Nor are the consequences of such doctrines confined to reasoning and speculation. It appears that Stahl and his followers, in the whole of their practice, whatever may have been asserted to the contrary, were very much governed by their general principles. Trusting to the wisdom and constant attention of nature, they proposed the *art of curing diseases by expectation.* As practitioners, therefore, they seem to have been cautious, indecisive, and timid, in the extreme; they adopted, for the most part, only very feeble, inert, and frivolous remedies; and they strenuously opposed the use of some of those which are most efficacious and the most deserving of confidence.

It would be doing injustice, however, to the *Stahlian* practitioners not to acknowledge that they greatly enriched medical science by their incessant and unwearied observation of the history and phenomena of diseases, and were instrumental in directing the attention of physicians to those salutary efforts of nature, which cannot be too accurately understood, or too diligently pursued in the treatment of diseases.

Frederick Hoffmann is the last of the three illustrious systematists whose different theories of medicine were disclosed to the world in the beginning of the eighteenth century*. He was the colleague and rival of Stahl in the university of Halle, and a most learned and voluminous writer. For more than fifty years he flourished as a practitioner and author, enjoyed a splendid reputation, and added greatly to the mass of medical science.

Hoffmann had the discernment early to perceive the errour of those who suffered themselves to be led away by the hypothetical doctrines of the *humoral pathology*, and the other wild opinions then prevailing among the chemical and mechanical theorists. He set himself to cultivate and improve what Boerhaave had neglected. He diligently undertook to explore the functions and diseases of the *nervous system*, and wisely concluded that noxious causes much more generally affect the *solid moving powers* than the *fluids* of the animal body. He admitted indeed into his system some portion of the mechanical, Cartesian, and chemical doctrines which had previously prevailed; but these did not blind him to the light which he derived from the pathology of the nervous system. According to him, *atony* and *spasm* are the great sources of disease; and he proceeded so far as to maintain that all in-

* Frederick Hoffmann was born at Magdeburg in the year 1660. The principal circumstances much known in the life of this illustrious physician are, that he travelled into England and Holland, where he became acquainted with Robert Boyle and Paul Hermann; that he never received any professional fees, being supported by his annual stipend; that he cured the emperor Charles VI, and Frederick I king of Prussia, of inveterate diseases; and that he had a very accurate and extensive knowledge, for that day, of the nature and virtues of mineral waters. Hoffmann survived his 80th year; and his works were printed at Geneva, in six volumes folio, in 1740.

ternal disorders are to be ascribed to some preternatural affection of the living solid *.

Hoffmann's pathology of fever deservedly excited great attention. Though he undertook, like many of his predecessors, to inquire into the intentions of nature, he certainly contemplated her process in fever with more sagacity; and, rejecting chemical and mechanical analogies on this subject, endeavoured to discover the cause of fever in the peculiar nature and affections of the vital motions. He supposed the noxious cause producing fever (in the language of the schools, the remote cause) to operate first on the living solids, producing a general spasm of the nervous and fibrous system, beginning in the external parts, and proceeding towards the centre. In consequence of this, a contraction of the vessels of the extremities must of course take place, impelling the circulating fluids in an increased ratio on the heart and lungs; which stimulating these organs to increased action, the fluids are thereby repelled towards the extremities, and thus the phenomena of fever are produced. There are, therefore, according to Hoffmann, two distinct sets of motions in fever; the first, from the extremities towards the centre, arising immediately from the spasm, and accompanied by a small pulse, anxiety, and oppression; the second, from the centre towards the surface, which is the effort of nature to resolve the spasm, and indicated by a full strong pulse and increased heat. The first of these sets of motions is baneful, and some-

* Vide Fred. Hoffmann. *Opera Omnia Physico-Medica*, vol. i, *Med. Rat. System.* tom. iii, § 1, cap. iv, p. 308. Geneva edition.

times fatal; the second is medicinal and salutary. By these views of the nature of fever, he supposes, the physician ought to be directed in counteracting the morbid actions, and in assisting the sanative process of nature*.

The general pathological doctrines of Hoffmann undoubtedly contain a great deal of truth, and form a distinguished æra in the history of medical theory. Though his opinions on the subject of fever, however improved by a succeeding theorist, must be supposed to be rapidly falling into disrepute; still they evince deep and just views of the animal economy, and much observation of the nature and phenomena of diseases.

The originality of Hoffmann's scheme of pathology has been brought into question; and nobody can doubt that he received many important hints from preceding writers. Van Helmont seems to have been the first who turned his attention to the nervous system with any discernment. Some, indeed, have gone so far as to pronounce him the author of the *spasmodic theory of fever;* but whatever intimations he may be supposed to have given of febrile spasm in different parts of his huge indigested work, they are surely too crude and indistinct to be considered in the light of a theory of fever. Dr. Willis, in the latter part of the seventeenth century, had also laid some foundation for this doctrine, in his *Pathologia Cerebri et Nervorum;* and Baglivi, in the beginning of the eighteenth, had improved it still further in his *Specimen de Fibra Motrici et Morbosa*†.

* Hoffmann. *Op. Omn.* vol. i, tom. ii, p. 10.

† Dr. Ferriar of Manchester, in the preface to his *Medical Histories and Reflections,* makes the following remark: "The asser-

The theory of diseases last stated formed the ground-work of a system which was adopted and taught for many years, with great celebrity, by the learned Dr. Cullen of Edinburgh*. He assumed the general principle of Hoffmann, that the phenomena of health and disease can only be explained by referring them to the state and affections of the primary moving powers of the animal economy. He endeavoured to extend the application and uses of this principle as far as possible, and for this purpose he expunged certain hypothetical doctrines of the humoral pathology which Hoffmann had suffered to remain; and to depreciate the value of his system.

According to the hypothesis embraced by Dr. Cullen, the *brain*, with all its ramifications and dependencies combined to form the nervous system, is the primary organ of the human body, the different conditions of which constitute the various states of health and disease. In pursuance of this hypothesis, the circulation of the blood, instead of being the principal of the vital functions, as in the Boer-

tion of a spasmodic state of the extreme vessels in the cold stage of fevers, commonly ascribed to Dr. Hoffmann, was first made by Dr. Piens, in his comprehensive treatise *De Febre*."

* Dr. William Cullen was born in Lanarkshire, in the west of Scotland, December 11, 1712. He was chosen one of the medical professors in the university of Edinburgh in 1756, and died in that city in 1790, in the 77th year of his age. The various publications of this distinguished physician are so well known, that it is unnecessary to dwell on their merits. Of these, his *Nosologia Methodica*, his *First Lines of the Practice of Physic*, and his *Materia Medica*, are the most valuable.—See an eloquent and interesting *Eulogium upon Dr. Cullen*, pronounced before the College of Physicians of Philadelphia, by Dr. Rush, 8vo, 1790.

haavian doctrine, occupies only a secondary degree of importance in the animal economy. Dr. Cullen supposed it to be evident that the nervous power, in the whole as well as in the several parts of the nervous system, and particularly in the brain, which unites the several parts, and forms them into a whole, is at different times in different degrees of mobility and force. To these different states he applies the terms of *excitement* and *collapse*. To that state in which the mobility and force are sufficient for the ordinary exercise of the functions, or where these states are any way preternaturally increased, he gives the name of *excitement;* and to that state in which the mobility and force are not sufficient for the ordinary exercise of the functions, or when they are diminished from the state in which they had been before, he gives the name of *collapse**.

Dr. Cullen's opinions concerning the nature of fever have excited much attention and controversy in the medical world. He delivers an account of them in the following words: "Upon the whole, our doctrine of fever is explicitly this. The remote causes are certain sedative powers applied to the nervous system, which, diminishing the energy of the brain, thereby produce a debility in the whole of the functions, and particularly in the action of the extreme vessels. Such, however, is, at the same time, the nature of the animal economy, that this debility proves an indirect stimulus to the sanguiferous system; whence, by the intervention of the cold stage, and spasm connected with it, the

* See his *Institutes of Medicine,* § 126 to 135

action of the heart and larger arteries is increased, and continues so till it has had the effect of restoring the energy of the brain, of extending this energy to the extreme vessels, of restoring therefore their action, and thereby especially overcoming the spasm affecting them; upon the removing of which, the excretion of sweat, and other marks of the relaxation of excretories, take place*."

As Hoffmann's theory of fever evidently produced that of Cullen, it is proper to ascertain the points of variance between them. According to Hoffmann, the first effect of the remote cause of fever is the spasm, producing a reaction, as has already been stated in the account given of his doctrine. Cullen introduced a previous link into the chain of effects: he contended that the first effect of the noxious power (the remote cause) was a general debility, consisting in a diminution of the energy of the brain. To this debility he attributes the spasm, and to the spasm the reaction of the heart and arteries; which reaction continuing till the spasm is resolved, removes the debility and the disease. According to Hoffmann, the spasm belongs to the class of motions which he pronounces to be baneful; but Cullen presumes it to be salutary, and therefore ascribes it, in the language of the schools, to the *vis medicatrix naturæ*.

Dr. Cullen's theory of fever was received with great applause, and, for a considerable time, maintained its ascendancy, especially in the British dominions and in the United States. Few, however, at the present day, seem to consider it as tenable.

* *First Lines of the Practice of Physic*, vol. i, p. 55.

The author has not undertaken to explain in what manner the debility in the whole of the functions proves an indirect stimulus to the sanguiferous system; nor how this stimulus operates in exciting the cold stage and spasm. The coexistence of atony and spasm in the same vessels is regarded by many as an insuperable difficulty. No explanation is offered of the mode in which the action of the heart and larger arteries is augmented by the intervention of the cold stage and spasm. The process by which this augmentation restores the energy of the brain, and extends such energy to the extreme vessels, is also left entirely in the dark. His introduction of the *vis medicatrix naturæ* is liable to almost all the objections of the *anima medica* of Stahl, and must be considered as no better than a confession of ignorance. In all these respects, and many others, this celebrated doctrine rests on hypothetical ground. This will appear the more surprising, as the learned author professed to disclaim all those hypothetical opinions which go to the formation of theories; and seems to have been persuaded that his doctrine of fever was only an induction from a generalisation of facts.

It would be injustice, however, to Dr. Cullen, not to subjoin that his merits are extensive and universally acknowledged. He was a diligent and faithful collector of facts. His works often contain admirable descriptions and sagacious discriminations of diseases. His great excellence seems to have consisted in methodical arrangement. But it is commonly remarked, and apparently with truth, that he was much more successful in demolishing the systems of others than in erecting his own.

The next system which demands attention, in the order of time, is that of Dr. John Brown of Edinburgh*. This original, eccentric, unfortunate man framed a physiological and pathological theory, which, amidst great errours, inconsistencies, and contradictions, contains many vigorous conceptions of truth and nature, and some which it is probable the improvements of future times will serve much further to elucidate and confirm.

Brown assumed, as the foundation of his system, the existence of an unknown principle, on which, when acted upon by stimuli, all the phenomena of life, health, and disease, depend, and which he denominated *excitability*. This excitability he believed to vary in different animals, and in the same animal at different times. As it is more intense, the animal is more susceptible of the action of exciting powers. Exciting powers, or stimuli, may be referred to two classes; either external, as heat, food, wine, poisons, contagions, the blood, secreted fluids, and air; or internal, such as the functions of the body itself, muscular motion, thought, emotion, and passion. Excitability produces no effect, or

* Dr. John Brown was born in the village of Dunse, in Scotland, in the year 1735. His parents were in very humble life; and through his whole career he maintained a struggle with poverty. He began to teach medicine by public lectures in Edinburgh, about the year 1777: he removed to London in 1786, where he died in 1788, in the 53d year of his age. He was undoubtedly a man of great and original genius, and of considerable acquirements, but the unfortunate victim of folly and intemperance. His *Elementa Medicinæ* were first published by him in Latin, and afterwards translated by the author into English.

rather does not exist, unless exciting powers are applied; for, if they be entirely withdrawn, death as certainly ensues as when excitability is consumed by the excessive application of them; life is therefore a *forced state.* Excitement may be in just measure, or too great, or too small. Stimuli applied in due proportion produce that just degree of excitement which constitutes the state of health. If the stimuli be diminished below the healthy proportion, he supposed the excitability to accumulate; if increased beyond this proportion, to be expended; and on these opposite states he attempted to found a theory of diseases, denominating the former *direct*, the latter *indirect debility.* Diseases he divided into two classes, *sthenic* and *asthenic*, or such as arise from increased and from diminished excitement. He believed no agent on the living body could properly receive the title of *sedative;* and insisted that every power that acts on such a body is stimulant, or produces excitement by expending excitability. Whatever powers therefore may be employed, and however they may vary from such as are habitually applied to produce due excitement, they can only weaken the system by urging it into too much motion, or suffering it to sink into languor. He is supposed to have included both the nervous and muscular powers under the term of excitability; yet he did not consider the excitability as a property residing in and depending upon the mechanism of particular parts, but as a uniform undivided property, pervading the whole system, which cannot be affected in any one part without being affected in a similar manner in every other.

Dr. Brown supposes the proximate cause of fever to consist in debility, which may be either direct or indirect, according to the nature of the noxious powers previously applied to the system. Hence he makes two divisions of fevers: 1st. Those which depend on direct debility, such as intermittent fevers, typhus, &c. 2d. Those which depend on indirect debility, such as malignant fever, confluent small-pox, plague, &c. Having therefore assigned to fever its place in his series of descending excitement, he neglected particularly to inquire into its symptoms, or to enlarge on its treatment. Thus debility, which was the first link in the chain of Dr. Cullen, formed, according to the theory of Dr. Brown, the essence of fever. He altogether denied the existence of spasm; he ridiculed reaction and the *vis medicatrix naturæ;* and he wholly overlooked the phenomena of morbid association and morbid heat.

In a word, the basis of Dr. Brown's system seems to be this; in every state of the body, except that of perfect health, there always exists either too strong or too weak an excitement. Hence there can be only two species of disease, two methods of treatment, and two kinds of medicinal agents.

In framing his system, Brown seems to have combined the *irritability* and *sensibility* of Haller to form his *excitability;* and to that eminent physiologist he was probably more indebted for the first hints of his doctrine, and especially for the facts on which it is founded, than to any preceding writer. His general principles are supposed more correctly to suit the condition of the animal economy in health than in disease. The fundamental position, that excitability is accumulated and expended in the inverse ratio of the stimulation, appears to be confirmed by many facts concerning the application of heat and the taking in of food, during the healthy states of the body, or when it is only affected by cold or hunger. Whether it equally hold good in the state of disease is more liable to doubt. He was acquainted with only one mode of action of the living principle, that which has been described by a succeeding theorist under the name of irritation; while he was wholly regardless of the influence of sensation, volition, and association. He neglected, or was ignorant of most of the important relations which the doctrines of modern chemistry bear to the animal economy, and to the composition of animal matter. These, however, comprise only a small portion of the criticisms to which this system is exposed.

But with all these, and many more faults, it cannot be denied that the praise of genius and originality in an eminent degree belongs to Dr. Brown. The simplicity, comprehensiveness, and consistency, as well as novelty, of his system, gave it a very seducing appearance, and contributed greatly to its prevalence. One of the greatest excellences of it, as applied not only to the practice of physic, but to the general conduct and preservation of health, is, that it impresses on the mind a sense of the impropriety and danger of suddenly going from one extreme of excitement to another*.

* See Brown's *Elements*, passim.

Near the close of the eighteenth century, a new medical theory was presented to the world by Dr. Erasmus Darwin, in his celebrated work which he entitled *Zoönomia**.

According to this theory, there is, in every part of the animal system, a living principle, which is termed *Sensorial Power*, which is considered as the immediate cause of all its motions, and is supposed to be secreted in the brain and spinal marrow. This sensorial power is capable of being acted upon in four different ways, or it possesses, in other words, four different faculties or modes of action, which, in their passive state, are denominated *irritability*, *sensibility*, *voluntarity*, and *associability*; and in their active state, or during exertion, they are termed *irritation*, *sensation*, *volition*, and *association*. The faculty termed irritation is exerted, and produces fibrous motions, in consequence of the stimulus of external bodies acting on any part of the system where sensorial power resides. That of sensation is exerted in consequence of the stimulus of pleasure or pain, occasioned by fibrous motions originally produced by the sensorial power of irritation. That of volition is exerted in consequence of the stimulus of

* Dr. Erasmus Darwin was a native of Nottinghamshire, where he was born, December 12, 1731. He was educated at the university of Cambridge, and graduated *Bachelor of Medicine* in that institution in 1755, and soon afterwards commenced the practice of physic at Litchfield, where he long resided in the honourable, useful, and profitable practice of his profession. His first great work, the *Botanic Garden*, was published in 1789; the *Zoönomia* in 1794; his *Phytologia* in 1799; and his *Temple of Nature* a short time after his death, which took place on the 18th of April, 1802.

desire or aversion, occasioned by fibrous motions, which had been previously produced by the sensorial power of sensation. That of association is at first exerted in consequence of the stimulus of fibrous motions, previously occasioned by irritation, sensation, or volition.

Having thus stated the various modes of action of the sensorial power, Dr. Darwin proceeds to deliver the other fundamental principles of his theory.

During the application of any of the above-mentioned stimuli, the sensorial power becomes exhausted; on the contrary, while any of them are withdrawn, it becomes accumulated.

In order to illustrate and establish his important doctrine of association, Dr. Darwin asserts that there are various circles of associate motions in the animal system, which may take their names from that faculty of the sensorial power by which they are introduced. Those circles, for example, which are introduced by an irritative motion, may be termed irritative associate motions; and, in like manner, the sensitive and voluntary associate motions are produced and denominated. All these several circles of motions act upon one another by means of the sensorial power of association; they may be affected by other sensorial motions, such as those of irritation, sensation, and volition; and they may be considered as compounded, each one of smaller circles; as, for instance, the great circle of irritative associate motions may be supposed to be made up of smaller circles of the same kind.

Conformably to this scheme of association, the introductory link of any circle of associate motions may have its action increased, diminished, or sustained in the natural degree. The first may take place either in consequence of excess of sensorial power, the stimuli being in their accustomed degree; or in consequence of excess of stimuli, the sensorial power being in its natural degree; or in consequence of excess of both. The second may arise either from want of sensorial power, the stimulus being in its usual degree; or, from subduction of stimuli, the sensorial power being in its natural quantity; or from want of sensorial power and subduction of stimuli. The third takes place, when both the sensorial power and the stimuli are in proper degree. In some cases, the morbidly increased, as well as the morbidly diminished, actions of the introductory link of a circle of associate motions are followed by similar actions of the other links; at other times, by contrary actions: in the former case there is *direct*, in the latter *reverse*, sympathy. The morbidly diminished actions arising from subduction of stimuli are sooner relieved than such as are occasioned by want of sensorial power. The morbidly increased actions which arise from excess of sensorial power are more violent than those which are produced by excess of stimuli. Hence inflammatory diseases are commonly preceded by subduction of stimuli, and consequent accumulation of sensorial power. But when excess of sensorial power is acted upon by excess of stimuli, the exertion which follows is far greater and more destructive. Hence the mortification of frozen limbs when brought near the fire.

According to Dr. Darwin, all those parts which are subjected, during health, to perpetual action, as the heart and arteries, accumulate sensorial power faster, when impeded, than those which are subjected only to intermitted action. When stimuli which are usually applied to any particular part of the system, are withdrawn, an accumulation of sensorial power takes place there, proportioned to the subduction of those stimuli and to the state of that part.

The exertion of any part of the system, Dr. Darwin believes, may be proper, or greater, or smaller than it ought to be. All diseases, therefore, originate in the exuberance, deficiency, or retrograde action, of the faculties of the sensorium, as their proximate cause; and consist in the disordered motions of the fibres of the body, as the proximate effect of the exertions of those disordered faculties. Hence, in conformity with the principles before mentioned, health, inflammation, and the various degrees of exhaustion of sensorial power, or torpor from accumulation of sensorial power, will be found to ensue.

After premising these general principles, and deducing from them many important doctrines concerning the sound and diseased states of the animal system, Dr. Darwin proceeds to offer his theory of fever, which, whatever may have been the remote cause of it, he supposes *to consist in the increase or diminution of direct or reverse associated motions*. It commences in a particular organ, occupies one or more disordered tribes or trains of associate motions, and is more or less complicated according to the number of such disordered tribes.

Dr. Darwin's doctrine of fever may therefore be considered as follows. When the torpor of any part of the system (owing to deficient irritation, occasioned either by the subduction of the natural stimuli, and consequent accumulation of sensorial power, or by the application of powerful stimuli, and consequent exhaustion of the same living principle) is such as to occasion diminished action of that part, the following effects will take place: the next link of the tribe of associate motions fails also into a torpor, from defect of excitement of the sensorial power of association; and so the subsequent one, till a general torpor affects the system. This constitutes the cold paroxysm of fever. This general torpor remains till the accumulation of the sensorial power of association is formed, which overbalances that defect of excitement of association; and then the torpor ceases, and the hot fit of fever is produced. When the torpor of the part first affected is occasioned by the subduction of the natural stimuli, this is likewise thrown into increased action during the hot fit. But if it arise from exhaustion of sensorial power, the part remains in a torpid state during the hot fit. The torpor induced by the subduction of natural stimuli, as it is overcome at the end of the cold fit, always gives rise to fevers of strong pulse; since, in such case, all the parts of the system have their actions increased during the hot fit. The torpor arising from the exhaustion of sensorial power produces various effects, according to the part in which it takes place. When seated in the stomach, it always produces continued fever, with weak pulse. In this case, in consequence of the torpid state of the stomach, the arterial system likewise falls into torpor, from defect of the excitement of association; therefore an accumulation of the sensorial power of association takes place in the arterial system. But this accumulation is so great, owing to the interrupted actions of the stomach, catenated with those of the arterial system, that it affects the next link of the associate train, that is, the capillaries of the skin, with increased energy. Hence these last, in this kind of fever, are perpetually exerted with great increase of action. When torpor affects the secerning vessels of the brain, it produces fever with arterial debility. In this case, the secretion of sensorial power being more or less impaired, languid actions of every part of the system must be the consequence. In fevers from this cause, the action of the capillaries is diminished with that of all the rest of the system. Hence the heat of the body does not rise above the natural standard, and sometimes it is even lower throughout the course of the disease; a phenomenon which serves to direct the attention to this cause. When torpor, from exhaustion of sensorial power, affects other parts of the system sympathetically associated with the stomach, such as the liver, spleen, &c., the stomach falls into torpor, from defect of the power of association; and, in like manner, the arterial system; till a general torpor is formed, which constitutes the cold fit. During this cold fit, an accumulation of the associative sensorial power takes place in the stomach, arterial system, &c., which more than compensates this defect of excitement in the sensorial power of association; consequently all these parts are thrown into increased action. This constitutes the hot fit;

which, according to the degree of accumulation of the sensorial power of association, and the force of stimuli applied to it, will produce various effects. Hence various kinds of intermittent fevers. Or these increased actions may be in such degree as to produce sensation, and thereby occasion inflammatory fevers: or, lastly, such increased actions may, in consequence of their violence, produce a smaller, or greater, or complete exhaustion of sensorial power in some part essential to life. Hence various kinds of continued fevers with arterial debility, or even death.

On this extensive scale of sympathy and association, Dr. Darwin endeavours to account for a great number of the phenomena of diseases, and especially for those of fever. From the same doctrine he deduces the indications of cure, and explains the operations of the remedies by which these indications are fulfilled*.

The extensive and accurate observations of the laws of organic life, the sagacious conjectures and profound reflexions, which abound in the *Zoönomia*, must be greatly admired. The most competent judges seem to concur in pronouncing it the ablest medical work of the eighteenth century. In collecting and arranging the facts belonging to animal

* The number of compartments which belong to the system of medical philosophy delivered in *Zoönomia*, the cycles and epicycles, and the variety and intricacy of the relations they bear to each other, render it difficult to comprise, within a short compass, such an abstract as can do justice to the ingenuity and learning of the celebrated author. If this attempt should be found unsuccessful, the difficulty of combining clearness and brevity in sketches of such a kind ought not to be forgotten.

life, and unfolding the influence of morbid association, which involves the essence of diseases, the author undoubtedly excels all preceding writers. Still, however, his work must be allowed to labour under great faults and radical deficiencies *. In many instances he gives the rein to his imagination, and suffers fanciful speculations to usurp the place of facts and legitimate reasoning. His doctrine of the retrograde action of the absorbents, of which he makes such frequent and important use, in a great many various states of disease, may be mentioned as one of those which seem to want confirmation. And there is reason, indeed, to apprehend that errours still more fundamental and essential have crept into this vast plan for binding together the scattered facts of medical knowledge, and converging into one point of view the laws of animated nature. That interesting doctrine, common to Dr. Brown and Dr. Darwin, that all the phenomena of life are to be explained on the principle of the excitability or sensorial power being accumulated and expanded in the inverse ratio of stimulation †, however elegantly it may admit of

* The *atheistical* tendency of his speculations can scarcely be doubted; and his crude and visionary *philosophy of mind* will not stand the test of sober inquiry. This, however, is not the place to enter into a discussion of these errours.

† The originality of some of the leading doctrines delivered by Dr. Darwin has been called in question. He himself recognises the coincidence of some of his opinions with those of Dr. Brown; but contends that he arrived at his conclusions on those subjects by a different train of reasoning from that of the Scottish theorist. He also declares, and asserts that his friends are able to attest the fact, that the greater part of his work had lain by him *twenty years* before its publication. These facts evidently preclude the pro-

illustration by the use of heat, light, and food, after coldness, darkness, and hunger, seems to fail in its application to many morbid states of the system. It appears, on the contrary, often to happen that excitement and excitability are increased at the same time, and perhaps still oftener that they are diminished and wasted together*. The radical defect in every inquiry of this kind is our unacquaintance with the nature of the vital principle, a defect which the scantiness and imperfection of all human knowledge does not seem likely speedily to supply.

In a review of the systematic arrangements of medical knowledge which have been undertaken in the course of the eighteenth century, it would be improper to pass without notice the learned and laborious work of M. Lieutaud, first physician to the monarch of France, published nearly fifty years ago, under the title of *Synopsis Universæ Medicinæ*. This singular work was attempted on the plan of collecting all the facts that experience has taught, without any reasoning concerning their causes. But the total want of method, perhaps the unavoidable result of the plan, continually introduced such confusion as to render this perform-

bability of his being much, if at all, indebted to Dr. Brown. Dr. Hartley seems to have been the first who, clearly and with effect, employed the principle of *association* to account for the phenomena of the animal economy. (See *Observations on Man*). It is not improbable that Dr. Darwin was indebted to him for some hints in forming his great work.

* The author is aware that Dr. Darwin's theory makes provision to meet this difficulty and to explain it; but whether the explanation be sufficiently satisfactory, remains to be decided.

ance much less instructive and useful than might have been expected.

It may also appear improper to omit some notice of a theory of fevers, formed by the late sir John Pringle, which, from its peculiar character, has been denominated the *putrid theory.* Having been long conversant with the malignant diseases of camps and military hospitals, that respectable physician adopted the notion of miasmata and contagions operating like a ferment on the animal fluids, and thereby producing putrid fevers. This doctrine of fevers, however, is regarded as so vague and improbable that few have been induced to adopt it.

Among living authors, many have been so justly distinguished for their efforts to improve the theory and treatment of diseases, that it would be inexcusable to omit their names in this retrospect. The learned and excellent Dr. Rush stands in the first rank of medical theorists in the United States. His doctrine of the *proximate cause of fever* is the result of a long, vigilant, and enlightened attention to the phenomena of febrile diseases, and to the various plans of cure which his extensive learning enabled him to survey. The pathology of the blood-vessels, which had been too much neglected by preceding theorists, seems to have employed a principal share of his attention in framing his doctrine of fevers; which makes their proximate cause consist of *a convulsion in the sanguiferous, but more particularly in the arterial, system.* In conformity to this opinion, his decisive and energetic treatment of febrile diseases is chiefly directed to the reduction of excessive and the liberation of oppressed action, by depletion, and other analogous means; or to the support of feeble action by appropriate stimulants; and afterwards to the transfer of remaining morbid action, of whatever kind, from the vascular system to parts less essential to life*.

The inquiries concerning the nature and constitution of *pestilential fluids*, which have been prosecuted with great learning and ingenuity by Dr. Mitchill, so radically concern many of the leading doctrines of diseases, that they may justly be said to embrace a new theory. His doctrine, as was before mentioned, is this, that the acid offspring of putrefaction, composed of oxygen and azote (which latter he denominates *septon*) chemically united, forms the febrile poison the ravages of which are often so fatally experienced; and that alkaline and calcareous substances afford the best means of extinguishing its virulence. The evidence he adduces to maintain this doctrine, drawn from ancient as well as modern authorities, and from facts observed in all parts of the globe, does equal honour to his diligence and erudition.

In Germany there are several eminent physicians who lately have published systems of medical doctrines, which are said considerably to differ from all preceding ones, and which attract much attention in that enlightened part of Europe. Among these, the names of Reil, Roschlaub, and Hufeland deserve particularly to be mentioned; but the confinement of their opinions to the German language prevents them from being suffi-

* *Medical Inquiries and Observations*, vol. iv.

ciently known to give any account of them in this review.

Within a few years, Dr. Reich, of that country, has presented to the public a new theory of fevers, which seems, however, to have attracted but little attention, and it is believed is now falling into neglect. His fundamental doctrine is, that fevers are produced by destruction of the equilibrium between oxygen and the other principles which enter into the composition of the animal body; and that fevers may be most speedily cured by introducing and restoring equally, to all parts of the body, such a quantity of oxygen as is necessary to re-establish the equilibrium between the different constituent parts. And hence he infers that acids, especially the mineral acids, and particularly the muriatic acid, are better adapted than any other remedies to the cure of fevers.

Among the improvements which occurred towards the close of the eighteenth century, *Pneumatic Medicine* holds a distinguished rank. The knowledge of the gases in the last quarter of the century assumed a regular and scientific form; and the analysis of the atmosphere by Scheele and Lavoisier, at that period, gave a new aspect to many doctrines of the animal economy, both in its healthy and diseased state. When the composition of the atmosphere, its influence in the function of respiration, and the constitution of animal matter, were ascertained, it was natural to suppose that many of the gases received into the lungs in breathing might become powerful remedies. M. Fourcroy took the lead in this inquiry, and was soon assisted by the exertions of Dr. Girtanner. Dr.

Beddoes was the first who introduced the pneumatic practice into Great Britain, where it appears to have been more assiduously cultivated, and applied to a greater variety of medical purposes, than in any other country. The names of Davy, Thornton, and Townshend, are also to be mentioned among the most enterprising cultivators and im provers of this practice. The sanguine expectations of those who first proposed this mode of applying remedies seem hitherto scarcely to have been answered; but how far industry and ingenuity may hereafter vary and improve the practice must be left to the decision of time.

The methodical arrangement of diseases, called *Nosology*, had its birth in the eighteenth century. This consists in a systematic distribution of diseases into classes, orders, genera, and species, on the plan of natural history. This scheme of arrangement was first conceived by Sydenham, and afterwards by Baglivi, towards the close of the seventeenth century. For the first actual attempt the world is indebted to Francois Boissier de Sauvages, an eminent professor of medicine at Montpellier, who published his laborious work in the early part of the eighteenth century. After Sauvages, this subject was cultivated by Linnæus, to whose genius for arrangement every branch of natural history is so greatly indebted; by Rodolphus Augustus Vogel, of Goettingen; by John Baptist Sagar, of Iglaw, in Moravia; by Dr. Cullen, of Edinburgh; by Dr. Macbride, of Dublin; and by Dr. Darwin, in his Zoönomia; beside some others of inferior note. For some time past, the influence of Nosology has been evidently on the decline. The ever-varying forms of diseases are so dissimilar to the steady and fixed character of the objects belonging to the three kingdoms of nature, that it is difficult to account for the confidence and zeal with which this subject has been cultivated by some distinguished names. It cannot, however, be denied, that nosological inquiries have produced many good effects: they doubtless promote the discrimination of diseases; and many of the questions they involve are extremely interesting to the practical physician. An undue reliance upon nosology, and allowing it to substitute names for realities, seem to have produced the mischief which has thrown it into discredit.

The *cool regimen in fevers* constitutes one of the most universally acknowledged improvements in the practice of physic of the eighteenth century. A revolution on this point was begun by the new and interesting doctrines, which the sagacity of Sydenham had enabled him to develop towards the latter part of the preceding age. Every day's additional experience gave some new confirmation of this important practice. A further acquaintance with the diseases of hot climates, where the pleasantness as well as the efficacy of coolness in fevers had overcome the opposition both of theory and prejudice, gave a deep blow to the alexipharmic and heating system. The good effects of coolness in the small-pox, and more especially in the improved stages of the inoculation of that disease, seem to have settled the determination of physicians to extend the same remedy to the treatment of fevers. And the conviction since wrought by experience and observation, both on the public and medical mind, may now be said to have established this improvement on the firmest basis.

It is remarkable, that, although the use of cold air and cold water had been recommended in ardent fevers by Hippocrates, Galen, Celsus, and most of the celebrated physicians of antiquity, as well as by many eminent moderns, it was discountenanced by Boerhaave and all the disciples of his school. In his commentator Van Swieten, and in the writings of Pringle, Cleghorn, Lind, and even Cullen, little is to be found in commendation of this salutary practice. It remained for the learned and judicious Dr. Currie, of Liverpool, to extend the cool regimen in fevers, by adding to the use of cool air and cool drinks, the affusion of cold water over the surface of the body, when in a very dry and heated state. This remedy, the application of which by long experience, he has been enabled precisely to regulate and determine, may be confidently pronounced to be one of the greatest of modern improvements in the practice of physic*.

In the course of the century under review, some particular diseases have been treated with more success than in former periods. It may not be improper to direct the attention of the reader to a few of the most remarkable of these.

The triumph of medicine over the *Small-pox* has been completed in the eighteenth century. This scourge of the human race has exceeded all other diseases in the number of its victims, and in the frequency of deformity, blindness, and other dread-

* See Dr. Currie's *Medical Reports on the Effects of Water, cold and warm, as a Remedy in Fever, and other Diseases.*

ful consequences inflicted on such as escaped with their lives.

The practice of *inoculation* has reduced this frightful malady to such a degree of mildness and safety that it no longer excites the terrour of the community *. The date of this interesting discovery is lost in the obscurity of tradition and immemorial usage. Traces of it may be found among the traditions of many former ages in Great Britain, particularly in Wales and the Highlands of Scotland; in Italy, France, Germany, Denmark, Sweden, and some other parts of Europe; in Africa and Asia, particularly in Hindostan and China †.

* See *Additional Notes.* (*E E.*)

† It is a remarkable fact, that, in all the countries above mentioned, there is satisfactory evidence of inoculation for the small-pox having been practised by the common people, for many years before its introduction by the physicians of Great Britain; and, in some of them, as far back as tradition can be traced. It is also a still more remarkable fact, that in *Wales*, in the Highlands of *Scotland*, among the ignorant peasantry of *Germany*, in the interior of *Africa*, and in several parts of the *Asiatic* continent, distant as they are from each other, differing widely as they do, in manners, customs, laws, and religion, the art of communicating this disease by inoculation was designated by the singular phrase of *buying the small-pox*; because it was superstitiously imagined that inoculation would not produce the proper effect, unless the person from whom the variolous matter was taken received a piece of money, or some article in exchange for it.—See Dr. Woodville's *History of Inoculation.*—How shall we account for so many different and distant nations agreeing in so remarkable a phrase to express inoculation, and agreeing also to connect with it such a superstitious ceremony? How shall we account, further, for this art being confined chiefly to the *common people*, or the less civilised part of mankind, while the learned were ignorant of it? May it not be admitted as one proof of the *great antiquity* of the practice, that precisely that portion of the community, whose habits, in every

But the eighteenth century may boast of the first regular and satisfactory notices of this noble improvement, and of making it to be understood and practised in an intelligent manner among all the enlightened part of mankind. It is generally said that the *Circassians* first inoculated their children in order to rear them as slaves for the Turkish seraglio; and it was certainly first introduced into *Constantinople* from *Georgia*, towards the end of the preceding age. From Constantinople the British nation received an account of the practice of it by the celebrated lady M. W. Montague, who caused the disease to be thus communicated to her own children. In 1721, inoculation was first regularly adopted in England; and in the succeeding year, the operation being performed upon some of the children of the royal family, it soon began to be in vogue. Objections both of a physical, moral, and religious kind were urged against this new practice, with great zeal and intemperance, by many respectable persons of the medical and clerical professions, as well as by others of inferior character. These objections for some time excited scruples in the minds of many well-disposed people, and greatly retarded the progress of inoculation. Having at length, however, surmounted these difficulties, the value of the discovery became every day more highly rated, and before the middle of the century might be considered as established upon the firmest basis.

In the year 1721, and in the same month in which the daughter of lady Montague was inocu-

country, are in general most simple, uniform, and stationary, were found to retain a practice which the more polished had lost?

lated in England, this mode of communicating the small-pox was introduced at Boston, in Massachusetts. Dr. Cotton Mather, one of the ministers of that town, having observed, in a volume of the *Philosophical Transactions*, printed in London, some communications from Constantinople and Smyrna, giving a favourable account of the practice, and the small-pox beginning, about the same time, to spread in the town, he recommended to the physicians of his acquaintance to make trial of inoculation. They all declined it except Dr. Boylston. He began with his own children and servants. But the degree of odium which he drew upon himself by this measure is scarcely credible. The physicians in general highly disapproved his conduct. Dr. Douglas *, one of their number, who had received a regular medical education in Scotland, his native country, stood foremost in the ranks of opposition. He wrote, declaimed, and employed all his influence against the intrepid innovator. The medical gentlemen were joined by the populace, who were so much inflamed against what they esteemed a species of murder, that Dr. Boylston was in danger of his life †, and Dr. Mather was scarcely less an ob-

* Dr. William Douglas is said to have been a man of learning and talents. He published some small medical pieces, and corresponded with Dr. Colden of New York, who, in one of his medical communications, speaks of him in terms of high respect. He was also the author of the work entitled, *A Summary of the British Settlements in America*, 2 vols, 8vo, London, 1755.—He was, however, conceited and arrogant, and behaved with great disingenuousness in his opposition to Boylston.

† Dr. Boylston's house was attacked with so much violence, that he and his family did not consider themselves safe in it. He was assaulted in the streets, loaded with every species of abuse,

ject of popular indignation. But the greater proportion of the clergy of Boston embarked in support of the measure; they preached and wrote* in favour of it, until, at length, their influence, greatly confirmed by the success attending Dr. Boylston's practice, gradually overcame the opposition; and near three hundred persons were soon after inoculated in Boston and the neighbouring towns†.

A degree of the same prejudice and opposition, which raged with so much violence in Boston, continued to be manifested not only there, but also in many other places, for a considerable time afterwards. But the practice gradually gained ground, and became general in New-England; in a few years it was adopted in New-York and Philadelphia; and in the year 1738 had reached Charleston, in South-Carolina.

Till near the close of the century now under consideration, the inoculation of the small-pox con-

and execrated as a murderer. Indeed, many sober pious people were deliberately of opinion, when he commenced the practice of inoculation, that, if any of his patients should die, he ought to be capitally punished. A bill was brought into the legislature for prohibiting the practice, under severe penalties, and actually passed the house of representatives; but some doubts existing in the council, its progress was arrested, and it never became a law.—See Hutchinson's *History of Massachusetts*, vol. ii, p. 247, &c.

* The *Newspapers* teemed with pieces on both sides of this interesting controversy; and especially with some of a very virulent character, from the opponents of inoculation. The *Courant*, a newspaper edited at that time by a brother of Dr. Benjamin Franklin, took a decided part with Douglas and his coadjutors. The young philosopher was then an apprentice in the office, and employed his opening talents in favour of the same deluded party. *MS. Letter of the Rev. Dr. Eliot to the Author.*

† Hutchinson's *History of Massachusetts*, vol. ii.

tinued more and more to prevail, and to become the settled habit of all that portion of society who were placed in easy circumstances, and possessed the better degrees of intelligence. The advantages, however, of this practice, notwithstanding all its benefits to the individuals who employed it, were supposed by many, on a general calculation of human life, to be extremely problematical. By carrying the disease more frequently and universally through cities and countries, it was found that the poorer classes of people, which constitute the great mass of every nation, were much oftener exposed to casual infection; and that, on the whole, the mortality of mankind from this disease was thereby much augmented.

But such doubts and difficulties as these arising in the mind of the philanthropist, and much of the importance of the inoculation of the small-pox, even to those who employed it, were removed by the discovery of the inoculation of the *Vaccine Disease*, in the year 1798. This may perhaps be justly considered as the most memorable improvement ever made in the practice of physic. By substituting a disease so much milder that it cannot fail of being universally preferred, and one which at the same time affords effectual security against the small-pox, the prospect is presented of speedily exterminating the latter disease, and thereby closing a great outlet of human life.

To Dr. Jenner, of Great Britain, the world is indebted for this incomparable discovery. For although there has existed, perhaps from time immemorial, some popular knowledge of the vaccine disease, and of the fact of its rendering the human system unsusceptible of the small-pox*, yet the practice of inoculating it successively from one person to another as a substitute for the small-pox, and the investigation of the principal circumstances which ought to regulate that inoculation, in order to confer upon it the greatest certainty and success, seem undoubtedly to have originated with that physician. Further investigations and discoveries have since been made, concerning the nature and the inoculation of this disease, by other physicians, particularly by Drs. Pearson and Woodville, and Mr. Ring, of London †.

* For a number of years before Dr. Jenner's discovery, it was known to many, physicians as well as others, that a disease existed among the cattle in Great Britain, particularly in Gloucestershire, which it *was said*, among the common people, when communicated to the human subject, formed a defence against *Small-Pox*. Dr. Barry tells us that this disease has been long known in Ireland, under the name of *Shinach:* he gives instances of persons who had passed through it *fifty years* ago; and mentions that one woman, *eighty years* of age, declares, that as long as she can remember, the opinion prevailed, that people who had the *Shinach*, or *Cow-Pox*, could not take the *Small-Pox;* and that many, at that early period, purposely exposed themselves to the former, to avoid taking the latter. Traces have also been found of some knowledge of this disease existing in other parts of Europe, among the lower classes of people, a number of years before the publication of Dr. Jenner.—See Barry on *Cow-Pox*.

† An institution for the purpose of preserving and communicating the *vaccine* infection, and particularly for inoculating the poor, has been formed in London since the publication of Dr. Jenner's discovery. For this the public are principally indebted to the enlightened and benevolent exertions of Dr. Pearson. A similar institution has been more recently formed in the city of New York. The first person who inoculated with the vaccine *virus*, in the United States, was Dr. Waterhouse, professor of the theory and practice of physic in the university of Cambridge, Massachusetts.

All preceding ages, and a considerable portion of the eighteenth century, abound in accounts of the destructiveness of the *Scurvy* in ships on long voyages, in armies, particularly in garrisons, as well as in some regions of the high latitudes. Towards the close of the period under examination, that dreadful disease has been disarmed of all its violence, and seems now to be completely reduced under the dominion of the healing art. This revolution has been effected by procuring for persons in the situations above mentioned more comfortable shelter, clothing, and food. Fresh meats substituted for salted, and vegetables plentifully supplied, especially the vegetable acids, may be considered among the principal means of prevention and cure. The *citric acid*, in particular, has accomplished wonders in this disease; and the late discovery of crystallising it renders the remedy conveniently portable to any distance, and capable of preservation in all climates and seasons, and for any length of time. The eminent services of Dr. Lind in improving our knowledge of this disease can never be forgotten. The philosophic and enterprising captain Cook was the first who reduced the improvements in nautical medicine to practice, in all their extent, and with complete success*.

* In the first voyage for the establishment of the East-India company, out of four hundred and eighty men one hundred and five died of *scurvy* before they reached the Cape of Good Hope. Lord Anson, in his voyage round the world, lost, from the same disorder, four-fifths of his original number. Those who have read the narrative of his expedition, by Robins, will recollect the dreadful picture which is drawn of the ravages of this disease in

Pestilential diseases are supposed to have greatly abated in frequency and malignity in the course of the eighteenth century. This observation, however, must be understood to be chiefly restricted to those parts of the world which, during that period, have been making progress in civilisation, intelligence, and refinement. In many parts of Asia and Africa, and in European Turkey, it is probable that little abatement of the ravages of such diseases has actually taken place. The degraded state of man in most of the Mohammedan countries; the poverty, filth, and wretchedness, which oppress the lower classes of people in their crowded cities, and the inattention to cleanliness and ventilation, even in the houses of the most opulent, aided by the influence of their doctrine of fatalism, seem to leave them little prospect of emerging from their present condition into one more respectable, and exempt from malignant diseases. The contrast of health and disease, in the Christian and Mohammedan world, while it affords to the pious mind a satisfactory confirmation of his faith, furnishes also to the philosopher and physician an instructive lesson, with regard to the comparative influence of the respective principles and institutions of Christianity and Mohammedanism.

the vessels under his command. Captain Cook, thirty years after Anson, with a company of one hundred and eighteen men, performed a voyage of three years and eighteen days, throughout all the climates, from 52 deg. north, to 72 deg. south, with the loss of only one man, who had been previously indisposed.—See Dr. Ramsay's learned and interesting *Review of the Improvements, Progress, and State of Medicine in the Eighteenth Century*, &c. pp. 28 and 30.

The comparative mildness and infrequency of pestilential diseases in Christian Europe, during the late century, are probably owing to a combination of many causes. Much may be safely ascribed to improvements in the cleanliness and ventilation of houses, in diet, in apparel, in habits, customs, and all the modes of life. Cities, which are usually the great nurseries of pestilence, are now less crowded than in former ages. The comforts, decencies, and elegancies of life, from a variety of causes, are now enjoyed by a greater portion of the community, and in a much higher degree than in preceding times. To the same causes, also, may be ascribed the almost entire banishment of that loathsome disease the *Leprosy*, from the civilised world, which has been in a great measure effected in the course of the last age.

The frequent and mortal prevalence of the pestilential disease called *Yellow Fever*, in the cities, and in some parts of the country, in the United States, for the last ten years, forms a memorable event in the medical history of this country, during the century which is the subject of this retrospect. The malignity and ravages of this epidemic impressed the public mind with the deepest apprehensions, and undoubtedly gave a new impulse and vigour to medical investigation. The origin of this disease has been warmly contested in the United States, in the West-Indies, and in Europe. While many maintain that it is produced by the exhalations of putrefaction, whether such putrefaction be found in the filth of cities, of marshy grounds, or of vessels on the water; others, on the contrary, assert, that it is always produced by contagion emitted from the sick labouring under the disease, and successively propagated from one person to another. The latter opinion seems to be fast losing ground among the better informed part of the medical profession, and of the public; while the evidence in support of the former is accumulated, and rendered more luminous and irresistible, by the occurrences of every epidemic season. Much light has been thrown on the origin, course, precursors, and concomitant circumstances of this, and of other pestilential diseases, by Mr. Noah Webster, in his *History of Epidemics*, an ingenious and learned work, in which a rich and curious amount of information on this subject is brought together and exhibited in a very impressive manner. Though the author is no physician, he has made a very valuable present to the medical world, and has entered and pursued with much ability a path of inquiry, which will probably conduct to very interesting and instructive conclusions. In the mean time, the modes of treating yellow fever have received great improvement during the period under consideration. Those who have written on this disease with most reputation, are Dr. Rush of the United States, who has had ample experience in the treatment of it *, and Drs. Jackson and Chisholm, of Great Britain.

* The intrepidity and benevolence displayed by Dr. Rush, during the several seasons in which pestilence has prevailed in Philadelphia, deserve the highest eulogium. This remark applies with peculiar force to the season of 1793, when the yellow fever appeared in that city, arrayed in greater terrour than ever before or since in any part of the United States; when the methods of treatment were comparatively little understood; when it was universally considered as a highly contagious disease; and when the fortitude and services of this distinguished physician, through the

The diseases of *Camps*, *Armies*, and *Military Hospitals*, have attracted much attention, and the treatment of them received great improvements in the course of the late century. The means of preventing diseases, in such situations, are much more attended to than formerly; particularly all circumstances which respect the sites of encampments, the shelter, clothing, food, cleanliness, &c. of troops, and the ventilation of the places in which they are stationed. For many of these improvements the public are indebted to sir John Pringle, Drs. Donald Monro, Brocklesby, Hunter, and others, who have written on the diseases of armies.

The means of preventing and curing the diseases incident to *Seamen* have also been more diligently and successfully studied in the course of the last age than ever before. For very enlightened inquiries and useful publications on this subject we owe much to Drs. Lind, Macbride, Clarke, Blane, and Trotter.

Modern times have also given rise to improved modes of preserving the health, and promoting the comfort, of persons confined in *Prisons*, and other close apartments. The honour due to the rev. Dr. Hales, and sir John Pringle, for their philosophic inquiries and enterprising exertions to forward this branch of improvement, are generally known. But to no individual that ever lived is the cause of humanity more indebted for services of this kind than

whole course of the epidemic, were preeminently conspicuous. If the admirers of moral heroism celebrate, as they justly do, the conduct of the good *bishop of Marseilles*, and of the benevolent *lord mayor of London*, it is conceived that the firmness and useful exertions of Dr. Rush, in similar circumstances, are in no respect less worthy of their commemoration and praise.

to the immortal Howard, whose long and painful journeys, persevering labours, and successful plans for meliorating the condition of *Prisoners*, in every part of the world, to which he could obtain access, will ever form one of the most honourable pages in the annals of human nature*.

The diseases of *Warm Climates* are become better understood, by the efforts of modern times to extend the range of geographical and commercial enterprise; and, from their bold and definite features, much light has been thrown on the theory and treatment of such as prevail in more *temperate* regions. In fact, the whole of that important and interesting field of inquiry which relates to the comparative frequency and force of particular diseases, as they appear in different regions of the earth, and in different states of society, had been but little explored prior to the period which we are now considering.

The exertions recently made to investigate the nature and causes, and to lessen the fatality of *Pulmonary Consumption*, deserve a transient notice. If such exertions have not yet produced all the beneficial consequences which humanity could wish, there is yet ground to believe they have effected some good; and that no effort in such a cause will be finally

* In John Howard the eighteenth century may boast of having produced an unique in the history of man. It would be unjust to compare him with any hero of benevolence, merely human, before or since his time, for such a one never existed. It has been truly said, that his plan for promoting the happiness of his fellow creatures was *original*; and that it was as full of *genius* as of *humanity*. That it was the religion of Christ which directed and animated the exertions of this wonderful man, no one can doubt who is acquainted with his history and character. He was born at Hackney in 1726, and died in 1790.

lost. Justice requires, whenever this subject is mentioned, that the philanthropic labours of Rush and Beddoes should be duly appreciated. Similar exertions have also been made, and with like considerable success, to throw light on the nature and cure of *Scrofula*, and the *Diseases of the Mind*, to say nothing of many others equally worthy of notice.

Under this head it is proper to take some notice of the successful attempts which have been made, during the eighteenth century, to enable the *Deaf* and *Dumb* to *speak*. Deafness has, in all ages, been considered such a total obstruction to speech, and the knowledge of written language, that the attempt to teach those who are destitute of the sense of hearing, either to speak or read, has been generally regarded as vain. One of the first teachers of the deaf and dumb was Bonet, a priest, secretary to the constable of Castile, in Spain. He undertook the tuition of his younger brother, who had lost the sense of hearing at ten years of age; and he published an account of his system in 1620, at Madrid. Amman, a Swiss physician, was the next systematic writer on this subject. He printed at Amsterdam a treatise in Latin, about the year 1692, entitled *Surdus Loquens.* Dr. John Wallis, a few years afterwards, suggested, in his *Grammatica Linguæ Anglicanæ*, a plan for conveying ideas to the minds of the deaf more distinctly than by ordinary signs. He was followed by Holder, Dalgarno, and Bulwer, each of whom devised a plan, and made some progress in its execution. There was, however, little done to any valuable purpose till the year 1764, when Mr. Thomas Braidwood, of Edinburgh, undertook the difficult task.

In that year he began with a single pupil, when, his exertions being attended with complete success, he was encouraged to extend his views, and afterwards taught a considerable number to speak distinctly, to read and write, and to understand arithmetic, and the principles of morality and religion. The same curious and highly interesting art has also been practised on different plans, but with great success, by Mr. Baker of London, by M. Heinecke of Leipsic; and by father Vanier, M. Perriere, and the abbé de l'Epée of Paris. The last named gentleman has been more successful than any other. He had instructed upwards of *one thousand* deaf and dumb persons, before he was succeeded by his pupil M. Sicard *. A regular institution for this kind of instruction was established in London, in 1792, under the care of Mr. Watson, a pupil of Mr. Braidwood.

The late century has likewise made great progress in ascertaining the means of *restoring the suspended actions of life. Humane Societies* for the recovery of drowned persons, which began to be instituted soon after the middle of the century, have since been multiplied to such extent, that they are to be found in most large sea-port towns. Great exertions have been made to improve the knowledge formerly possessed on this subject; and the means now employed are much more rational and successful than the rude and often pernicious ones which used to be resorted to. Many efforts have likewise been made to prevent the premature interment of such as are only apparently dead; by

* See *The Method of Educating the Deaf and Dumb,* by the abbé de l'Epée, translated from the French, 8vo, 1801.

which some valuable lives have been saved, and more caution relative to this point impressed on the community. The service rendered by many physicians to the cause of humanity, by promoting objects of this kind, deserves honourable commemoration. Of these perhaps few are entitled to a larger tribute of acknowledgement than Drs. Hawes and Lettsom, of London.

It would be easy to descend to a great variety of particulars, in which the means of curing or mitigating diseases have been radically improved during the period under consideration; but the limits of this retrospect forbid such details. It is sufficient to remark, that a large portion of diseases, however faithfully observed by preceding, and even by the most ancient physicians, have, within this period, been better understood, arranged, and discriminated, than ever before; and that remedies of superior efficacy have been selected, their qualities, virtues, and uses, more fully ascertained, and the best mode of their application rendered more definite and precise. The number of incurable diseases, also, has been diminished, and the treatment of many hazardous and violent ones so far improved, as greatly to diminish their force and danger. The recent doctrines of *Association* and *Sympathy* in morbid action, and the interesting practical doctrine which results from them, of the *transfer of morbid action* from vital parts to such as are less essential to life, have unfolded a vast extent of medical exertion and usefulness, which was nearly unknown to the physicians of former centuries.

The *practical writers* on medicine, during the eighteenth century, were very numerous and respectable. From so large a catalogue it is difficult to select the few names of which the brevity of this review will allow the insertion. Beside a considerable number of those mentioned in the foregoing pages, Wintringham and Huxham, on epidemical diseases, deserve a high place; Cleghorn, on the diseases of Minorca; Hillary, Whytt, Fothergill*, Heberden, Lind, Jackson, Fordyce, and Chisholm, do honour to the British nation. Among the French Senac and Lieutaud, and among the Germans Storck and von Haen hold the first rank; to say nothing of many others, in almost every cultivated part of Europe, who have obtained much distinction by their practical writings on medicine.

SECTION IV.

SURGERY AND OBSTETRICS.

That department of medicine which treats of diseases to be cured or alleviated by the hand, by instruments, or by external applications, is denomi-

* Dr. Fothergill died in 1780, in the 68th year of his age. Distinguished as he was for his learning, the solidity of his talents, and the extent and success of his medical practice, he was rendered still more conspicuous by the purity of his moral and religious character, and the ardour of his philanthropy. His great influence was continually exerted for the increase of human happiness. Of every institution within his reach, which had for its object the advancement of useful knowledge, or the interest of humanity, he was a zealous and active promoter. Of public and private charity he was an illustrious example; and we are informed that a large number of those improvements, which have so much contributed to the health of the city of London, either originated from his counsels, or were effected, in a great measure, by his influence.

nated Surgery. At the close of the seventeenth century this art had considerably emerged from the low state in which all preceding ages had left it. Many respectable writers had appeared in the course of that century, whose exertions to improve the practice of surgery, and to diffuse the knowledge of such improvements, were attended with so much success as to render the progress of it comparatively rapid at the commencement of the eighteenth century.

It will be easy to perceive that the numerous improvements in other branches of medicine, which are detailed in the preceding parts of this chapter, must have greatly advanced the progress of surgery. Every step in the cultivation of anatomy and the theory and practice of physic confers some advantage on medical or operative surgery. The improved state of the mechanic arts has likewise served to divest it of much of that useless machinery with which it was formerly encumbered, to retain only what appears to rest on the basis of experience, and to aid ingenuity in supplying many important deficiencies. Hence, the surgery of the eighteenth century may not only boast a more intimate acquaintance with the structure and functions of the hnman body, and with the fundamental principles of diseases, but likewise a superior simplicity, neat ness, ease, and expedition, in the performance of operations.

Early in the century which forms the subject of this retrospect, Laurence Heister, professor of surgery in the university of Helmstadt, published his System of Surgery, which continued till about fifteen years ago to be the only tolerably complete system in possession of the public. This work comprised whatever the experience of former times had approved as useful, and such observations and precepts as the knowledge and experience of the learned author himself enabled him to add. Some other systematic arrangements of chirurgical knowledge were, indeed, attempted about the middle of the century. Platner, professor of surgery at Leipsic, published his Institutes of Surgery in the year 1745; and Ludwig, of the same university, favoured the world with a similar publication in 1767. But both these works, though possessed of great merit, are too compendious to give a clear and distinct account of the numerous topics of which they treat.

In Great Britain, Mr. Cheselden was much distinguished by his chirurgical eminence in the early part of the century. He improved the lateral operation of *Lithotomy*, and devoted much attention to the diseases of the *Eyes*. His pupil, Mr. Samuel Sharpe, obtained soon afterwards a high reputation. His *Treatise on the Operations of Surgery*, and his *Critical Inquiry*, were deservedly considered as performances of great value at that period. The elder Monro, of the university of Edinburgh, deserves also to be mentioned among those who did much to improve the practice of surgery about that time. Towards the middle of the century Dr. William Hunter began to acquire great celebrity as an anatomist and surgeon, and was joined not long afterwards by his brother, Mr. John Hunter, who, as an operator, was still more distinguished. To the exertions of these eminent men the art is indebted for many valuable improvements, both in theory and practice. After the middle of the century Mr. Percival Pott began to take a high station among British surgeons, added greatly to the progress of the art, and published many excellent writings, which are still in the highest esteem. The present professor Monro, of Edinburgh, has enriched surgery by many important additions to the preceding stock of knowledge, which greatly increase the lustre of his reputation. Late in the century, about the year 1788, Mr. Benjamin Bell, of Edinburgh, completed his *System of Surgery*, which was compiled with much learning and diligence, and exhibited an advantageous view of the progress and improvements in surgery up to that period.

The particular improvements in surgery during the late century are extremely important, and reflect great credit on the ingenuity and labours of those by whom they were made; but they are likewise so numerous that only a few of them can be mentioned consistently with the necessary brevity of this retrospect.

The means of putting a stop to *Hæmorrhages* from the division of the larger blood-vessels have been much improved during the period under consideration. The first notices of the instrument for this purpose, called the *Tourniquet*, originated in the seventeenth century. It is amazing that so simple an instrument, and so obvious a mean of compressing arteries, should have remained unknown till that period. Surgery must have been in a deplorable state of rudeness and imbecility, when no operation of importance could be undertaken on any of the extremities but with the greatest danger of bleeding to death, and large wounds, otherwise in no degree hazardous, must often have proved mortal for the want of this simple contrivance. The first attempts to construct it were very rude and imperfect; and it was reserved for Mons. Petit of Paris, by adding the screw, to render it much more convenient and powerful in the compression of arteries. Another interesting improvement in securing arteries belongs to the late century. Instead of the *needle* and *ligature,* which were formerly used for this purpose after operations, the *tenaculum,* or *forceps,* is now employed, which produces much less pain, and prevents many ill consequences of the old method. The first application of the needle and ligature to surgical purposes, which is ascribed to Ambrose Parey, of the sixteenth century, was a great improvement. Since that time many variations have taken place in the mode of using them; and in the course of the eighteenth century, the different kinds of *sutures* have been still further improved in many important respects.

The treatment of diseases of the *Head* from external violence has been extremely improved within the period of this retrospect. For this interesting part of the progress of surgery the world is much indebted to M. le Dran, Mr. Pott, Mr. Bromfield, and others.

The various species of *Herniæ* are much better understood within the last fifty years; and much of the progress in this branch of surgery is due to the acuteness and indefatigable labours of the late Mr. Pott. The disease termed *Hydrocele* has also, within the same period, been investigated with much more success than ever before; for which much is to be ascribed to Mr. Pott, Mr. Benjamin Bell, and sir James Earle.

The interesting subject of *Aneurisms* has derived great additional light from the researches of modern anatomists and surgeons. Dr. William Hunter examined the phenomena of this disease with great diligence and success. The present treatment of the *popliteal aneurism*, which forms a memorable improvement in surgery, is to be ascribed to Mr. John Hunter.

The lateral operation of *Lithotomy*, which is now generally preferred, owes much of its present improved state to the labours of the surgeons of the late century. Mr. Cheselden did a great deal to improve it in the first half of the century; and, since his time, much has been done by Pott, Bromfield, Gooch, sir James Earle, and many others. The *Gorget*, which is so important among the several instruments employed in this operation, was the invention of Mr. Hawkins of London.

In the management of *Fractures* and *Luxations* much advantage has been obtained, within the last fifty years, by avoiding the constrained and unnatural positions formerly imposed in such cases, and generally placing the affected limb in that easy, relaxed, and bent position which the natural inclination of the patient prompts him to assume. By these means much pain is spared, and the straightness and perfect recovery of the affected limbs exceedingly promoted. The efforts of Mr. Pott in effecting this salutary reform deserve very honourable mention.

The treatment of *Gunshot Wounds* is another point on which the surgery of the eighteenth century claims a great deal of improvement. This has been effected chiefly by giving up the artificial and over-officious management of former times, by admitting the operation of general principles, instead of considering them as poisoned wounds, and by adopting the light, easy, and superficial dressings which experience has been found to approve.

Much light, during the late century, has been thrown on the various diseases of the *Eyes*, and particularly on the *Cataract*. The same may be observed of *Fistula Lacrymalis*, and of *Fistula in Ano*. Among many others, Mr. Pott has largely contributed to the elucidation of all these subjects, and to the banishment of many prejudices and errours concerning them, which fifty years ago existed in great force. To the same distinguished practitioner surgery is indebted for a mode of treating *Curvatures of the Spine*, far more successful than any previously known.

Lately Mr. Abernethy, of London, has suggested a mode of treating *Lumbar Abscess*, which sometimes succeeds very happily, and often affords reasonable grounds of hope in that deplorable disease. And not long since, the theory and management of *Ulcers* has been gradually improved by the persevering labours of many surgeons, among whom it would be unjust not to mention Mr. Benjamin Bell, Mr. Home, Mr. Baynton, Mr. Whately, and Mr. Nayler. The subject of *Wounds* has recently been treated with great ability and discernment by Mr. John Bell, of Edinburgh, who deservedly sustains a high rank among the surgeons of the Scottish metropolis.

But the greatest of all improvements in surgery which the eighteenth century can boast, consists in the maxim of *Saving Skin* in all operations, and in the universal doctrine and practice of *Adhesion*, as now received. This improvement is so simple and so important that it is wonderful to find it reserved for the surgeons of so late a period. The merit of this discovery does not seem to belong exclusively to any individual. A share of it doubtless attaches to Mr. Alanson of Liverpool, and several others who directed their inquiries to this object about the same time. But to Mr. John Hunter more is certainly due than to any other person. This improvement was first applied to *amputation*, then to the operation of the *trepan*, next to the extirpation of scirrhous breasts, afterwards to all the great operations, and, lastly, to all recent wounds. In short, it would not be too much to assert, that this doctrine and practice of *adhesion* have done more to promote the progress of surgery, within a few years, than any discovery of modern times, not excepting, perhaps, even that of the circulation of the blood.

It remains to offer a few remarks concerning the progress of *Obstetrics* in the late century. By this term it is usual now to understand not only the art of facilitating the birth of children, but that of managing pregnant and puerperal women. During the period of our retrospect, the improvements which this art has received may justly be considered as numerous and important, and fully equal to those which are claimed in the other departments of medicine.

Both the theory and practice of obstetrics have assumed a much more regular and scientific form within the period in question. The anatomical structure of the body, so far as it concerns this art, was well understood in former ages. But the intricate and interesting relations of one part to another, their distances and their inclinations, both with respect to each other, and to different parts of the body, as well as with regard to the fœtus, form a branch of inquiry on this subject which has been prosecuted to advantage only in modern times. Dr. Smellie, is supposed to deserve the praise of beginning this improvement and pursuing it to considerable extent*.

By the light of the eighteenth century, not only many new truths have been brought into view, but a multitude of errours, prejudices, and superstitious opinions, which formerly misled the obstetrical art, have been in a great measure banished†. Nature has resumed its dominion, and is now followed as the safest guide. Much of the officious and violent interposition of former practitioners, to hasten or control the natural process of parturition, has been

* Dr. Smellie is said to have been the first writer who considered the shape and size of the female pelvis as adapted to the head of the fœtus; to have abolished many superstitious notions, and erroneous customs, that prevailed in the management of women in labour and of children; and to have had the satisfaction of seeing most of his maxims adopted in the greater part of Europe.—Ramsay's *Review*, p. 13.

† Van Swieten quotes several authors of reputation, who had advised lying in women to keep their beds till the tenth or twelfth day after parturition; and this was frequently done without changing their bed-linen. The children were also incased from head to foot, so as to be totally deprived of the use of their limbs. These absurd and unnatural practices have, within the last half century, been gradually exploded.—*Ibid.*

found to be injurious, and is now generally relinquished. The modern instruments, in comparison of those employed by the ancients, are few in number, simple in construction, and seldom resorted to.

The diseases of the puerperal state have been much better understood, discriminated, and treated, within a few years, than in preceding times. The late publications of Dr. Smellie, Dr. Manning, Dr. Hulme, Dr. Leak, Mr. White, Mr. Moss, Dr. Hamilton, Dr. Denman, Dr. Osborn, M. Baudelocque, and many others, whose names are only excluded by the brevity of our plan, have thrown much light on the subject of obstetrics, and do great credit to their profession. The elegant plates of doctor William Hunter, before mentioned, may also be considered as a great acquisition to the theory and practice of this art.

ADDITIONAL NOTES.

Note (A), page 18.—THE following compendious view of the system of J. Hutchinson, esq., as it respects Natural Philosophy, is extracted from *a Letter to a Bishop, concerning some important Discoveries in Philosophy and Theology*, by the right honourable Duncan Forbes, president of the court of session in Scotland. As this gentleman appears to have been favourable to the *Hutchinsonian* philosophy, and had doubtless devoted much attention to it, he may be supposed by some to give a more satisfactory account of it than that which is exhibited in the page above referred to.

"The first thing that is met with in the books of *Moses* is an assertion that God created the heavens and the earth, which is followed by a particular account of the order and manner of the formation of all that was created, till the work was perfected. After which, God is said to have rested; and our author asserts, that it is also said, the perfect machine, then left to itself, carried on all the operations in this system, by certain known laws of mechanism, explained by *Moses*, and throughout the Scriptures by the other inspired penmen.

"The sum of what our author avers to be the doctrine of the Scriptures, on this head, is, that, beside the differently formed particles, of which this earth, and the several metals, minerals, and other solid substances in it, and in the other solid orbs, are composed, God at first created all that subtile fluid which now is, and from the creation has been, in the condition of fire, light, or air, and goes under the name of the heavens.

"The particles of this fluid (which our author calls atoms), when they are single and uncompounded, are inconceivably minute, and so subtile as to pervade the pores of all substances whatever, whether solid or fluid, without any great difficulty or resistance; when they are pushed forward in straight lines by the action of fire, or are reflected or refracted in straight lines, they produce light, and are so called; but when the interposition of any opaque body hinders their progress in straight lines, they pass, but cease to produce light.

"These particles or atoms, which, when moving in straight lines, produce light, and, if collected and put into another sort of motion, would produce heat and fire, are, as our author insists, when the force impelling them ceases to act with vigour, and when their motion is retarded, so made, that they are apt to adhere in small masses or grains, which the author calls spirit or air, and is of the same kind and texture with that air which we daily breathe, and which we feel in wind when it blows.

"The sun, which our author places at the centre of this system, is an orb included in a vast collection of this subtile matter in the action of fire, which continually melts down all the air that is brought into it by the powerful action of the firmament or expansion, hereafter to be explained, into the subtile matter just mentioned; and with an immense force sends forth, in perpetual streams of light, this same subtile matter, so melted down, to the circumference of this system, which the author says is bounded, as he avers the space comprehended within it is absolutely full.

"The matter thus melted down at the orb of the sun into light must, as every thing is full, either stand still or make its way outwards to the circumference; being forced by the particles which are concreted into air at the utmost extremities, and return towards the sun, where the fluid, being most subtile, gives least resistance, and take up the place that the light left.

"And therefore this endless uninterrupted flux of matter from the sun in light, in place of being an expense that should destroy that orb (which our author takes to be an insupportable objection to sir *Isaac Newton's* scheme) is the very means of preserving it, and every thing else in this system, in its action and vigour, by pressing back perpetual supplies of air to be melted down into light, and thereby producing a continual circulation. These perpetual fluxes or tides of matter outwards and inwards, in every point, from the centre to the circumference, mechanically, and necessarily, as our author insists, produce that constant gyration in the earth and the planets round their own centres, and round the sun; and he avers, though he has not yet thought fit to explain it, that the same principle, with some circumstances arising from the situation and fluxes of light coming from the other orbs, will account also for the motions of the moon.

" Beside the rotation of the orbs, the author affirms that the adverse motions of the light pushing towards the circumference, and the air pushing towards the centre with immense force, form a general expansion (as he translates the word rendered firmament) which brings that stress or compressure on all bodies it meets with, that binds together solids, keeps fluids as they were, causes the variation of times and seasons, the raising of water, the production of vegetables and animals, and, in short, produces all the effects falsely ascribed to gravity or attraction; continues motion without the assistance of the unmechanical principle of projection; produces, supplies, and supports vegetables, fruits, and animals; in short, produces almost all the effects and phænomena in nature."

Note (B), p. 19.—I have scarcely done justice to Parkhurst, Horne, and Jones, those truly learned, pious, and excellent divines of the church of England, in representing them, without qualification, as having adopted the philosophy of Hutchinson. Though they all went a considerable length in embracing the opinions of that singular man, yet they were none of them *thorough Hutchinsonians.* Perhaps the most satisfactory information on this subject may be obtained from the perusal of Mr. Jones's *Memoirs of the Life, Studies, and Writings,* of bishop Horne.

The philosophical works of the rev. Mr. Jones deserve to be mentioned with great respect, in this class of writings which belong to the eighteenth century. On a variety of subjects I am far from agreeing with him in opinion; but his learning, his ingenuity, his love of truth, and particularly the zeal and success with which he shows the consistency between true philosophy and revelation, entitle him to the veneration and gratitude of all good men.

In representing both the knowledge and the admiration of Hutchinson's voluminous writings, as having nearly disappeared before the end of the century, it is possible that the fact is stated rather too strongly. It is believed, however, that very *few* gentlemen now living in Great-Britain, who hold a respectable rank in the scientific world, either embrace the opinions of Hutchinson, or study his works.

It is not easy to account for the prejudices entertained by

Hutchinson and his followers against the philosophy of Newton, as if it were hostile to revelation; and, above all, for the suspicion indulged by him, that sir Isaac and Dr. Clarke had formed a design, "by introducing certain speculations, founded on their new mode of philosophising, to undermine and overthrow the theology of Scripture, and to bring in the heathen *Jupiter*, or the stoical *Anima Mundi* into the place of the true God." I believe that nothing was further from the minds of those great men, than to represent matter as possessing inherent *activity*. If any who profess to be their followers be chargeable with falling into this errour, none can be too severe upon the atheistical tenet. In the Newtonian system, the *attraction* ascribed to all matter is not an *independent principle* or *agent*, but simply a *fact*, referred for its first and continued existence to the immediate power of God. If either class of philosophers be chargeable with going too far in attempting to ascertain *causes*, and in ascribing *agencies* to material objects, it appears to me to be the *Hutchinsonians.*

Note (C), p. 22.—The learning and talents of father Boscovich are universally acknowledged; and he is represented as "unstained in his morals, sincerely attached to the Christian religion, and exact in the performance of all Christian duties, as became a catholic priest." His publications on *Mathematics, Optics, Astronomy, Hydrodynamics,* &c., render him one of the most distinguished men of the age.

The friends of the *Theory of Natural Philosophy* laid before the public by this celebrated Italian speak of it in the highest terms and consider it as one of the noblest efforts of modern genius. It has been substantially adopted by Mr. Mitchel, by Dr. Priestley, and by some other distinguished writers on the physical sciences, who all regard it as relieving philosophy from many pressing difficulties, and opening the way to much new and important light. One great objection to this system immediately presents itself to the mind, and has been forcibly urged against it, viz.—If every particle of matter be strictly *inextended,* wherein does it differ from that *ens rationis,* a mathematical point, *without parts or magnitude?* or rather, wherein does it differ from a mere point of *space?* Will not the adoption of this system conduct its advocate a step further, and lay him under the necessity of denying the *real* existence of a *material world,* and of supposing that what we call by that name is a mere system of *attractions* and *repulsions,* without any *substance* in which they can inhere? It is proper to observe, that Boscovich was aware of this objection, and answered it by denying that *extension* is a necessary attribute of matter. But is not this a *petitio principii?* And if it be admitted, we may well ask, wherein does *matter*, according to this philosopher, differ from *spirit?*

Leibnitz had taught before Boscovich, that the first principles of matter are *inextended points*. The principal difference between the *monads* of the former, and the *inextended atoms* of the latter, lies in the qualities or forces with which they are represented as endowed. The *attractive* and *repulsive* powers of Boscovich differ materially from the *active* and *perceptive* powers of Leibnitz, which he considered as sufficient not only to actuate the *monad* at a particular point of time, but also to produce all the changes which it undergoes from the beginning to eternity.

Boscovich seems to have been the first who rejected all *immediate contact* between bodies, and their constituent particles. In this way he got rid of the difficulty of supposing an *extended* substance to be made up of *inextended* points. Leibnitz, by not resorting to the same bold doctrine, left this difficulty lying in all its force against his system.

Note (D), p. 26.—The following account of experiments on the influence of electricity, in forwarding the germination and growth of plants, is extracted from the *Botanic Garden*, part i, canto i, note.

" The influence of electricity, in forwarding the germination of plants and their growth, seems to be pretty well established; though M. Ingenhousz did not succeed in his experiments, and thence doubts the success of others; and though M. Rouland from his new experiments believes, that neither positive nor negative electricity increases vegetation, both which philosophers had previously been supporters of the contrary doctrine: for many other naturalists have since repeated their experiments relative to this object, and their new results have confirmed their former ones. M. d'Ormoy, and the two Roziers, have found the same success in numerous experiments which they have made in the last two years; and M. Carmoy has shown, in a convincing manner, that electricity accelerates germination.

" M. d'Ormoy not only found various seeds to vegetate sooner, and to grow taller, which were put upon his insulated table, and supplied with electricity, but also, that silk-worms began to spin much sooner which were kept electrified, than those of the same batch which were kept in the same place and manner, except that they were not electrified. These experiments of M. d'Ormoy are detailed at length in the Journal de Physique of Rozier, tom. xxxv, p. 270.

" M. Bartholon, who had before written a tract on this subject, and proposed ingenious methods for applying electricity to agriculture and gardening, has also repeated a numerous set of experiments; and shows both that natural electricity, as well as the artificial, increases the growth of plants, and the germination of seeds; and opposes M. Ingenhousz by very numerous and conclusive facts.—*Ibid.* tom. xxxv, p. 401.

" Since, by the late discoveries or opinions of the chemists, there is reason to believe that water is decomposed in the vessels of vegetables; and that the hydrogen, or inflammable air, of which it in part consists, contributes to the nourishment of the plant, and to the production of its oils, resins, gums, sugar, &c.; and, lastly, as electricity decomposes water into these two airs, termed oxygen and hydrogen, there is a powerful analogy to induce us to believe that it accelerates or contributes to the growth of vegetation, and, like heat, may possibly enter into combination with many bodies, or form the basis of some yet unanalysed acid."

For a number of years after the experiments of Mr. Maimbray, and the abbé Nollet, by which it appeared that electricity had been found to forward the germination and growth of vegetables, there was no doubt entertained of the truth of their doctrine. It remained uncontradicted until Mr. Swankhardt published the facts which he had learned from M. Ingenhousz. Since that time the number of sceptics or opposers has increased; and it seems to be now doubtful whether the first experimenters on this subject were not mistaken.—M. Sennebier, in a late work, concludes that the effect of the electric fluid on vegetables is at least dubious.—See *Physiologie Végétale,* &c. tom. iii, p. 399.

Note (E), p. 29.—The principal advocates of the *Franklinian theory,* viz. that all the phenomena of electricity may be accounted for by the different states and operations of *one homogeneous fluid,* are Canton, le Roy, Priestley, Henley, Beccaria, Cavallo, Morgan, and several others. To the class of those who reject this theory, and consider the agency of *two electric fluids* as necessary to be supposed, belong Symmer, Eeles, Cigna, Adams, Cuthbertson, Darwin, Brooke, and several other distinguished writers on this subject.

Those who adopt the opinion that there are *two electric fluids*, are, however, by no means agreed among themselves. Some, as Symmer, Eeles, Adams, &c., believe in two fluids, which operate on each other, and on other bodies, upon *mechanical* principles. They suppose that these are two distinct, positive, and active powers, which equally and strongly attract and condense each other; that they exist together in all bodies, in their natural state, conjoined; but that their electric signs, or what we call electricity, only become sensible in consequence of the separation of these two powers. That, while united, they are latent and invisible; but when separated they become immediately visible and active. These two fluids or powers are called *Vitreous* and *Resinous* electricities. — See Eeles's *Philosophical Essays*, 1771, and Adams's *Lectures*.

There are others who explain the phenomena of electricity upon *chemical* principles. They also believe in the existence of two distinct and positive fluids; but instead of a *mechanical* operation, they consider all their sensible effects as arising from *chemical* affinity and union. The following theory of Dr. Darwin may serve as a specimen of chemical electricity.—See *Temple of Nature, Additional Notes*, p. 46. 4to. Lond. 1803.

1. There are two kinds of electric ether, which exist either separately or in combination. That which is accumulated on the surface of smooth glass, when rubbed with a cushion, is here termed *vitreous* ether; and that which is accumulated on the surface of resin, or sealing-wax, when rubbed in like manner, is here termed *resinous* ether: and a combination of them, as in their ususl state, may be termed *neutral* electric ethers.

2. Atmospheres of vitreous, or of resinous, or of neutral electricity, surround all separate bodies, are attracted by them, and permeate those which are called conductors, as metallic, aqueous, and carbonic substances; but will not permeate those which are called nonconductors, as air, glass, silk, resin, sulphur.

3. The particles of vitreous ether strongly repel each other, but attract the particles of resinous ether, and *vice versâ*. When the two electric ethers unite, a chemical explosion occurs, in some respects like that of gunpowder, light and heat are liberated, and rend or fuse the bodies which they occupy.

4. Glass holds within it, in combination, much resinous elec-

tric ether, which constitutes a part of it, and which more forcibly attracts vitreous electric ether from surrounding bodies, which stands on it, mixed with a less proportion of resinous ether, like an atmosphere, but cannot unite with the resinous ether combined with the glass. And resin, on the contrary, holds within it, in combination, much vitreous electric ether, which constitutes a part of it, and which more forcibly attracts resinous electric ether from surrounding bodies, which stands on it, mixed with a less proportion of vitreous ether, like an atmosphere, but cannot unite with the vitreous ether which is combined with the resin.

5. Hence the nonconductors of electricity are of two kinds, and opposite to each other; the one class the vitreous, the other the resinous. But the most perfect conductors, such as metal, water, and charcoal, having neither kind of electric ether *combined* with them, though *surrounded* with both, suffer both kinds to pass through them easily.

6. Great accumulation or condensation of the separate electric ethers attract each other so strongly, that they will break a passage through nonconducting bodies. Hence trees and stone walls are rent by lightning.

7. When artificial or natural accumulations of these separate ethers are in very small quantity or intensity, they pass slowly, and with difficulty, from one body to another, and require the best conductors for this purpose. Whence many of the phenomena of the *Torpedo*, or *Gymnotus*, and of *Galvanism.*

8. The electric ethers may be separately accumulated by the contact of conductors with nonconductors—by vicinity of the two ethers—by heat—and by decomposition.

9. When these two ethers unite suddenly, and with explosion, a liberation of light and heat takes place, as in all chemical explosions. Accordingly it is said that a *smell* is perceptible from electric sparks, and even a *taste*, which must be supposed to arise from new combinations or decompositions.

The theory founded on the principles above stated is supposed, by those who adopt it, to solve many difficulties which can scarcely be accounted for on the theory of Franklin. To say that the former mode of accounting for the electrical phenomena will probably be found the true one, would be, in the present state of our knowledge, to pronounce rashly; but if this subject should ever be developed, it will probably be found that *Electricity* ought to be considered as a branch of *Chemistry;* that its phenomena result from the union of two substances, by the chemical combination of which explosion is produced, and light and heat are liberated.

Dr. Gibbes also adopts a chemical theory of electricity. He supposes that oxygen gas is produced by the union of *positive electricity* with water; and hydrogen gas by the union of *negative electricity* with water; and that water, uniting in different proportions with the two electricities, is the ponderable part of all the elastic fluids. He asserts that, by the *positive electricity*, metals are oxydated, and blue vegetable colours reddened; and also that the acidifying effect of electric commotions in the atmosphere, on weak fermented liquors, is unquestionable. On the other hand, according to this writer, by *negative electricity* the vegétable blue is restored, and the oxydated metal revived.

These circumstances, among others, lead Dr. Gibbes to conclude, that when hydrogen gas is produced by the affusion of water on red-hot metal, and the metal is at the same time oxydated, a decomposition of *fire* rather than of *water* has taken place; that the hot metal has parted with negative electricity, which, uniting with a small proportion of the water, has formed hydrogen gas; that a greater proportion of the water has united with the positive electricity, and entered, as oxygen gas, into combination with the metal. When the two gasses are inflamed together the spark attracts to itself, in due proportions, the two electricities contained in the two gasses, which unite with explosion, and produce fire. The water with which they were before combined is of course deposited.

The reason why inflammable substances burn in oxygen gas, and not in hydrogen, Dr. Gibbes supposes to be that negative electricity greatly prevails in all inflammable substances. Neither of the gasses can be inflamed separately, because fire depends on the union of the two electricities; and such union cannot be effected unless both are present in due proportion.

Dr. Gibbes supposes that the further illustration of the effects of the two electricities as chemical agents will set aside some of the leading doctrines of the Lavoisierian theory, and afford an easy solution of certain phenomena which that theory cannot explain.

It is a curious fact that Dr. Gibbes, in supposing that *oxygen* gas is produced by the union of *positive electricity* with water, and that *hydrogen* gas is produced by the union of *negative electricity* with water, was anticipated by Dr. Priestley.—See his Letter to Dr. Woodhouse, Sept. 16, 1801, in the *Medical Repository*. New York, vol. v. p. 158.

Note (F), p. 30.—Mr. Æpinus, of the imperial academy of St. Petersburg, has attempted to class the phenomena of *Electricity* and *Magnetism* in a mathematical method. In the course of his work he gives some views of the subject which are new, and highly ingenious, and, as some good judges suppose, calculated to surmount many difficulties, and to answer many questions which occur in considering the Franklinian theory.—The leading principles of his plan are comprehended in the following propositions.

The phenomena of electricity are produced by a fluid of peculiar nature, and therefore called the *Electric fluid,* having the following properties.

1. Its particles repel each other with a force decreasing as the distances increase.

2. Its particles attract the particles of some ingredients in all other bodies, with a force decreasing, according to the same law, with an increase of distance; and this attraction is mutual.

3. The electric fluid is dispersed in the pores of other bodies, and moves with various degrees of facility through the pores of different kinds of matter. In those bodies which we call *non-electrics,* such as water or metals, it moves without any perceivable obstruction; but in glass, resins, and all bodies called *electrics,* it moves with very great difficulty, or is altogether immovable.

5. The phenomena of electricity are of two kinds:—1. Such as arise from the actual motion of the fluid from a body containing more, into one containing less of it. 2. Such as do not immediately arise from this transference, but are instances of its attraction and repulsion.

These principles are applied at great length, and with a pleasing degree of precision, by the ingenious theorist, to the *Leyden Phial,* and to the various phenomena of electric attraction and repulsion. It will be readily seen that Æpinus adopts, in substance, the theory of Franklin; of which, in some particulars, he presents new and more satisfactory views than the American philosopher. In the sixty-first volume of the *Philosophical Transactions* there is a *Dissertation,* by the honourable Mr. Cavendish, on this subject, which he considers as an extension and more accurate application of Æpinus's theory.

Note (G), p. 33.—The *Gymnotus Electricus* is a native of the river of Surinam, in South America. Those which were carried to England about eight years ago were about three or four feet long, and gave an electric shock, by putting one finger on the back, near its head, and another of the opposite hand into the water near its tail. In their native country they are said to exceed twenty feet in length, and kill any man who approaches them in a hostile manner. It is not only to escape its enemies that this surprising power of the fish is used, but also to take its prey, which it does by benumbing them, and then devouring them before they have time to recover, or by perfectly killing them at once; for the quantity of the power seems to be determined by the will of the animal; as it sometimes strikes a fish twice before it is sufficiently benumbed to be easily swallowed.

The organs productive of this wonderful accumulation of electric matter have been accurately dissected and described by Mr. J. Hunter, *Philos. Trans.* vol. lxv. They are so divided by membranes as to compose a very extensive surface, and are supplied with many pairs of nerves, larger than any other nerves of the body: but how so large a quantity is so quickly accumulated as to produce such amazing effects in a fluid ill adapted for the purpose, is not yet satisfactorily explained. The *Torpedo* possesses a similar power in a less degree, as was shown by Mr. Walsh: so does another fish lately described by Mr. Paterson.—*Phil. Trans.* vol lxxxvi. *Botanic Garden,* part I, canto i, p. 12, note.

Note (H), page 36.—Four epochas may be observed in the history of Galvanism, each of them distinguished by the development of important facts. The *first* was formed by the publication of the fundamental Galvanic fact, *viz.* the production of muscular contraction by the application of metals to the nerves and muscles of animals, and which was entirely limited to organised bodies. The *second* may be derived from the discovery of the Galvanic influence in inorganic matter. The researches of Fabroni, Dr. Ash, and Creve, exhibiting the peculiar action of metals in contact with each other upon water, demonstrated the production of the Galvanic influence in combinations wholly composed of inorganic matter, and thereby connected it with the general principles of physics. The *third* epocha in the history of Galvanism is founded on the discovery of the means of accumulating this influence by the *battery* or *pile* of Volta, which paved the way for a distinct exhibition of the analogy between Galvanism and common electricity. The *fourth* arises from the discovery of the *chemical* agencies of Galvanism. In the prosecution of this last train of inquiry, the principal degree of praise is due to the British experimenters; and, among these, chiefly to Messrs

Carlisle, Nicholson, Cruickshank, Haldane, Henry, and more particularly to Mr. Davy and Dr. Wollaston.

Messrs. Carlisle and Nicholson did much towards establishing the electricity of the pile, by ascertaining that it is *minus* in the silver end, and *plus* in the zinc end. They also demonstrated its chemical action, especially in the decomposition of water; a highly interesting experiment, which has led to many very important results.

Mr. Cruickshank was the first discoverer of the Galvanic production of *alkali*. In his experiments he supposed *ammoniac* to be generated; while, according to those of some others, the alkali produced was thought to be fixed. He likewise invented the mode of placing the metals horizontally in a kind of trough, which, in several respects, is much more convenient than the apparatus of Volta. And he was the first who succeeded in charging the Leyden phial by means of the Galvanic pile.

Mr. William Henry ascertained, by his experiments, that the sulphuric and nitric acids may be decomposed by the operation of the Galvanic influence; but, in his attempts on the muriatic acid, he only succeeded in decomposing the water adhering to it. He also demonstrated that ammoniac may be decomposed in a similar manner.

Colonel Haldane found that the effects of the apparatus of Volta were suspended when it was immersed in water; and that this likewise was the case when it was confined in azotic gas, or placed under the vacuum of an air-pump. He observed that the pile acted more powerfully when immersed in a given quantity of oxygen gas, than in the same bulk of atmospherical air.

Dr. Wollaston has greatly contributed to enlarge our knowledge of the nature and principles of Galvanism. He read an excellent paper on this subject to the Royal Society, which appeared in their *Transactions* for the year 1801. After stating a variety of experiments most ingeniously devised, and cautiously as well as accurately conducted, he advances his induction, from a great number of distinct and luminous proofs, that the phenomena of electricity and Galvanism are all results of the same principle.

But scarcely to any one in Great Britain is Galvanism more indebted for its extension and improvement than to Mr. Davy, of the Royal Institution. Among many other discoveries of less importance, which the rapidity of this sketch does not allow to be mentioned, he first ascertained the fitness of *charcoal*, when used with silver, as a conductor of the Galvanic influence. He discovered that a pile may be constructed with one metal only, provided proper fluids of different kinds be applied to its different surfaces. And he found that a similar result takes place with respect to charcoal alone, if a like diversity in the fluids applied to its different surfaces be duly observed. Mr. Davy also discovered that the energy of the pile is nearly in proportion to the rapidity with which the zinc becomes oxydated; and, consequently, that the effects will be found to be most powerful when nitric acid is interposed between the metals. This seems to be one of the first steps towards the true theory of the action of Volta's pile.

Most of the improvements by the British philosophers above-mentioned were communicated to the public in the course of the year 1801; a year very memorable for the number, variety, and importance of the additions made to the stock of knowledge in this science.

Roused by the success and eclat of the British discoveries which have been just detailed, the votaries of this science on the continent of Europe soon began to furnish their additional contributions.

Tromsdorff found that gold leaf, and other metallic leaves, may readily be subjected to combustion by being fixed to the zinc end of the wire of Volta's pile.

Fourcroy made the remarkable discovery, that the *shock* is greater in proportion to the accumulation of the *number of plates* in the pile, and the *combustion* in proportion to the *extent of their surface.*

Dr. van Marum, of Holland, and professor Pfaff, of Kiel, succeeded in charging *electrical batteries* of 140 feet square, by a single contact with the pile of Volta, and proved that this pile is a true excitatory apparatus of electricity. They melted, by the electricity of this apparatus, a large portion of iron wire, and even wire of *platina.* The communication of Dr. van Marum on this subject to signor Volta (see *Annales de Chimie,* tom. 40) is highly interesting. He charged both single jars and large batteries by means of the pile, and always found that they were charged to the same degree of intensity with that which the pile itself indicated to the electrometer. He found, also, that the shocks given by the battery, when charged from powerful electrical machines, were not perceptibly different from those given by batteries charged from the pile. He found, further, that piles which consist of the same *number* of plates, but of different *diameters,* gave equal intensities and equal shocks; but that those made of larger plates are considerably more powerful in fusing metals.

Dr. Bostock's *Theory of Galvanism.*

John Bostock, M. D. of Liverpool, has offered the following Galvanic theory:—He thinks that the phenomena of the pile of Volta may be all easily explained by admitting the truth of the following *postulates.*

1. That the electric fluid is always generated or liberated when a metal, or any oxydable substance, is united to oxygen.

2. That the electric fluid has a strong attraction for hydrogen.

3. That when the electric fluid, in passing along a chain of conductors, leaves an oxydable substance to be conveyed through water, it unites itself to hydrogen, from which it is again disengaged, when it returns to the oxydable conductor.

The *first* of these propositions Dr. Bostock considers as almost proved by the experiments of Fabroni, Davy, and Wollaston. The *second* and *third* have not been directly established by experiment, but are viewed by Dr. Bostock as highly probable.

Dr. Bostock accounts for the operations carried on at the end of the wire, in the interrupted circuit, as discovered by Nicholson, in the following manner.

As the current of the electric fluid appears to pass from the zinc, or *plus* end of the apparatus, to the silver end, it is first proper to ascertain the action which takes place at the zinc end of the wire. This appears to be the disengagement of oxygen in a concentrated state, by which the wire itself, when oxydable, is corroded; but which, when the wire is formed of a perfect metal, is disengaged in the form of oxygen gas. This oxygen appears to be derived from the decomposition of the water in which the wire terminates, in consequence of the attraction which the electric fluid possesses for hydrogen, and its incapacity of passing through water without being united to this substance, according to the second and third *postulates.* The electric fluid, thus united to hydrogen, is carried to the other point of the wire, where, upon entering the oxydable conductor, it is disengaged in the form of hydrogen gas, if water be the medium of communication. If a solution of metallic oxyd be employed, it unites with the oxyd, and reduces it. The decomposition of water is, therefore, effected at the zinc point alone, though the different gases which compose it are disengaged at each of the points; and the process will continue even when the points terminate in two different portions of water, as was discovered by Mr. Davy, provided that the glasses are united by a conductor which is not oxydable.

To explain the operation carried on in the body of the pile itself, Dr. Bostock says—

In the construction of the pile there are two points which are essential to its action; viz. 1. That the electric fluid be disengaged; and, 2. That it be confined and carried forward in one direction, so as to be concentrated in the end of the apparatus. The first object is evidently attained by the oxydation of the zinc, or other oxydable body employed. If both sides of the zinc were oxydated, the electric fluid would, indeed, be liberated, but it would be immediately dispersed, and its effects could not be observed. As soon, however, as the electric matter is evolved, it is immediately attracted by the hydrogen; which is, at the same time, necessarily generated in the fluid which oxydates the metal; and it is by this means conveyed across the water to the silver plate, when two metals are used, or, in other cases, simply to the opposite surface of the oxydating substance. The electric fluid then enters the silver plate, and, instantly passing on to the contiguous zinc plate, arrives at a second oxydating surface. The same series of events that have been described is here repeated, except that the electric fluid being in some degree accumulated in the metallic plate, is disengaged by the second oxydating surface in larger quantity, and in a more concentrated state than before. By pursuing the same train of operations, it is easy to see how the electric matter will continue to be accumulated in each successive pair of plates, until, by sufficient repetition, it may be made to exist, in the zinc end of the pile, in any assigned degree of force.

The analogy between Galvanic phenomena and many circumstances connected with muscular action, and other processes of vitality, began, several years ago, to make an impression on the minds of many who engaged in the pursuit of this science. The appearance of Galvanic action in living animals, such as the *Torpedo*, &c., was found strongly to confirm this impression. Organised beings contain all the substances necessary for the formation of Galvanic arrangements; and chemical changes are continually going on in different parts of the living body, which are probably connected with variations in their states of electricity. These circumstances, together with the original Galvanic fact of the production of muscular contraction when the influence was applied, and the dependence of irritability, and even life, upon the oxygenation of the blood, served to strengthen the analogy.

These speculations seem to have been reduced almost to demonstration by some recent experiments. Professor Aldini, of Bologna, is supposed to have decisively shown, that a vital attraction subsists between a nerve and muscle. The suspended sciatic nerves of a frog, after detaching the spine, being brought near the intercostal muscles of a dog, while the assistant who held the frog, with his other hand, touched the muscles of the thigh of the dog (thus forming a circle); in this situation the suspended nerves approached and came into contact with the muscle, as evidently as a silken thread is attracted by sealing-wax. But a still more important fact was that of exciting contractions by making a circle of nerves and muscles, of different animals, without employing any metallic exciter or conductor. M. Circaud found that the coagulum of blood recently drawn from a living animal is susceptible of the Galvanic stimulus, as appeared from contractions evidently excited by the pile of Volta. And M. Garve formed a kind of pile, by alternate pieces of muscle and brain, with the intervention of pasteboard or cloth, which produced, in some small degree, similar phenomena with those of the common pile.

Identity of Electricity and Galvanism.

There appears to be now no longer any doubt that the Galvanic and electric fluids are the same, differing in the means of their excitement, and in the modes of their exhibition. Beside the evidence arising from the celebrated experiment of van Marum, in which a large electrical battery was charged by a single contact with the pile of Volta, as before stated, we find, among the Galvanic phenomena, indications of the *plus* and *minus*, or the negative and positive operation, which holds so important a station among the doctrines of electricity: we find also the electric *spark*, and substantially the same results, on employing the *Condenser* of electricity and the *Electrometer*. The interesting experiments of Dr. Wollaston, before-mentioned, tend strongly to the establishment of this point. He even found that, when common electricity is passed through water, by means of two very fine metallic points, chemical changes are effected by it, similar to those occasioned by the transmission of the Galvanic influence.

It is scarcely necessary to add, that the most able experimenters on the subject of Galvanism are as unanimous in considering this fluid as an important *chemical* agent.—"That a strong chemical action takes place among the substances composing the pile of Volta is clearly proved, since one of the metals is always *oxydated*, and the saline solution employed to moisten the pasteboard is decomposed; and that this action is intimately connected with the excitation of the electric energy, is established by numerous experiments. The power of the apparatus ceasing when it is placed in the exhausted receiver of the air-pump, or in a vessel filled with azotic or hydrogen gas, strongly illustrates this point. When it is considered, also, that the apparatus is more powerful in oxygen gas than in the atmospheric air, and that in either the oxygen is consumed; and that its powers are much increased when the water in contact with the metal holds in solution oxygen, nitrous gas, diluted nitric or muriatic acid, or any substance which either affords oxygen with facility, or promotes the oxydation of the metal, the evidence of strong chemical action will be viewed as still more unquestionable. The power of the Galvanic series or column seems, indeed, to be proportioned to the oxydation of the metal which composes it; and hence it may, with much probability, be concluded, that it is to this chemical action that the excitation of the Galvanic influence is owing."

Those who wish to see a more detailed account of the history of Galvanism, especially of the numerous and very interesting experiments and discoveries made in this branch of philosophy, in the years 1801 and 1802, will do well to consult the *Philos. Trans.* for 1801, Tilloch's *Philos. Mag.*, and Nicholson's *Journal of Natural Philosophy.*

Note (I), p. 37.—The theory of this celebrated philosopher of St. Petersburg may be comprised in the following propositions.

1. There exists a substance in all magnetic bodies, which may be called the magnetic fluid; the particles of which repel each other with a force decreasing as the distances increase.

2. The particles of magnetic fluid attract and are attracted by the particles of iron, with a force that varies according to the same law.

3. The particles of iron repel each other according to the same law.

4. The magnetic fluid moves, without any considerable obstruction, through the pores of iron and soft steel: but it is more and more obstructed in its motion as the steel is tempered harder; and in hard tempered steel, and in the ores of iron, it is moved with the greatest difficulty.

5. When the quantity of this fluid contained in iron is such that the accumulated attraction of a particle for all the iron balances, or is equal to, the repulsion of all the fluid which the iron contains, the quantity may be said to be the *natural quantity* of the iron, which may then be said to be in its *natural state.*

6. The magnetic fluid may be abstracted from one end of a magnetic bar, and constipated in the other, and on this depends the exertion of its force. In other words, the condensation and motion of the magnetic fluid are subject to the same laws *(mutatis mutandis)*, in the opinion of this philosopher, as the electric fluid on the Franklinian theory, the motion and sensible signs of which depend on the *plus* and *minus* states, or the deficiency and redundancy of the same fluid in different bodies.

Note (K), p. 37.—" As every piece of iron which was made magnetical by the touch of a magnet became itself a magnet, many attempts were made to improve these artificial magnets, but without much success, till Servingdon Savary, esq. made them of *hardened steel bars,* which were so powerful, that one of them, weighing three pounds avoirdupois, would lift another of the same weight.

" After this Dr. Gowin Knight made very successful experiments on this subject, which, though he kept his method secret, seems to have excited others to turn their attention to magnetism. About this time the rev. Mr. Michel invented an equally efficacious and more expeditious way of making strong artificial magnets, which he published in the end of the year 1750, in which he explained his method of what he called the *Double Touch,* and which, since Dr. Knight's method has been known, appears to be somewhat different from it.

" This method of rendering bars of hardened steel magnetical consists in holding vertically two or more magnetic bars nearly parallel to each other, with their opposite poles very near each other (but, nevertheless, separated to a small distance): these are to be slided over a line of bars, laid horizontally, a few times backward and forward.

" What Mr. Michel proposed by this method was, to include a very small portion of the horizontal bars intended to be made magnetical, between the joint forces of two or more bars already magnetical, and, by sliding them from end to end, every part of the line of bars became successively included; and thus bars, possessed of a very small degree of magnetism to begin with, would, in a very few times sliding backwards and forwards, make the other ones much more magnetical than themselves, which are then to be taken up and used to touch the former, which are in succession to be laid down horizontally in a line."—*Botanic Garden*, Part I, Canto ii, l. 193, note.

Dr. Knight's method of making *artificial magnets*, referred to by Dr. Darwin in the abvove-mentioned note, was as follows: He reduced iron to a very subtle powder, made it into a paste with oil, moulded the composition into pieces of a convenient form, dried them before a moderate fire, and then imparted to them the magnetic virtue, by placing them between the extreme ends of his large magazine of artificial magnets, for a few seconds or more, as he thought requisite.

After Michel, the manufactory of artificial magnets received further improvements by Mr. Canton, in 1756, and by M. Antheaume, in 1766.

Note (L), p. 40.—Among other attempts to extend the bounds of chemistry, it has been lately proposed to place the magnetic fluid in the list of its subjects. Accordingly, several writers have considered this fluid as a chemical agent, and explained its phenomena on corresponding principles. Among these, Dr. Darwin, in the *Additional Notes* to his *Temple of Nature*, proposes the following hypothesis.

1. Magnetism coincides with electricity in so many important points, that the existence of *two magnetic ethers*, as well as of two electric ones, becomes highly probable.

2. In a common bar of iron or steel, the two magnetic ethers (which, for the greater ease of speaking, may be called *arctic ether* and *antarctic ether)*, exist intermixed, or in their *neutral* state: in this state, like the two electric fluids, they are not cognizable by the senses.

3. When these two magnetic ethers are separated from each other, and the *arctic* ether is accumulated in one end of an iron or steel bar, which is then called the north pole of the magnet; and the *antarctic* ether is accumulated in the other end of the bar, which is then termed the south pole of the magnet, they become

capable of attracting other pieces of iron or steel, and are thus cognisable by experiments.

4. It seems probable that it is not the magnetic ether itself which attracts or repels particles of iron; but that an attractive and repulsive ether attends the magnetic ethers, as in the case of the electric.

5. While the two electric ethers, when separated by nature or art, combine, by chemical affinity, with explosion, emit light and heat, and leave a residuum; the two magnetic ethers, after being separated in like manner, combine by chemical affinity, but without explosion, and produce, by their union, a neutralised fluid.

Note (M), p. 43.—This great practical philosopher was born, about the year 1753, at Woburn, a small town in Massachusetts, ten miles north of Boston. His parents were in humble life, and his advantages, with respect to education, were small. But he was early distinguished as a lad of spirit and enterprise, and discovered a fondness for knowledge. After spending some time in a retail store in Boston, where he was more fond of amusing himself with a *violin* than of attending on customers, and preferred making experiments with an *electrical machine* to either, he returned to Woburn: here, however, he did not remain long. In 1772 he attended professor Winthrop's lectures on experimental philosophy, in Harvard college. He was not a matriculated student; but, being regarded as an ingenious and promising young man, was permitted to attend this part of the usual course of instruction, for which he manifested a particular predilection.

In 1772 or 1773, young Thompson went to New Hampshire, and settled in a town called *Rumford,* at that time under the jurisdiction of Massachusetts, but afterwards, by a new territorial arrangement, assigned to New Hampshire, and now called *Concord.* Here he married a widow, of the name of Rolfe, with whom he received a large fortune. In 1775 he went to England; and, soon after his arrival, was introduced to lord George Germaine, then secretary of state, to whom he so far recommended himself as to be appointed one of the first clerks in his office. When his lordship went out of office, he still exerted his influence in favour of Mr. Thompson, and obtained for him a colonel's commission. With this commission, towards the close of the American war, he came to New York, with the view of raising a regiment of loyalists; but the regiment was never completed; he was, however, still active in the service of the king, and, soon after the peace of 1783, he returned to England.

Here the proofs of his activity, enterprise, and philosophic acuteness, and particularly of his taste for improvements in military affairs, were so numerous, that he began to attract more public attention than before, and offers were made to him of preferment in foreign service. He at length accepted a flattering invitation given to him by the reigning duke of *Bavaria*, and went into his service in 1784. By this prince he was made lieutenant-general of horse, and soon rendered himself conspicuous by introducing a new system of order, discipline, and economy among the troops under his command. He remained a number of years in Bavaria, where he was much distinguished by his successful exertions to destroy mendicity, and to meliorate the condition of the poor; and by a variety of improvements highly favourable to manufactures, economy, and humanity. On leaving the service of the elector he was created a count; his title being taken, by his own choice, from the name of the town in America in which he had for some time resided.

Count Rumford has chiefly resided, for a number of years past, in Great Britain, where he has been so much celebrated for his experiments, discoveries, and improvements in military, economical, and chemical science, that it is unnecessary to dwell on his merits. Beside the new light which he threw on the subject of *gunnery*, before mentioned, the friends of science and humanity are indebted to him for improved methods of constructing *chimnies* and *stoves;* for important discoveries and improvements relative to *cookery* and *aliment;* for curious and highly interesting experiments on heat; &c. In short, it seems to be generally agreed, that he stands in the first class, if not at the head, of all the *practical*, and particularly the *economical* philosophers, now living.

He was *knighted* by the king of Great Britain in 1784, and has received many honourable testimonies of public and private respect in that country. His only child, a daughter, now resides in the town of Boston.

Note (N), p. 57.—" The expansive force of steam was known, in some degree, to the ancients. Hero, of Alexandria, describes an application of it to produce a rotatory motion by the reaction of steam issuing from a sphere mounted upon an axis, through two small tubes bent into tangents, and issuing from the opposite sides of the equatorial diameter of the sphere; the sphere was supplied with steam by a pipe communicating with a pan of boiling water, and entering the sphere at one of its poles.

"A French writer, about the year 1630, describes a method of raising water to the upper part of a house, by filling a chamber with steam, and suffering it to condense of itself; but it seems to have been mere theory, as his method was scarcely practicable as he describes it. In 1655, the marquis of Worcester mentions a method of raising water by fire, in his Century of Inventions; but he seems only to have availed himself of the expansive force, and not to have known the advantages arising from condensing the steam by an injection of cold water. This latter and most important improvement seems to have been made by capt. Savary, some time prior to the year 1698, for in that year his patent, for the use of that invention, was confirmed by act of parliament. This gentleman appears to have been the first who reduced the machine to practice, and exhibited it in a useful form. His method consisted only in expelling the air from a vessel by steam; condensing the steam by an injection of cold water, which making a vacuum, the pressure of the atmosphere forced the water to ascend into the steam-vessel through a pipe of 24 or 26 feet high; and, by the admission of dense steam from the boiler, forcing the water in the steam-vessel to ascend to the height desired. This construction was defective, because it required very strong vessels to resist the force of the steam, and because an enormous quantity of steam was condensed by coming into contact with the cold water in the steam-vessel.

"About, or soon after that time, M. Papin attempted a steam-engine on similar principles, but rather more defective in its construction.

"The next improvement was made very soon afterwards by Messrs. Newcomen and Cawley, of Dartmouth: it consisted in employing for the steam-vessel a hollow cylinder, shut at bottom and open at top, furnished with a piston sliding easily up and down in it, and made tight by oakum or hemp, and covered with water. This piston is suspended by chains from one end of a beam, moveable upon an axis in the middle of its length: to the other end of this beam are suspended the pump-rods.

"The danger of bursting the vessels was avoided in this machine; as, however high the water was to be raised, it was not necessary to increase the density of the steam, but only to enlarge the diameter of the cylinder.

"Another advantage was, that the cylinder, not being made so cold as in Savary's method, much less steam was lost in filling it after each condensation.

"The machine, however, still remained imperfect; for the cold water thrown into the cylinder acquired heat from the steam it condensed, and being in a vessel exhausted of air, it produced steam itself, which, in part, resisted the action of the atmosphere on the piston; were this remedied by throwing in more cold water, the destruction of steam in the next filling of the cylinder would be proportionably increased. It has, therefore, in practice, been found advisable not to load these engines with columns of water weighing more than seven pounds for each square inch of the area of the piston. The bulk of water, when converted into steam, remained unknown, until Mr. J. Watt, then of Glasgow, in 1764, determined it to be about 1800 times more rare than water. It soon occurred to Mr. Watt, that a perfect engine would be that in which no steam should be condensed in filling the cylinder, and in which the steam should be so perfectly cooled as to produce nearly a perfect vacuum.

"Mr. Watt having ascertained the degree of heat in which water boiled in vacuo, and under progressive degrees of pressure, and instructed by Dr. Black's discovery of latent heat, having calculated the quantity of cold water necessary to condense certain quantities of steam so far as to produce the exhaustion required, he made a communication from the cylinder to a cold vessel previously exhausted of air and water, into which the steam rushed, by its elasticity, and became immediately condensed. He then adapted a cover to the cylinder, and admitted steam above the piston to press it down instead of air, and instead of applying water, he used oil or grease to fill the pores of the oakum, and to lubricate the cylinder.

"He next applied a pump to extract the injection water, the condensed steam, and the air, from the condensing vessel, every stroke of the engine.

"To prevent the cooling of the cylinder by the contact of the external air, he surrounded it with a case containing steam, which he again protected by a covering of matters which conduct heat slowly.

"This construction presented an easy means of regulating the power of the engine, for the steam being the acting power, as the pipe which admits it from the boiler is more or less opened, a greater or smaller quantity can enter during the time of a stroke, and, consequently, the engine can act with exactly the necessary degree of energy.

"Mr. Watt gained a patent for his engine in 1768; but the further prosecution of his designs was delayed by other avocations till 1775, when, in conjunction with Mr. Boulton, of Soho, near Birmingham, numerous experiments were made, on a large scale, by their united ingenuity, and great improvements added to the machinery, and an act of parliament obtained for the prolongation of their patent for twenty-five years: they have, since that time, drained many of the deep mines in Cornwall, which, but for the happy union of such genius, must immediately have ceased to work. One of these engines works a pump of eighteen inches diameter, and upwards of a hundred fathom, or 600 feet high, at the rate of ten or twelve strokes, of seven feet long each, in a minute, and that with one fifth part of the coals which a common engine would have taken to do the same work. The power of this engine may be easier comprehended, by saying, that it raised a weight equal to 81000 pounds, eighty feet high, in a minute, which is equal to the combined action of two hundred good horses. In Newcomen's engine this would have required a cylinder of the enormous diameter of 120 inches, or ten feet; but as in this engine of Mr. Watt and Mr. Boulton the steam acts, and a vacuum is made, alternately above and below the piston, the power exerted is double to what the same cylinder would otherways produce, and is further augmented by an inequality in the length of the two ends of the lever.

"These gentlemen have also, by other contrivances, applied their engines to the turning of mills for almost every purpose, of which that great pile of machinery, the Albion Mill, is a well-known instance. Forges, slitting-mills, and other great works, are erected where nature has furnished no running water, and future times may boast that this grand and useful engine was invented and perfected in our own country."—*Botanic Garden,* Part i, *Additional Note* XI.

Note (O), *p.* 64.—It appears that Dollond was not the first person who invented *Achromatic* glasses. As early as 1729, Chester More Hall, esq., of *More-Hall,* in the county of Essex, as appears by his papers, considering the different humours of the eye, imagined they were placed so as to correct the different refrangibility of light. He then conceived, that if he could find substances having such properties as he supposed these humours might possess, he should be enabled to construct an object glass that would show objects *colourless*. After many experiments, he had the good fortune to find these properties in two different kinds of glass; and by forming lenses made of such glass, and making them disperse the rays of light in contrary directions, he succeeded. About 1733 he completed several achromatic object glasses (though he did not give them this name), that bore an aperture of more than two inches and a half, though the focal length did not exceed twenty inches. One of these glasses, which, in 1790, was in possession of the rev. Mr. Smith, of Charlotte-street, Rathbone Place, London, has been examined by several gentlemen of eminence in the scientific world, and found to possess the properties of the present achromatic glasses.

In the trial at Westminster-Hall, about the patent for making achromatic telescopes, Mr. Hall was allowed to be the inventor; but lord Mansfield observed, "that it was not the person who locked up his invention in his scrutoire that ought to profit by a patent for such invention, but he who brought it forth for the benefit of the public."

That Mr. Ayscough, optician, on Ludgate-Hill, was in possession of one of Mr. Hall's achromatic telescopes in 1754, is a fact indisputable.—*Gentleman's Magazine*, vol. lx, part ii, for 1790, p. 890, &c.

Note (P), p. 75.—Since the close of the eighteenth century *two new planets* have been discovered. The first was discovered January 1, 1801, by Mr. Piazzi, of Palermo, in Sicily. It is called by the discoverer *Ceres*, but by his brother astronomers *Piazzi*. The second was discovered on the 28th of March, 1802, by Dr. Olbers, of Bremen, and is called by him *Pallas*, but others give it the name of *Olbers*.

The planet *Piazzi* (or *Ceres*) revolves between Mars and Jupiter. It is not, apparently, larger than a fixed star of the eighth magnitude. The inclination of its orbit to the plane of the ecliptic is about 10 deg. 36 min. 57 sec., and the time of its periodical revolution is four years, seven months, and ten days.

The planet *Olbers* (or *Pallas*) also revolves in the wide space between Mars and Jupiter. It differs very little in appearance from stars of the eighth magnitude. The inclination of its orbit to the plane of the ecliptic is 35 deg., a very extraordinary degree of obliquity, which shows that the *Zodiac* must be considerably enlarged, if we continue to distinguish by that name the zone in the heavens in which all the planets perform their revolutions. The period of its revolution is four years, eight months, and three days.

The orbits of these two planets are nearer together than those of any others in our system. In its distance from the sun *Piazzi* varies from 21 to 25, and *Olbers* from 27 to 28, taking the distance of the earth as the standard, and estimating it at 10.

Beside the discoverers, Herschell, de la Lande, Delambre, and Burckhardt, have particularly distinguished themselves in observing the phenomena, and in calculating the elements, of these planets.—Mr. Herschell proposes to designate these celestial bodies, for the present, by the term "Asteroids."

Note (2), p. 79.—Catalogues of stars are of two kinds, either as collected into certain figures called *Constellations*, or according to their *right ascensions*, or, in other words, according to their order in passing over the meridian.

The first specimen of this latter kind of catalogue, that is, according to the order of the right ascensions, was that published by de la Caille, in 1755. It contains the right ascensions and declinations of 307 stars, adapted to the beginning of the year 1750. In 1757 the same great astronomer published his *Astronomiæ Fundamenta*, containing a catalogue of the right ascensions and declinations of 398 stars. And in 1763, the year after his death, was published the *Cœlum Australe Stelliferum*, also by the same author, containing a catalogue of the places of 1942 stars.

In the *Nautical Almanack* for 1773 is given a catalogue of 387 stars, in right ascension, declination, longitude, and latitude, derived from the observations of the celebrated Dr. Bradley, astronomer royal of Great Britain, and adapted to the beginning of the year 1760.

In 1775 was published a catalogue among the papers of the late Tobias Mayer, containing the right ascensions and declinations of 998 stars, which may be occulted by the moon and planets, adjusted to the year 1756.

At the end of the first volume of "Astronomical Observations made at the Royal Observatory at Greenwich," published in 1776, Dr. Maskelyne, the present astronomer royal, has given a catalogue of the places of 34 principal stars, in right ascension, and north polar distance, adapted to the beginning of the year 1770.

In 1782, prof. Bode, of Berlin, published a very extensive catalogue of 5058 stars, collected from the observations of Flamstead, Bradley, Hevelius, Mayer, de la Caille, Messier, Monnier, d'Arquier, and other astronomers; all adapted to the beginning of the year 1780, and accompanied with a celestial atlas, or set of maps of the constellations, engraved in a very delicate and beautiful manner.

To these may be added Dr. Herschell's catalogue of double stars, printed in the *Philosophical Transactions* for 1782 and 1783; Messier's *nebulæ* and clusters of stars, published in the *Connoissance des Temps* for 1784; and Herschell's catalogue of the same kind, given in the *Philosophical Transactions* for 1786.

In 1792, Dr. von Zach, of Gotha, annexed to his *Tabulæ Motuum Solis* a new catalogue of the principal fixed stars, from his own observations, made in the years 1787, 1788, 1789, 1790. This catalogue contains the right ascensions and declinations of 381 principal stars, adapted to the beginning of the year 1800.

But all these catalogues yield, both in extent and value, to that of de la Lande, whose diligence, skill, and perseverance, in this department of astronomical observation, do him the highest honour.—*Supplement to the Encyclopædia.*

Note (R), p. 82.—Professor Testa, of Rome, has read to the Academy of Religion there, a memoir written by him, in which he proves, in the most evident manner, that the *Zodiacs* lately discovered in Egypt have not that antiquity which some pretend to give them; and, consequently, that they prove nothing against the chronology of Moses. He asserts that the Egyptians were not acquainted with the motion of the fixed stars in longitude, and that Hipparchus was the first who discovered it. Hipparchus, the astronomer here alluded to, was a native of Nicea, and flourished about the year 129 before Jesus Christ. Professor Testa remarks also, that the Zodiac of Dendera is found in a temple of Grecian architecture, which bears the name of Tiberius; that this temple not being two thousand years old, the Zodiac discovered in it cannot have existed above four thousand; that in these Zodiacs is seen the sign of Libra, a constellation absolutely unknown to the ancient Egyptians. It appears, therefore, that a certain class of philosophers will not derive from the discovery of these Zodiacs that advantage which they expected.

Note (S), p. 85.—It is asserted in the page here quoted, that the celebrated instrument called the *quadrant*, which bears the name of Mr. Hadley, and which is generally ascribed to him as the inventor, was really invented by Mr. Thomas Godfrey, of Philadelphia. It will be proper, in this place, to give the reader some account of Mr. Godfrey, and of the evidence on which the above assertion was made.

The fullest and most satisfactory information on both these points, which the author has been able to obtain, is presented in the following letters, extracted from the *American Magazine*, for the months of July and August, 1758. Two of these letters are written by James Logan, esq., the distinguished classic scholar and botanist whose name has been mentioned in several parts of this work. For furnishing him with accurate copies of these documents, the author is indebted to his friend Ebenezer Hazard, esq., of Philadelphia, a gentleman who has been long distinguished for his researches in various departments of American history, and who has probably amassed a larger store of curious relics and facts relating to this extensive subject, than any other individual in the United States.

From the American Magazine for July, 1758, p. 475.

To the Proprietors, &c.

GENTLEMEN,

All civilised states have thought it their honour to have men of great ingenuity born or bred among them. Many cities of ancient *Greece* had long and sharp contentions for the honour of Homer's birth-place. And in latter times volumes have been written in *Europe*, in disputing which city had the true claim to the invention of the art of printing. Nor is it to be wondered that mankind should be so generally eager in this respect, since nothing redounds more to the honour of any state than to have it said that some science of general utility to mankind was invented or improved by them. Nevertheless it often happens that the true author of many a useful invention, either by accident or fraud, loses the credit thereof, and from age to age it passes in the name of another. Thus it happened, heretofore, to Columbus and many others; and thus also it happened to a native of *Philadelphia*.

Mr. Thomas Godfrey, it is well known to many of us here, was the real inventor of that very useful instrument called Hadley's quadrant or octant. To him the merit is due, and to his posterity the profit ought to belong. This will fully appear from the three following genuine letters, which, I persuade myself, you will think worthy of being recorded in your magazine, in order to restore, as far as possible, the credit of that invention to our city, and to the posterity of Mr. Godfrey. How he came to be deprived of it may be made a question by some. I answer that Mr. Godfrey sent the instrument to be tried at sea by an acquaintance of his, an ingenious navigator, in a voyage to *Jamaica*, who showed it to a captain of a ship there just going for *England*, by which means it came to the knowledge of Mr. Hadley, though, perhaps, without his being told the name of the real inventor. This fact is sufficiently known to many seamen and others yet alive in this city; and established beyond doubt by the following letters, written about that time. It is, therefore, submitted to the world whether, after perusing the letters, they ought not, in justice, to call that instrument, for the future, Godfrey's, and not Hadley's, quadrant.

To Dr. EDMUND HALLEY *.

ESTEEMED FRIEND,

The discovery of the longitude having, of late years, employed the thoughts of many, and the world now expecting, from thy great sagacity and industry, some advances towards it, far exceeding all former attempts, from the motion of the moon, to the ascertaining of which thy labours have so long and happily been directed; the following notice, I hope, will neither be thought unseasonable nor prove unacceptable. That the success of this method depends on finding the moon's true place for one meridian by calculation, and for another by observation, I think is generally allowed; the first of which being depended on from thy great genius, what remains is some certain method for observation, practicable on that uncertain element the sea. In order to this, thy predecessor at *Greenwich*, if I mistake not, for some years published his calculations for the moon's future appulse to the fixed stars, which would save all observation but that of a glass; but these not often happening, and the moon often having a considerable parallax when they did, that project dropped.

For finding her place by taking her greater distances from stars, the fore-staff or cross-staff cannot be exact enough: and quadrants, sextants, &c., with two telescopes, are impracticable at sea.

Dr. Biester's late proposal for taking the difference of right

* An introductory paper which I have not transcribed, not thinking it important, mentions this letter as N° 435 in the *Philosophical Transactions*, and entitled an "Account of Mr. Thomas Godfrey's Improvement of Davis's Quadrant transferred to the Mariner's Bow."

E. H.

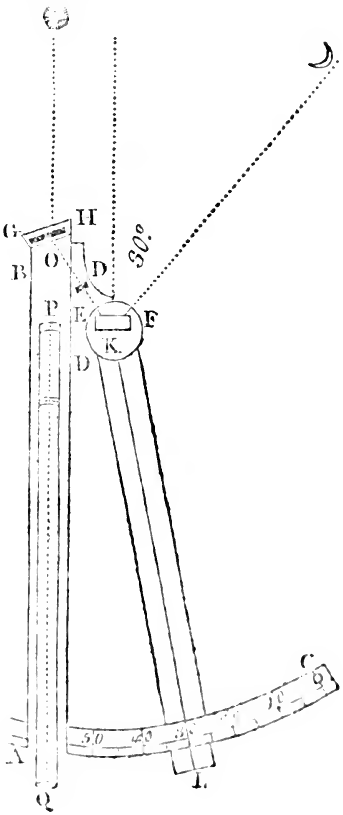
ascension between the moon and a star, if that should prove practicable with sufficient exactness, would undoubtedly answer the intention of all that is to be expected from the moon, if her place were taken on or near the meridian. But to keep the arch of this instrument in the plane of the equator, and at the same time view two objects of unequal altitudes, and considerable distance from each other, by the edges of two sights, with the necessary accuracy, will not perhaps be so easy in practice as he would have it believed.

I shall, therefore, here presume, from thy favour shown me in England, in 1724, to communicate an invention that, whether it answer the end or not, will be allowed, I believe, to deserve thy regard. I have it thus:

A young man, born in this country, Thomas Godfrey by name, by trade a glazier, who had no other education than to learn to read and write, with a little common arithmetic, having, in his apprenticeship with a very poor man of that trade, accidentally met with a mathematical book, took such a fancy to the study, that, by the natural strength of his genius, without any instructor, he soon made himself master of that, and of every other of the kind he could borrow or procure in *English;* and finding there was more to be had in *Latin* books, under all imaginable discouragements, applied himself to the study of that language, till he could pretty well understand an author on these subjects; after which, the first time I ever saw or heard of him to my knowledge, he came to borrow sir Isaac Newton's *Principia* of me. Inquiring of him hereupon who he was, I was indeed astonished at his request; but after a little discourse he soon became welcome to that or any other book I had. This young man, about eighteen months since, told me he had for some time been thinking of an instrument for taking the distances of stars by reflecting speculums, which he believed might be of service at sea; and not long after he showed me a common sea quadrant, to which he had fitted two pieces of looking-glass in such a manner as brought two stars, at almost any distance, to coincide; the one by a direct, the other by a reflecting ray, so that the eye could take them both together as joined in one, while a moving label or index on the graduated arch marked exactly half their distance: for I need not say that the variations of the angles of reflexion from two speculums are double to the angle of the inclination of their planes, and therefore give but half the angle or arch of the distance, which is the only inconveniency that appears to me to attend this. But as it may be made so simple, easy, and light, as not to be much more unwieldy or unmanageable, though of considerable length, than a single telescope of the same, that inconveniency will be abundantly compensated.

The description of it, as he proposes it, and has got one made, is nearly thus, which he is willing I should communicate to thee, if possibly it may be of service.

To a straight ruler or piece of wood, AB, of about three inches in breadth, and from forty to forty-five in length (or of any other that may be thought convenient), with a suitable thickness: an arch or limb, AC, of about 30 degrees to the radius, KL, is to be fixed. To the upper end of the piece AB, a piece, DD, is to be morticed, and in it the centre K taken, so that OP may be about six inches, and the angle KOP about 40 degrees. On this centre K, the ruler or index KL is to move, having a fiducial edge below answerable to the central point, to cut the graduations on the limb. On the upper end of this index a speculum of silvered glass, or rather metal, exactly plain, EF, of about three inches in length and two in height, is erected perpendicular to the plane of the index, and also nearly at right angles with its sides, the plane of the reflecting surface standing exactly over the central point. At the end B, of the piece AB, another speculum of glass is to be in the same manner erected, which may be somewhat less than the other, with a square or oblong spot in it unsilvered, that a star, by a direct ray, may be seen through it; and the back of this speculum should be guarded with a thin brass



plate, with an aperture in it equal to the unsilvered part of the glass; the edge of the aperture toward H to be exactly straight, dividing between the silvered and unsilvered part of the speculum, and standing in the line of the axis of the telescope. This speculum is to be set at an angle of about 20 degrees, with the square of the piece AB, or at 110 degrees, with the sides of it. Upon the piece AB, the telescope PQ is fixed, of a good aperture and field, with the axis placed as above. The limb is to be graduated by diagonals, or parallel circles, to half degrees and half minutes, beginning from C, which are to be numbered as whole ones. And if it be practicable to face wood with brass without warping, the whole face should be so covered; if not, then along the outward edge of the limb a narrow strip of brass plate may be let into the face of it, finely and equally indented on the edge, to take a screw fitted to that toothing to be fixed on the moving index at L, as your instruments are made that count by revolutions; and then, before this is used, it would be proper to take the distance of the two objects first nearly by a fore-staff, and from thence accordingly to set the index. This screw, at land, would be highly useful, but at sea it cannot be wrought, while the instrument is directed by the same person; though, as the motion of the moon and variation of the angle is but slow, it may be brought to exactness by several trials in the intervals of direction. The instrument, as above described, will not take an angle of much above 50 degrees, which, for the purpose intended, may be fully sufficient, But if the speculum EF be made to take off and put on, and the end of the index at K be so notched as to turn that speculum from its first perpendicularity, to make an angle of about 25 degrees, it will then take any distance to 100 degrees.

By this description it may be thought that the utmost accuracy will be required in making the instrument: yet, of all that ever have been invented of so curious a kind, it will probably be found to demand the least; for, provided the speculums are good, on which the whole depends, if the first EF be set truly over the centre, the limb well graduated, and the other speculum be also set perpendicular, there can, I think, be no other errour but what the instrument itself will easily rectify: for if it be directed to one star, and that be taken, at the same time, both by a direct ray through the glass GH, and by a reflexion from EF, both exactly coinciding at O, it is evident that then the speculums are exactly parallel. And if this falls not precisely when the index cuts 0 degrees, if the variation be noted, this constantly added or subtracted, according as it falls, will fully rectify all other errours. So in fixing the speculum EF to another angle, as has been proposed, the like method may or must be taken, *viz.* to observe two stars at the distance of about 45 or 50 degrees, by the speculum, in its first situation, and then the same stars by it again in its second, and the difference of the intervention of the index on the limb being noted, and constantly added to the arches taken in the second situation, will give the true distance. This method of observing one and the same star, in the first manner, or two stars in the second, as has been mentioned, will also rectify errours even in the speculums: for the line of the ray KO is in all cases constantly the same; and, upon the whole, I may safely say the instrument will be found much more certain in practice than at first it may appear in theory, even to some good judges. But I am now sensible I have trespassed in being so particular when writing to Dr. Halley; for I well know, that to a gentleman noted for his excellent talent of reading, apprehending, and greatly improving, less would have been sufficient; but as this possibly may be communicated by thee, I shall crave leave further to add, that the use of the instrument is very easy. For if the index be set so near the distance of the moon and stars, and the limb so held as to cut the body of the moon, upon directing the telescope to the star her image will, of course, be reflected on some part of the speculum GH. There is no absolute necessity the star and moon should coincide exactly at the line limiting the silvered and unsilvered part of the latter speculum; for the transparent part of that glass will often reflect on the moon's image sufficiently for the telescope to take it, and if her limb in that and the star exactly coincide near it, it may be sufficient, though the nearer to that line the better. Now their distance being found, the tables that give the moon's place may be depended on for her diameter and her latitude; which last being known, there are three sides of a triangle given to find the angle at the pole of the ecliptic, which, compared with the star's longitude, determines her place for that instant: for, in respect to her latitude when she is swiftest in motion, when nearest her nodes, and when the inclination of the orbs is greatest (if these could all happen together), yet the variation of her latitude, in the space of one hour, equal to 15 degrees of longitude on the earth, if a star be taken somewhat near the ecliptic, and not very near the moon, will not alter the angle at the pole but a very few seconds. The nearness of the speculum GH is no disadvantage, because the rays come reflected in the same manner as they come direct. It may be needless to add that, when practicable, the moon should be taken when near the meridian—or that the instrument will equally take the distance of the sun from the moon, when visible, as she often is, in the day-time; for which purpose there must be a place made at M for a darkening glass, to be fixed there when necessary, and the telescope directed to the moon. Nor need I add, that the same instrument will very well serve for taking the distance of any two stars, a comet, &c., always taking the brightest by reflection; all which is obvious. But I must further observe, with pleasure, that if we do not quite mistake in all that has been said here, there is now a method found by it to obtain what is equivalent to a bodily appulse of the moon to a fixed star, or to the sun at any moment when visible, which, indeed, might be wished; but if the longitude could ever be expected to be determined by the motions of the moon (to which end J. Flamstead's, and thy more assiduous labours in observing her, have, I suppose, been principally levelled), and this instrument be duly made to answer what is proposed, as it may be framed light and easily manageable, thou wilt then, with thy accurate tables, have obtained the great desideratum, and all that can in this way be had from our satellite. And if this method of discovering the longitude by the moon is to meet with a reward, and this instrument, which, for all that I have ever read or head of, is an invention altogether new, be made use of, in that case I would recommend the inventor to thy justice and notice. He now gets his own and family's bread (for he is married) by the labour of his own hands only, by that mean trade. He had begun to make tables of the moon, on the very same principles with thine, till I lately put a copy of those that have lain so many years printed, but not published, with W. Innys, into his hands, and then, highly approving them, he desisted. We both wish very much to see thy tables completed, and ushered into the world by thy own hand. On the receipt of this I shall hope for a line, with thy thoughts on it; which, however they prove, will afford a pleasure to

Thy friend,

Pennsylvania, May 25, 1732. J. LOGAN.

From the American Magazine for August, 1758, p. 528.

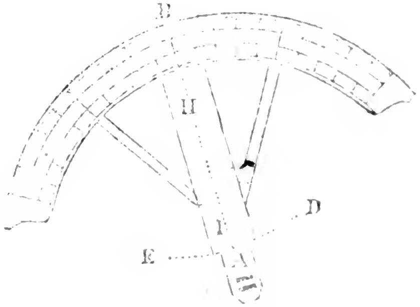
To the Royal Society.

Gentlemen,

As none are better able than the *Royal Society* to prove and judge whether such inventions as are proposed for the advancing useful knowledge will answer the pretensions of the *inventors* or not; and as I have been made acquainted, though at so great a distance, of the candour of your learned society in giving encouragement to such as merit approbation, I have therefore presumed to lay before the society the following, craving pardon for my boldness.

Finding with what difficulty a tolerable observation of the sun is taken by Davis's quadrant, and that in using it, unless the spot or shade be brought truly in the line of the horizon-vane, the observation, when made, is good for nothing; to do which requires much practice, and at best is but catching an observation; and considering further the smallness of the 60 deg. arch, and the aptness of wood to cast, which makes often little better than guess-work; I *therefore* applied my thoughts, upwards of two years, to find a more certain instrument, and contrived the following improvement, as I think, in the make and use of the bow; *viz.*

The quadrant is to be numbered from each end to 90 at the other, as in the figure. The sight and glass vanes are the same with the common, excepting that the glass should be larger, and I think it would be better if ground to the segment of the cylinder. The horizon-vane should be like that of the figure thereof; having three holes, IKL; one hole, I, to fit on the centre of the quadrant, A; the other two, KL, to see the horizon through, whose length across the vane may be one-eighth of the radius AB, or more; the horizon-vane should be a little hollowed, answerable to the curvature of the circle DAE, or cylinder, whose semidiameter, AH, is about seven-elevenths of AB, the radius of the quadrant.



In observing with this quadrant at sea, let the sight and glass vanes be kept nearly on the same numbers, or at equal distances from the ends of the arch, and then it will be sufficiently exact to bring the spot and horizon in a right line, on any part of the horizon-vane, by moving the vanes nearer together or further apart, the middle of the horizon-vane being parallel to the horizon, then the zenith distance will be the sum of the distances of the vanes from the end of the quadrant arch. For, putting $r =$ the radius of the quadrant, $a =$ the distance of the spot from the middle of the horizon-vane, $s =$ the sine, and $c =$ the cosine of half the sun's altitude, unity being radius, the sine of the errour will be nearly equal to $c\frac{11}{14} \times \frac{2saa}{11}$; and, therefore, when greatest (which is when the zenith distance is 00·00, or 47 degrees 45 minutes), of the distance of $\frac{1}{16}$ of the radius of the quadrant from the middle of the horizon-vane, it is but 1·30; I would advise to bring the upper or lower edge of the spot, and not the middle and horizon, on a right line, and then subtract or add sixteen minutes for the sun's semidiameter from or to the zenith distance given by the vane.

N. B. There should be an allowance for the observer's height above the surface of the sea, by subtracting four, five, or six minutes. A table of this kind would not be amiss on the back of the quadrant.

There may be some graduations put on the staff, near the centre, to be cut by a plumb-line hung on a pin put into a small hole for land observations. One of these quadrants, being eighteen inches and two feet radius, if well graduated, will be sufficient to take the sun's zenith distance within two or three minutes.

Succeeding so well with the sun, encouraged me to take what appeared a more difficult task, the finding some way to take the altitude of the stars at sea (when the horizon may be seen) better than by the fore-staff, which I concluded must be by bringing the two objects, horizon and star, together. I first considered one reflexion; but the faults of Davis's quadrant were here enlarged, which is chiefly the flying of the objects from each other, by the least motion of the instrument. I then examined what two reflexions would do, which perfectly answered my desire, being equally useful in taking the distance of stars from each other, and also from the moon, and I believe practicable at sea; for I found that when one star was made to coincide by two reflexions with another, the distance of these stars would be double the inclination of the reflecting planes, as may be easily demonstrated.

I see but one fault in this instrument, and that is, that three feet radius in this has a graduation no larger than a quadrant of eighteen inches radius. I hope Dr. Halley has received a more full account of this from J. Logan, esq., therefore I shall add no more than that I am, gentlemen,

Yours, &c.
T. GODFREY.

Philadelphia, Nov. 9, 1734.

Page 529. *Extracts from "A further Account of* Thomas Godfrey's *Improvement of* Davis's *Quadrant transferred to the Mariner's Bow."*

Being informed that this improvement, proposed by Thomas Godfrey, of this place, for observing the sun's altitude at sea with more ease and expedition than is practicable by the common instrument in use for that purpose, was last winter laid before the Royal Society, in his own description of it, and that some gentlemen wished to see the benefit intended by it more fully and clearly explained, I, who have here the opportunity of knowing the author's thoughts on such subjects, being persuaded, in my judgement, that if the instrument, as he proposes it, be brought into practice, it will in many cases be of great service to navigation, have therefore thought it proper to draw up a more full account of it than the author himself has given, with the advantages attending it, which if approved of by better judgements, to whom what I offer is entirely submitted, it is hoped the use of it will be recommended and further encouraged, as well as the author. The use of the improvement, with its conveniences, as also a description of it, are as follows.

[Then follows a repetition of the account of Godfrey's having studied—what occurred to him about the importance of knowing the latitude and longitude of a ship's place, &c., which I do not transcribe, as it is long, and not to your purpose.

E. H.]

Page 532.—Some masters of vessels who sail from hence to the *West Indies* have got some of them * made, as well as they can be done here, and have found so great an advantage in the facility and in the ready use of them in those southerly latitudes, that they reject all others. And it can scarce be doubted, but when the instrument becomes generally known, it may, upon

* Godfrey's instruments.

the Royal Society's approbation, if the thing appears worthy of it, more universally obtain in practice. It is now four years since Thomas Godfrey hit on this improvement: for his account of it, laid before the Society last winter, in which he mentioned two years, was wrote in 1732; and in the same year, 1730, after he was satisfied in this*, he applied himself to think of the other, *viz.* the reflecting instrument by speculums for a help in the case of longitude, though it is also useful in taking altitudes; and one of these, as has been abundantly proved by the maker, and those who had it with them, was taken to sea, and there used in observing the latitude the winter of that year, and brought back again to *Philadelphia* before the end of February 1731, and was in my keeping some months immediately after.

It was indeed unhappy, that, having it in my power, seeing he had no acquaintance nor knowledge of persons in *England*, I transmitted not an account of it sooner†. But I had other affairs of more importance to me; and it was owing to an accident which gave me some uneasiness, *viz.* his attempting to publish some account of it in print here, that I transmitted it at last, in May 1732, to Dr. Halley, to whom I made no doubt but the invention would appear entirely new; and I must own I could not but wonder that our good-will at least was never acknowledged. This, on my part, was all the merit I had to claim, nor did I then, or now, assume any other in either of these instruments. I only wished that the ingenious inventor himself might, by some means, be taken notice of, in a manner that might be of real advantage to him.

There needs not, I suppose, much more of a description of the instrument than has been given. I shall only say that the bow had best be an arch of about 100 deg. well graduated and numbered both ways; the radius 20 or 24 inches; the curve at the centre to be one-twentieth of the radius on each side, that is, one-tenth of it in the whole; the radius of that curve $\frac{64}{100}$ parts

* That is, I suppose, being "satisfied," that he had made a real *improvement* in the quadrant. E. H.

† All these circumstances of Mr. Logan's complaint, and almost every thing that follows to the end, except the directions for making the instrument, are left out of the account published in the *Philosophical Transactions*, which strengthens the conjecture that justice has not been done to the original inventor.

of the radius of the instrument; that the glass for the solar vane should not be less, but rather larger, than a silver shilling, with its vertex very exactly set; and that the utmost care be taken to place the middle of the curve exactly perpendicular to the line or radius of 45 deg., as the observer must also take care that the two vanes on the limb be kept nearly equidistant from that degree. To which I shall only add, that it may be best to give the horizontal vane only one aperture, not two. The rest, I suppose, may be left to the workman. Thus, doubting I have already been too prolix on the subject, to which nothing but a sincere inclination to promote any thing that might contribute to a public benefit, and to do some justice to merit, could induce me, I shall only request that what I have here offered may be construed by that intention.

J. LOGAN.

Philadelphia, June 28, 1734.

P. S. [*By the Editors of the Magazine.*] It is easy to see, by a careful perusal of these two letters, and that in our last Magazine, the progress of this invention, and how far Mr. Godfrey ought to be considered as the inventor. It is our business to give impartial accounts of facts and transcripts of authentic papers. The reader, after that, is to judge for himself. For our own part, we have no hesitation in pronouncing Mr. Godfrey the real original inventor of this famous and useful instrument.

The following extract of a letter from Mr. Hazard, which accompanied the above documents, ought to be added, in justice both to the Royal Society and to Mr. Godfrey.

"Alderman Hillegas, of this city (Philadelphia), knew Godfrey. He says, he remembers to have heard, perhaps fifty years ago, that, as Hadley had obtained the patent, complete justice could not be done to Godfrey; but that the Royal Society, thinking his ingenuity ought to be rewarded, either subscribed for him as individuals, or gave him out of their funds, £200 sterling: and knowing his infirmity (for it seems he was apt to indulge in intemperate drinking), they thought it better to send the amount in household furniture than in cash, and, *inter alia*, sent him a *clock*, which the alderman remembers to have seen."

Godfrey had a son, Thomas Godfrey, junior, who, in 1765, published a volume of *Juvenile Poems*. The young man is spoken of, by the writer of the preface, as possessing great natural endowments, with but little cultivation; and as deserving to be ranked, as well as his father, among the *curiosities* of Pennsylvania.—*MS. Letter of the Rev. Dr. Elliot, of Boston, to the Author.*

It is worthy of notice, that the use of the *quadrant* in question was confined to the English nation until the year 1736, when M. d'Apres de Mannevillette, the great maritime geographer, employed it on board a French ship; and on his return to France, one of the earliest objects of his attention was to state, in a public print, his high estimation of this curious instrument. He thus had the honour of introducing to his countrymen one of the most valuable inventions of the age.

Note (T), p. 101.—Dr. Priestley concluded from his experiments, and it has been since generally believed by Ingenhousz, Sennebier, and other vegetable physiologists, that vegetables, in the course of their germination and growth, when exposed to solar light, absorb azote and emit oxygen, and thus purify the surrounding air. But, by a series of ingenious experiments lately published, professor Woodhouse, of Philadelphia, has drawn into question the truth of these conclusions. From the result of these experiments, he contends that the germination of seeds and the growth of plants do not purify atmospherical air; but that, whenever they appear to afford oxygen gas, it is by devouring the coal of carbonic acid gas for food, and leaving its oxygen in the form of pure air. He has also made experiments on the effects produced by the leaves of plants in common air, impregnated with carbonic acid gas, and exposed to solar light; in which cases the carbonic acid disappeared, and the oxygenous gas increased. And from trials made with the fresh leaves of many different plants, exposed to sunshine in pump-water, river-water, and this latter charged with carbonic acid, he is confirmed in the same conclusion. Dr. Woodhouse, therefore, denies that vegetables either decompose water, emit oxygen, or absorb azote, as has been some time commonly believed.—Nicholson's *Philos. Journal,* 8vo. series, vol. ii. for July 1802.

Note (U), p. 111.—The important services of M. Lavoisier, in forming the theory of the French academicians, and the intrinsic worth of his character, render it proper that some account should be given of him in this place.

Antony Laurence Lavoisier was born at Paris, in the year 1743. He early discovered a taste for the study of the physical sciences, and, for a considerable time, directed his attention to most of them in succession, without discovering a preponderating inclination for any one in particular. This continued to be the case till about the year 1770, when the important discoveries in chemistry, by Black, Priestley, Scheele, and Cavendish, fired his ambition, and directed his attention more particularly to chemical philosophy, to which he almost exclusively attached himself during the remainder of his life.

It is generally known that his experiments and discoveries were among the principal means of establishing that revolution in the *theory* and *nomenclature* of chemical science, which has been, with great propriety, denominated the *Lavoisierian* theory. After numerous publications on different departments of chemistry, in the *Memoirs* of the *Academy of Sciences*, and other scientific journals, in which he successively treated of *combustion*, the analysis of *atmospheric air*, the formation and fixation of *elastic fluids*, the properties of *heat*, the composition of *acids*, the decomposition and recomposition of *water*, the dissolution of *metals*, *vegetation*, &c., he at length combined his philosophical views into a consistent body, which he published in 1789, under the title of *Elements of Chemistry*; a work which has been pronounced one of the most elegant models of philosophical arrangement, and of clear logical composition, that was ever presented to the world.

He continued after this to pursue his favourite study with unabated diligence: his wealth enabled him to make experiments on a great scale; his ardour, acuteness, and extended views, enabled him to avail himself of every advantage; and he continued to instruct his countrymen and the world, by the developement of new truths, or the recommendation of useful economical improvements, until the month of May 1794, when he became an object of the malignant phrensy of Robespierre, and suffered under the guillotine, in the fifty-first year of his age.

Note (V), p. 122.—Modern philosophers have discovered that the influence of light on growing *vegetables* is great and important. Plants may be made to vegetate tolerably well in the dark; but in this case their colour is always white, they have scarcely any taste, and contain but a very small portion of combustible matter. In a very short time, however, after their exposure to light, their colour becomes green, their taste is rendered much more intense, and the quantity of combustible matter is considerably increased.—Thompson's *Chemistry.*

"It has been found by Dr. Herschell (see *Philos. Trans.* for 1800) that the rays of light differ in their power of illuminating objects: for if an equal portion of each of these rays, one after another, be made to illuminate a minute object, a printed page for instance, it will not be seen distinctly at the same distance when illuminated by each. We must stand nearest the object when it is illuminated by the *violet.* We see distinctly, at a somewhat greater distance, when the object is illuminated by the *indigo* ray; at a greater when by the *blue;* at a still greater when by the deep *green;* and at the greatest distance of all when by the lightest *green* or deepest *yellow.* We must stand nearer when the object is illuminated by the *orange* ray; and still nearer when by the *red.* Thus it appears that the rays towards the middle of the spectrum possess the greatest illuminating power, and those at the extremity the least; and that the illuminating power of the rays gradually diminishes from the middle of the spectrum towards its extremities."—*Ibid.*

Note (W), p. 131.—In Fahrenheit's thermometer the *freezing* point is fixed at 32 deg. and the *boiling* point at 212 deg. In Reaumur's, or rather de Luc's, the freezing point is 0, and the boiling point 80 deg. In Delisle's, the usual order of graduation is inverted, the freezing point being 150 deg. and the boiling point 0. And, finally, in the thermometer of Celsius, the point of freezing is marked 0, and that of boiling 100 deg. To reduce the degrees of Reaumur to those of Fahrenheit, the following formula may be employed: $\frac{R \times 9}{4} + 32 = F$. To reduce the degrees of Celsius to those of Fahrenheit, the following is sufficient: $\frac{C \times 9}{5} + 32 = F$. To reduce the degrees of Delisle, under the boiling point, to those of Fahrenheit, say, $212 - \frac{6\,D}{5} = F$. To reduce those above the boiling point to Fahrenheit, say, $212 + \frac{6\,D}{5} = F$.

Note (X), p. 133.—The numerous *eudiometers* proposed by different chemists may be reduced to *five*.

1. The first is that invented by Dr. Priestley, in which *nitrous gas* is mixed, over water, with the air the purity of which it is wished to ascertain. The diminution of the volume of this mixture is proportioned to the quantity of oxygen contained in the air, which is rapidly absorbed by the nitrous gas, and the nitric acid thus formed is also rapidly absorbed by the water. This eudiometer has received various modifications and improvements by Falconer, Cavendish, and von Humboldt, but is still liable to considerable anomaly and inaccuracy in its indications.

2. The second kind of eudiometer was proposed by Volta. His method was to mix given proportions of the air to be examined, and *hydrogen gas*, in a graduated glass tube; to fire the mixture by an electric spark; and to judge of the purity of the air by the bulk of the residuum. But this furnishes a measure even less to be depended on than the preceding.

3. Scheele was the inventor of the third kind of eudiometer. It is merely a graduated glass vessel, containing a given quantity of air, exposed to a newly-prepared liquid alkaline or earthy sulphuret, or to a mixture of iron filings and sulphur, formed into a paste with water. These substances absorb the whole of the oxygen of the air, which converts a portion of the sulphur into an acid. The oxygen contained in the air thus examined is judged of by the diminution of bulk which the air has undergone. This method is simple, and as accurate as any other. The only objection to which it is liable is the slowness of the process. But this objection has been removed by M. de Marti, who has brought the eudiometer of Scheele to a great degree of accuracy, by improving the apparatus, and, instead of iron filings and sulphur, using the *hydrogenated sulphurets* only.

Guyton-Morveau employs *sulphuret of potash*, and measures the proportion of oxygen present by the quantity absorbed by the *sulphuret*.

4. In the fourth kind of eudiometer, the abstraction of the oxygen of air is accomplished by means of *phosphorus*. This eudiometer was first proposed by Achard. It was considerably improved by Reboul, Seguin, Lavoisier, and, above all, by Berthollet, who has rendered it equal in simplicity with the eudiometer of de Marti, and scarcely inferior to it in precision.

5. The fifth eudiometer has been lately proposed by Mr. Davy. In this the substance used to absorb the oxygen from the air is a solution of sulphat or muriat of iron in water, and impregnated with nitrous gas. This eudiometer is simple, and its indications nearly, if not quite, as accurate as those of the two last mentioned.—Thompson's *Chemistry*.

Note (Y), p. 151.—M. Cuvier, of France, a member of the National Institute, and a celebrated zoölogist, has been for some time engaged in a very extensive work upon the species of quadrupeds, the bones of which have been found in the interior parts of the earth. He has undertaken to settle the controversy concerning these animal relics. He says, that the strata of every country upon earth contain bones different from those of the animals which now inhabit their surface: that, with the single exception of ruminant animals, all the complete fossil bones which he has seen, are different from those of quadrupeds now alive: that of these he has been able to ascertain *twenty-three species*, all certainly unknown at this day; and which appear to have been entirely destroyed, though their bones evince their existence in former ages.

These species of creatures, the races of which are now extinct, M. Cuvier divides into two classes—1. Those which have been determined by others; and, 2. Such as have been settled by himself. In the first he enumerates the following: 1. The *Siberian animal*, which affords fossil ivory. 2. The *mammoth*, differing from the former chiefly in the size and points of its grinders. 3. The *long-headed rhinoceros*. 4. That animal of the *tardigrade family* called *megatherium* and *megalonyx*. 5. An extinct species of *large bear*. 6. *Another species* of the bear. 7. A *carnivorous animal*, intermediate between the wolf and hyæna. 8. A *creature akin to the moose*, the horns of which measure fourteen feet from tip to tip. 9. The great *fossil tortoise*. 10. The *Maestricht crocodile*. 11. A *sort of dragon*. 12. An unknown kind of reptile or cetaceous animal.—In the second class, the chief of which have been discovered in France, M. Cuvier places the following species: 1. That animal the *teeth* of which, *when impregnated with copper*, form the occidental turquoise. 2. A *tapir*, differing from that of South America only in the form of its grinders. 3. *Another tapir*, of a gigantic or elephantine size. 4. A *species of hippopotamos*, about the size of a hog. 5, 6, 7, 8, 9, 10. Six fossil skeletons of an unknown species, between the rhinoceros and the tapir, from the plaster quarries in the neighbourhood of Paris. 11. A species of crocodile, considerably like that of the Ganges.

But these are not all which the earth contains: there are *parts* of skeletons of which M. Cuvier cannot speak with equal assurance; but of which, however, enough is known to encourage a hope that the list of zoölogical antiquities will be soon lengthened. Of these, some resemble the bones—1. Of the tiger. 2. Of an hyæna, or sea-calf. 3. Of the fallow-deer. And others of uncertain characters; as the petrified bones, 1. Near Verona. 2 and 3. Two sorts in the Rock of Gibraltar. 4. In the vicinity of Dax. 5. Near Orleans. 6. Near Aix and Cette. 7. In the islands of Dalmatia, &c. And, 8. All other *uncertain bones* found in the peat mosses of all parts of Europe and Asia. In the course of a short time M. Cuvier hopes to determine the exact place in the system to which these doubtful species are to be referred.

M. Cuvier solicits information on these subjects from all parts of the world. He wishes to procure the bones themselves, or figures of them, or correct descriptions in words.—*Medical Repository.*

The naturalists of France derived great advantages when Holland fell into the power of their countrymen, from the opportunities which were afforded them of inspecting the rich museum of the stadtholder. M. Cuvier's attention was more particularly directed to two elephants' heads, which having examined with some nicety, he found to exhibit characters that warrant their being considered as belonging to two distinct species. One of them from Ceylon, he remarked, differed from the other (which came from the Cape) in respect not only to the general contour of the forehead, but to the shape of the teeth, which last he was at length induced, like Blumenbach and others, to constitute the distinguishing characteristics of elephants in general: and extending his inquiries to such as we know only by their fossil *exuviæ*, he has furnished us with the following specific descriptions: *viz.*

"*Elephas Capensis, fronte convexa, lamellis molarium rhomboidalibus.*

E. *Indicus, fronte plano-concava, lamellis molarium arcuatis undatis.*

E. *Mammonteus, maxilla obtusiore, lamellis molarium tenuibus rectis*

E. Americanus, molaribus multi-cuspidibus, lamellis post detritionem quadrilobatis."

C. Cuvier, since the publication of his Memoir, has discovered several new species of elephants, differing not only from the fossil ones hitherto described, but from all living animals with which we are acquainted. One of them is found in Peru, and other countries, and comes nearest to the elephant of the Ohio: another has been discovered in the *strata* of the Black Mountain, in the department of l'Herault: a third is found at Comminges; and fragments of the fourth abound in the vicinity of Paris.—*Mém. de l'Inst.* tom. ii, p. 22.

The origin of these *fossil bones,* especially of some, found in peculiar circumstances, has employed the ingenuity of many eminent naturalists, and been made the subject of much speculation in later years. On the supposition, which has been adopted by a considerable number of these inquirers, that the account of the general *deluge* given in the sacred writings is false, the question is, indeed, of difficult solution. But, admitting the truth of that account (and every mountain and valley lifts up its voice to confirm it), the difficulty, in a great measure, if not entirely, vanishes. Let us suppose that the animals the fossil *exuviæ* of which are now found were inhabitants of the antediluvian world, is it not evident that many of the facts observed are precisely such as must necessarily have arisen from this state of the case?

The fossil remains of *elephants* have been discovered in various parts of the *North-American* continent, where none of this genus of animals are now to be found in the living state. This has been made a wonder. But how could it have been otherwise? If the *flood* destroyed all the inhabitants of the earth, except those which were preserved in the *ark;* and if the ark rested, after the subsiding of the waters, on the eastern continent, as is generally supposed by biblical commentators; then no animals, excepting those capable of making occasional and considerable expeditions by *water,* or of living in frozen regions, and by this means passing from the eastern to the western continent on the ice, could be expected to be found in the latter, in any other than the *fossil* state. It is true, we find animals in South America which appear, at present, only capable of inhabiting warm regions; but it is well known, that both animals and vegetables have the faculty of accommodating themselves to the climate in which they are placed, and of gradually changing their character. It is by no means improbable, therefore, that the ancestors of the animals now living in South America had once a northern constitution; that, after crossing the strait between Asia and America, they gradually strayed further south; and that, in process of time, their offspring acquired southern habits and constitutions.

Nor is it by any means difficult to suppose, that these fossil *exuviæ* were deposited in the places where they are found, at the subsidence of the waters of the general deluge. They have been generally found in circumstances calculated long to preserve them; in strata of earth which tend to resist putrefaction, and which may account for their remaining entire after so great a lapse of time.

Note (Z), p. 181.—At the close of the eighteenth century, only *five* dissertations, it is believed, had been published by the medical graduates of America on botanical subjects. These are respectfully noticed in the above-mentioned page. Since that time, publications of this kind have considerably multiplied. The learned and interesting lectures on botany, delivered by professor Barton, of the university of Pennsylvania, and his enlightened zeal in pursuing this branch of science, have produced a very sensible effect in recommending it to the attention of the students in that seminary. In the course of the last three years, the following dissertations on botanical subjects have been added to the former small list.

1. On the *Digitalis Purpurea*, by John Moore, of Pennsylvania.
2. On the *Kalmii Latifolia* and *Angustifolia*, by George Thomas, of Virginia.
3. On the *Melia Azedarach*, by Grafton Duval, of Maryland.
4. On the *Prunus Virginiana*, by Charles Morris, of Virginia.
5. On the *Liriodendron Tulipifera*, by Patrick Rogers, of Ireland.
6. On the *Magnolia Glauca*, by Thomas D. Price, of Virginia.
7. On the *Spigelia Marylandica*, by Hedge Thompson, of New Jersey.
8. On the *Sanguinaria Canadensis*, by William Downey, of Maryland.
9. On the *Bignonia Catalpa*, by Robert Holmes, of Virginia.

10. On the *Polygala Senega*, by Thomas Massie, of Virginia.
11. On the *Arbutus Uva Ursi*, and *Pyrola Umbellata* and *Maculata*, by John S. Mitchell, of Pennsylvania.
12. On the *Cornus Florida*, and *Sericea*, and the *Cinchona Officinalis*, by John M. Walker, of Virginia.

Some of these academic publications have great merit: they afford conclusive evidence, that this department of Natural History is more studied in the middle and southern than in the eastern states. It will be observed, that the authors of all the dissertations above mentioned reside to the south of New York, excepting the student from Ireland.

Note (AA), p. 184.—Two gentlemen of this name have contributed to our knowledge of American plants, viz. John and William Bartram, both natives of Pennsylvania. John Bartram, the father, was born in the year 1701, and died in 1777. He was a self-taught philosopher and botanist. He travelled much in the American colonies, particularly to the southward and westward; discovered many new plants, and made large collections of our indigenous vegetables. (See vol. iii, chap. 26 of this work.) He made several valuable communications to Peter Collinson, on different subjects in zoölogy, which were published in the *Philosophical Transactions*, chiefly between the years 1743 and 1749. Professor Barton is preparing for the press some account of this distinguished man, who may justly be styled "one of the fathers of natural history in North America."—His son, William Bartram, is still living, and advantageously known by his *Travels through North and South Carolina, Georgia, East and West Florida*, &c. He still cultivates the garden established by his father, and continues to devote himself to botanical inquiries and delineations with great zeal, and in a manner both useful and honourable to our country.

Note (BB), ibid.—The work of professor Barton, announced in the above-mentioned page, bears the following title: *Elements of Botany, or Outlines of the Natural History of Vegetables*, &c. 8vo. 1803. Dr. Barton has the honour of being the first American who gave to his country an elementary work on Botany; and if we may judge of the subsequent harvest by the first fruits, it will be rich indeed. This work is illustrated by *thirty plates*, and discovers an extent of learning, an acuteness and vigour of mind, and an elegance of taste, highly honourable to the author. Dr. Barton adopts the *sexual system,* and a great part of the Linnæan nomenclature; but is by no means a servile follower of that illustrious naturalist. He thinks the sexual system would suffer no injury by the total abolition of the *eleventh* class *(Dodecandria)*; and though he dissents from the proposed alteration by Thunberg, yet he thinks, with Dr. J. E. Smith, that the *twenty-third* Linnæan class *(Polygamia)* is unnatural, variable, and obscure, and ought to be entirely suppressed.

Of the *thirty plates* which accompany this work, twenty-eight have claims to more or less originality, and many of them are completely original. They are well executed; and most of the subjects selected for delineation are remarkable for their rarity, their beauty, or some other peculiarity of character. Every part of this work discovers that the author has not been contented with compiling the facts and opinions of his predecessors, but that he has accurately observed and thought for himself. He will, therefore, no doubt, be pronounced, by the best judges, to have presented his countrymen with the most comprehensive, instructive, and satisfactory work of this kind in the English language *.

Note (CC), p. 187.—Among the numerous and important services rendered to botanical science, by means of accurate and elegant *drawings*, and other modes of exhibiting plants, the following more particularly deserve notice.

It is a singular fact that physic is indebted for the most complete set of figures of the medicinal plants to the genius and industry of Mrs. Elizabeth Blackwell, a native of Scotland, who, in 1739, published a splendid work under the following title—*A curious Herbal, containing five hundred Cuts of the most useful Plants which are now used in the Practice of Physic, engraved on Folio Copperplates, after Drawings taken from the Life*, 2 vols, folio. This ingenious lady, after she had completed the drawings, engraved them on copper, and coloured the prints with her own hands. It ought to be mentioned, to the honour of Mrs. Blackwell, that she undertook and went through this ingenious labour for the purpose of procuring her husband's liberation from prison, where he was confined for debt, and from which she extricated him in two years.—Pulteney's *Sketches*.

* This work has been republished in London, in an improved form.

"Mrs. Delany has finished nine hundred and seventy accurate and elegant representations of different vegetables, with the parts of their flowers, fructification, &c., according with the classification of Linnæus, in what she terms *paper-mosaïc.* She began this work at the age of 74, when her sight would no longer serve her to paint, in which she much excelled. Between the age of 74 and 82, at which time her eyes quite failed her, she executed the curious *Hortus Siccus* above mentioned, which I suppose contains a greater number of plants than were ever before drawn from the life by any one person. Her method consisted in placing the leaves of each plant, with the petals, and all the other parts of the flowers, on coloured paper, and cutting them with scissors accurately to the natural size and form, and then pasting them on a dark ground; the effect of which is wonderful, and their accuracy less liable to fallacy than drawings. She is at this time (1788) in her 89th year, with all the powers of a fine understanding still unimpaired. I am informed that another very ingenious lady, Mrs. North, is constructing a similar *Hortus Siccus,* or *paper-garden,* which she executes on a ground of vellum, with such elegant taste and scientific accuracy, that it cannot fail to become a work of inestimable value."—*Botanic Garden,* part ii, canto ii, l. 155.

Note (DD), p. 187.—The late royal government of France, for the promotion of botanical science, was in the habit of establishing *Botanical Gardens* in various parts of her colonies, and of foreign countries. A piece of land of moderate fertility and extent, hired or purchased at the public expense, served, in the distant country where it was situate, as a house for a botanist, a repository for the seeds he might collect, and a nursery for the plants he should cultivate. From establishments of this nature in distant regions, rich treasures of botanical specimens and information have been transmitted to France.

The late king of France provided two gardens of this kind in the United States; one in Bergen county, in the state of New Jersey, within eight or nine miles of the city of New York; the other in South Carolina. The botanist employed to superintend these, and to perform all the duties of a botanical pensionary, was M. Andrew Michaux, who has lately distinguished himself by his *Histoire des Chênes de l'Amérique,* &c. Paris. 1801. Folio.

The first person who conceived and carried into effect the design of a *Botanic Garden* for the reception and cultivation of American vegetables, as well as exotics, was the celebrated John Bartram, mentioned in a former note. His establishment, though small, and scarcely worthy of the name when compared with those of Europe, was respectable, considering the situation of the proprietor, and is now probably the best in our country. Those formed and supported by the French government, though calculated to answer the purposes intended, were also far from being regular or complete botanical gardens. Nothing that deserves this character has yet been established in America. It is hoped the plan now in execution by professor Hosack, of Columbia college, will be fostered by the public, and succeed better than any former attempts.

Note (EE), p. 353.—It has been made a question whether the *inoculation* of the small-pox ought to be considered as a blessing or an evil to society. Some have supposed that its effect has been to keep the disease more steadily alive, and more extensively diffused; and thus, on the whole, that it has produced an injury rather than a benefit. Professor Waterhouse, of Massachusetts, in a late publication recommending the substitution of the *Cow-Pox*, makes the following statement:—"No less than forty millions of people die of the small-pox every century. The Europeans have carried the small-pox over the globe. The Danes carried it to Greenland, and the Spaniards to South America, where one hundred thousand perished with it in the single province of Quito. When the annual number of births in London was sixteen thousand two hundred and ninety-one, the number who died with the small-pox was two thousand five hundred and fifty-four, and still greater in some other large cities of Europe. A greater number have died of the small-pox since the introduction of its inoculation than before it, that practice being the means of keeping it always in large cities."

END OF VOL. I.

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