THURSDAY, AUGUST 20, 1874

SCIENTIFIC WORTHIES

IV.—John Tyndall

In the valleys of Gloucestershire may still be seen a few clothiers' mills, the residue of a once extensive industry. Almost exactly two centuries ago some members of the Tyndall family inhabiting these valleys, and engaged for the most part in this industry, crossed over to the opposite coast of Ireland. This fact, the date of which is fixed by Mr. Greenfield, coupled with family tradition, points to the origin of Prof. Tyndall. In Ireland the Tyndalls fared variously, dividing themselves into magistrates, aldermen, medical men, farmers, and tradesmen. To the last, and indeed to the poorest of the last, Prof. Tyndall's father belonged. He was a man of singular force of intellect and independence of character, and he kept his son at school until his nineteenth year. In accordance with transmitted family habit, Prof. Tyndall, when young, was exercised in all the subtleties of the controversy between Protestantism and Catholicism. In 1839 he quitted school to join a division of the Ordnance Survey, with which he remained connected for nearly five years. His excellent chief, now his intimate friend, General George Wynne, R.E., gave him an opportunity of mastering all the details of the survey, in the office and in the field. For four years subsequently he was engaged on railway work; and while thus employed met Mr. Hirst, who is now the Director of Studies in the Royal Naval College, Greenwich, who afterwards joined him in Marburg, and with whom his relations are more those of a brother than a friend. In 1847, with a view to self-improvement, he accepted a post in Queenwood College, Hampshire, where Dr. Frankland was chemist; and in 1848 they went together to the University of Marburg, Hesse Cassel. Bunsen and others had rendered the little University celebrated; and to Bunsen, whose lectures he attended and in whose laboratory he worked, Prof. Tyndall owes obligations never to be forgotten. He found in Germany a second home. With Stegmann he studied mathematics; he heard Gerling lecture on physics, and subsequently Knoblauch, who, preceded by a distinguished reputation, and accompanied by a choice collection of instruments, came to Marburg as Extraordinary Professor when Tyndall was there. Prof. Knoblauch, in conjunction with whom Tyndall subsequently conducted various inquiries on diamagnetism, supports his old friend and pupil in Belfast; Wiedemann is also there, and Bunsen would have been there if he could. Tyndall subsequently worked in the laboratory of Prof. Magnus in Berlin. In 1851 he accompanied Prof. Huxley to the meeting of the British Association at Ipswich, and thus commenced a friendship which has never faltered to the present hour. Dr. Bence Jones heard of Tyndall in Berlin, and, always alert in the promotion of science and in aiding those who pursued it, had him invited in 1853 to give a Friday evening lecture at the Royal Institution. Soon afterwards, on the proposal of Faraday, Tyndall was appointed Professor of Physics in the Institution, where he still remains.

In 1852 he was one of the secretaries of the Physical Section of the British Association, which then met for the first time in Belfast. Its president was Col. Sabine, to whom Tyndall was indebted in those days for various acts of kindness and encouragement, and who took, unsolicited, charge of his candidature for the Royal Society. But Tyndall's earliest scientific memory happens to be associated with Belfast. In the school to which he was sent in his childhood three different arithmetical treatises were made use of, one written by Gough and another by Voster; but young Tyndall was the only boy in the school who could speak of his *Thomson*. The first germ of science was dropped into Prof. Tyndall's mind by the father of Sir William Thomson, who was then Professor of Mathematics in the Belfast Institution. He also remembers distinctly, many years afterwards, reading in a Glasgow magazine about Davy's experiments on Radiant Heat, and the longing which they excited in him to be able to do something of the kind. With the very apparatus there figured Prof. Tyndall now illustrates his own lectures. In the "Kildare Street Schools," to which he was sent when a little boy, he learned very little, being, indeed fonder of play than of school. His first serious application to study was under a clever teacher of a national school named John Conwill, with whom he mastered Euclid, some algebra, conic sections, and plane trigonometry. Prof. Tyndall is now about fifty-four years of age. He was born in 1820 in the village of Leighlin Bridge, County Carlow, situated on the Barrow, but a fragment of which only now remains. When a boy he was expert at climbing trees; he was a good swimmer, a good runner, and though not unfrequently thrashed by an antagonist, a fair fighter. His first mountain experience was among the hills of Westmoreland eight-and-twenty years ago; his first visit to the Alps was in 1849; his second visit, in company with the present President of the Royal Society and Prof. Huxley, was in 1856; and he has continued to visit them every year since. In 1859, having paid his summer visit, he reached the Montanvert at the end of December and determined the winter motion of the Mer de Glace. At the Bel Alp, this year, he prepared his address to the British Association.

That our readers may have the opportunity of knowing the opinion of an eminent continental physicist as to the importance of good popular expositions of scientific subjects, and as to the special talent which Prof. Tyndall has shown in this direction, we give some extracts from a preface to the recently published German translation of Tyndall's "Fragments of Science," which the writer, Professor Helmholtz, has been good enough to revise and send to us for that purpose.

The awakening desire for scientific instruction, ever finding new expression among the educated classes of all European countries, we must consider not merely as a striving after new forms of amusement, or a mere empty and barren curiosity; it is rather a well-justified intellectual necessity, and is in close connection with the most important springs of mental development in these times. The natural sciences have become a powerful influence in the formation of the social, industrial, and political life of civilised nations, not only from the fact that the great forces of nature have been subordinated to the aims of man, and have supplied him with a host of new means to attain them ; though this mode of their action is sufficiently important that the statesman, the historian, and the philosopher, as well as the manufacturer and the merchant, cannot pass without participation in, at least, the practical results; but because there is another form of their action which goes much deeper and further, though it is, perhaps, more slow in manifesting itself; I mean their influence in the direction of the intellectual progress of humanity. It has often been said, and even brought as a charge against the natural sciences, that, through them, a schism (*zwiespalt*), formerly unknown, has been introduced into modern education. And, indeed, there is truth in this. A schism *is* perceptible; yet such must mark every new step of intellectual development wherever the New has become a power, and the question to be settled is, the definition of its just claims, as against the just claims of the Old. The past progress of education of civilised nations has had its central point in the study of language. Language is the great instrument through possession of which man is most distinctly separated from the lower animals ; through use of which he is able to share the experience and knowledge of other individuals of his time, as also those of past generations ; without which each man would, like the lower animals, be limited to his instinct and to his own particular experience. That therefore the improvement of language was formerly the first and most necessary work of a growing race, and that the most refined perfection of its comprehension and its use is, and must ever be, the primary problem in the education of each individual, is undoubted. The culture of modern European nations has a peculiarly intimate connection with the study of the remains of antiquity ; and thereby, directly with the study of language. With the latter study was associated that of the forms of thought, which are coined in speech ; logic and grammar, that is, according to the original meaning of the words, the art of speaking and the art of writing, both taken in the highest sense, have therefore been hitherto the natural hinge points of mental education.

But while language is the means of handing down and preserving truth once recognised, we must not forget that its study teaches nothing as to how fresh truth is to be found. Similarly, logic shows how, from the proposition which forms the major of a syllogism, conclusions are to be drawn ; but it can tell us nothing as to whence this proposition has come. He who will convince himself of its independent truth must, on the other hand, begin with knowledge of the individual cases which fall under the law, and which afterwards, if this have been established, may doubtless also be accepted as deductions from the law. But only where a knowledge of the law is one which has been communicated by others, does it actually take precedence of knowledge of the deductions, and in such a case, the treatises of the old formal logic assume their undeniable practical importance.

Thus all these studies do not themselves lead us to the proper source of knowledge—do not bring us face to face with the reality which we seek to know. There is therefore, undoubtedly, a danger in communicating to each one, by preference, a knowledge the source of which he has not personally contemplated. Comparative mythology and the criticism of the metaphysical systems can tell a great deal of how figurative word-expression has in time been exalted to the importance of real knowledge and even become valued as ultimate wisdom.

While fully recognising, then, the significance (not to be sufficiently appreciated), of the finely elaborated art of communicating the acquired knowledge of others, and receiving in return such communications from others, in regard to the mental improvement of our race ; while also recognising the importance attaching to the contents of the classical writings, for the cultivation of the moral and æsthetic sentiments, for the development of an intimate knowledge of human feelings, conceptions, and conditions of culture ; we must yet hold that an important element is wanting from the exclusively literary-logical mode of education ; and that is the methodical discipline of the activity by which we reduce the confused material which meets us in the actual world, apparently (at first sight) ruled by wild chance rather than reason, to clear conception, and thereby make it fit for expression in speech. Such an art of observation and experiment, methodically developed, we have hitherto found in the natural sciences alone ; and our hope, that the psychology of individuals and peoples, with the practical sciences of education and of social and political government based upon it, will attain the same end, can only be fulfilled in a distant future.

This new enterprise, prosecuted by natural science on new paths, has quickly enough yielded fresh and, of their kind, unheard-of results, evidencing what achievements human thought is capable of, where it can go the whole way from the facts to the full knowledge of the law under favourable conditions, testing and knowing everything for itself. The simple relations, especially those of inorganic nature, permit of our posessing such a penetrating and accurate knowledge of their laws, such far-reaching deduction of inferences from them, and the testing and verification of these by such an exact reference to fact, that, with the systematic unfolding of such conceptions (*e.g.* with the deduction of astronomical phenomena from the law of gravitation), there is hardly any other edifice of human thought which, for strict logic, certainty, correctness, and productiveness, can at all be compared with it.

I point out these relations merely with the view of showing in what sense the natural sciences are a new and essential element of human education ; of indestructible importance, also, for all further development of this in the future ; and that a complete education of the individual man, as of nations, will no longer be possible without a union of the past literary-logical with the new natural-science direction of study.

Now, the majority of the educated hitherto have been instructed only in the old way—have hardly at all come into contact with the work of thought in natural science ; at the most, perhaps, a little with mathematics. It is men of this kind of education that our Governments appoint, by preference, to educate our children, to maintain reverence for moral order, and to preserve the treasures of knowledge and wisdom of our forefathers. It is they, too, who must organise the changes in the mode of education of the rising generation ; where such changes are required they must be encouraged or compelled thereto by the public opinion of the intelligent classes of the whole community, both men and women.

Apart from the natural impulse of every warm-hearted man to lead others to that which he has found to be true and right, there will be in every friend of natural science a strong motive to share in such work, in the reflection that the further development of these sciences themselves, the unfolding of their influence on human education, and, so far as they are a necessary element of this education, the healthiness of the future mental development of the people, depend on an insight being afforded to the educated classes, into the nature and the results of scientific investigation, such as is generally possible, without a personal engrossing occupation with these subjects.

And in proof that the need of such an insight is felt even by those who have grown up under the predominant linguistic and literary instruction, may be cited the large number of popular books of natural science annually published, and the eagerness with which lectures of a popular character on subjects in natural science are attended.

It lies in the nature of the case, however, that the essential part of this want, owing to the depth of its roots, is not easily satisfied. It is true that what science may have established and wrought out in solid results can, by intelligent compilers, be put together and brought into suitable form, so that a reader without previous knowlege of the subject may, with some perseverance and patience, understand it. But such a knowledge, limited to the actual results, is not properly that which we have in view. These books, indeed, compiled with the best intentions, often lead into devious paths. To prevent weariness, they must seek to rivet the attention of the reader by an accumulation of curiosities, whereby the image of science is rendered quite false. One often feels this when the reader begins from his own impulse to tell what he has considered important. Then there are the further objections that the book can give only word-descriptions, or, at the most, drawings representing more or less imperfectly the things and processes of which it treats; and that the reader's power of imagination is thereby subjected to a much greater strain, with much less satisfactory results, than that of the investigator or student who, in museum collections and laboratories, sees the things before him in their living reality. A portion of the difficulties named may readily be obviated in popular lectures, if, at least, some objects or experiments can be shown: the opportunities of doing so in Germany, hitherto, have been mostly very limited.

It appears to me, however, that it is not so much a knowledge of results of scientific investigations in themselves, that the most intelligent and well-educated of the laity ask, but rather a perception of the mental activity of the investigator, of the individuality of his scientific procedure, of the aims at which he strives, of the fresh point of view which his work affords in reference to the great problems of human existence. There can hardly be anything of all this in the properly scientific treatment of scientific objects; on the contrary, the severe discipline of the exact method requires that, in scientific treatises, only that be spoken of which is surely ascertained, hypotheses only where equivalent to the proposal of questions for further investigation, a certain answer to these appearing probable from the next progress of the research. A natural prudence recommends great rigour in this connection. For it is pretty much the same to the greater number even of the instructed hearers whether a man of science says "I know," or "I suppose;" they only ask after the result and the authority by which it is supported, not the grounds or the doubts. It is thus not to be wondered at if earnest investigators do not willingly shock the confidence of their readers in what the former may think true and demonstrable, by the enumeration of ideas of the correctness of which they do not feel themselves quite secure. These may be very probable, and may be expressed with ever so much prudence and careful guardedness; they still expose him who utters them to the danger of vexatious misrepresentation.

It is, further, not to be overlooked, that the peculiar discipline of scientific thought which is necessary for the most abstract and rigorous grasp possible of newly-found ideas and laws, and for the purification from all accidents of the sensuous order of phenomena, along with the habitual residence of the mind among a circle of ideas far removed from general interest, are not quite favourable preparatives for a popular intelligible exposition of the insights obtained, to hearers who have not had the like discipline. For this task there is rather required an artistic talent of exposition, a certain kind of eloquence. The lecturer or writer must find generally accessible standpoints from which he may call forth new representations with the most vivid distinctness, and then allow the abstract principle, which he seeks to make intelligible, to derive from these concrete life. This is almost an opposite mode of treatment to that which obtains in scientific treatises, and it can readily be understood that the men are rare who are equally fitted for both these kinds of intellectual labour.

Owing to all these circumstances a sort of dividing wall is raised between the men of science and the laity who might obtain instruction and guidance from them. That many, and indeed some of the most able, investigators have the qualities and peculiarities belonging to abstract work is natural, and will, in each individual case, be at once willingly excused. I have here merely to guard against the reversal of this relation, as if the defects named were necessary, or at all constituted a prerogative.

The compilers can give no help in those directions where the original thinkers have neglected or avoided expressing themselves. So much the more gratifying is it, I consider, in such a state of things, when, among those who have shown the highest ability for original scientific work, there is found, at times, a man like Tyndall, full of enthusiasm for the problem of making the newly-acquired insights and outlooks of his science available for the wider circle of the people, and, at the same time, endowed with other qualities which are the necessary conditions of success towards this end, eloquence and the gift of lucid exposition.

In England the custom of popular scientific lectures has been much longer in existence than in Germany. Since the constitution of the English Universities is very different from ours, fewer individuals are there in a position to prosecute scientific research, or give scientific instruction to regularly prepared scholars, as their life-calling. This generally makes it much more difficult for individuals to go deeply into a special department of study, though Genius of course everywhere breaks through these and other hindrances. The same circumstance has, on the other hand, maintained a closer connection of the workers in science with all other classes of the population, and incited to a more liberal care for the instruction of the student not regularly trained. While this has hitherto been quite rare in Germany, there have long been in England solid and well-furnished institutions for the purpose.

In the two circumstances, first that in England courses of a moderate number of connected lectures can be delivered, and secondly that this can be done in buildings well suited for demonstrations and experiments of every kind, there is a great advantage over the general custom in Germany, where each lecturer only delivers one lecture.

Now, it is intelligible that during the seventy years since this state of things has arisen, and under so much more favourable external conditions, the English public have educated their lecturers, and the lecturers their public, much better than has hitherto been the case in Germany. The Royal Institution has had, among its professors, two men of the first rank, Sir Humphry Davy and Faraday, who have co-operated to that end. At present Prof. Tyndall is held in peculiarly high esteem, both in England and in the United States, on account of his talent for popular expositions of scientific subjects. Anyone who is conscious within himself of the gift and the power of working in a particular direction for the mental development of humanity, has usually a pleasure in such activity, and is ready to devote to it a good share of his time and his energies. This is especially the case with Prof. Tyndall. He has, therefore, remained true to his post at the Royal Institution, though other honourable posts have been offered him. But it would be quite an erroneous conception to think of him merely as the able, popular lecturer; for the greater part of his activity has always been given to scientific investigation, and we owe to him a series of (in part) highly original and remarkable researches and discoveries in physics and physical chemistry.

In his discourse On the scientific use of the Imagination, delivered before the British Association at Liverpool, Prof. Tyndall has given a peculiarly characteristic description of his manner of intellectual working. There are two ways of searching out the system of laws in nature—that of abstract ideas, and that of thorough experimental research. The former way leads ultimately, through mathematical analysis, to an accurate quantitative knowledge of the phenomena. But it can only advance where the other has already, in some measure, opened up the region, *i.e.* given an inductive knowledge of the laws, at least, for some groups of the phenomena belonging to it, and the point is merely the testing and clearing up of the already found laws, the passage from them to the last and most general laws of the region in question, and the complete unfolding of their consequences. This other way leads to a rich knowledge of the behaviour of natural substances and forces, in which at first the law-element is recognised only in the form in which artists perceive it, through vivid sensuous contemplation of the type of its action, in order to a later working out of it in the pure form of an idea. These two sides of the physicist's work are never quite separate from each other, though sometimes the diversity of individual gifts will adapt one man for mathematical deduction, another for the inductive activity of experimentation. Should the first method, however, become wholly divorced from actual observations, it falls into the danger of laboriously building castles in the air, on unstable foundations, and of not finding the points at which it may verify the agreement of its deductions with fact. The second, on the other hand, would lose sight of the proper aim of science, if it did not work towards ultimately bringing its observations into the precise form of the idea.

The first discovery of laws of nature previously unknown, that is, of new forms of likeness in the course of apparently unconnected phenomena, is a matter of sense (taking this word in its widest meaning), and must nearly always be accomplished only by comparison of numerous sensuous perceptions. The perfection and purification of that which has been found falls afterwards under the working of the deductive method of thinking, and preferentially of mathematical analysis, as the final question is ever about equality of quantities.

Now Mr. Tyndall is *par excellence* an experimenter; he forms his generalisations from extensive observations of the play of natural forces, and carries over what he has seen, in some cases to the greatest, in others to the smallest relations of space (as appeared in the lecture referred to). It is quite a mistake to consider what he calls imagination as mere fancy (*Phantasterei*). It is exactly the opposite that is meant—full sensuous contemplation. To this mode of working is evidently to be attributed the clearness of his lectures on physical phenomena, as also his success as a popular lecturer.

H. HELMHOLTZ

GROVE'S "CORRELATION OF PHYSICAL FORCES"

The Correlation of Physical Forces. Sixth edition. With other Contributions to Science. By the Hon. Sir W. R. Grove, M.A., F.R.S., one of the judges of the Court of Common Pleas. (London: Longmans, 1874).

THERE are few instances in which anyone whose life has not been exclusively scientific has made such valuable contributions to science as those of Sir W. R. Grove. His nitric acid battery, to the invention of which he was led, not by accident, but by a course of reasoning, which in the year 1839 was as new as it was original, is a contribution to science the value of which is proved by its still surviving and continuing in daily use in every laboratory as the most powerful generator of electric currents, while hundreds of batteries invented since that of Grove have fallen into disuse, and become extinct in the struggle for scientific existence.

The gas battery, though not of such practical importance, is still of great scientific interest, and the collection which we have before us of those contributions to science which took the form of papers, tempts us to indulge in speculations as to the magnitude of the results which would have accrued to science if so powerful a mind could have been continuously directed with undivided energy towards some of the great questions of physics.

But the main feature of the volume is that from which it takes its name, the essay on the Correlation of Physical Forces, the views contained in which were first advanced in a lecture at the London Institution in January 1842, printed by the proprietors, and subsequently more fully developed in a course of lectures in 1843, published in abstract in the *Literary Gazette*. This essay has a value peculiar to itself. Though it has long ago accomplished the main point of its scientific mission to the world, it will always retain its place in the memory of the student of human thought, as one of the documents which serve for the construction of the history of science.

It is not by discoveries only, and the registration of them by learned societies, that science is advanced. The true seat of science is not in the volume of Transactions, but in the living mind, and the advancement of science consists in the direction of men's minds into a scientific channel; whether this is done by the announcement of a discovery, the assertion of a paradox, the invention of a scientific phrase, or the exposition of a system of doctrine. It is for the historian of science to determine the magnitude and direction of the impulse communicated by either of these means to human thought.

But what we require at any given epoch for the advancement of science is not merely to set men thinking, but to produce a concentration of thought in that part of the field of science which at that particular season ought to be cultivated. In the history of science we find that effects of this kind have often been produced by suggestive books, which put into a definite, intelligible, and communicable form, the guiding ideas that are already working in the minds of men of science, so as to lead them to discoveries, but which they cannot yet shape into a definite statement.

In the first half of the present century, when what is now called the principle of the conservation of energy was as yet unknown by name, it "flung its vague shadow back from the depths of futurity," and those who had greater or less understanding of the times sketched out with greater or less clearness their view of the form into which science was shaping itself.

Some of these addressed themselves to the advanced cultivators of science, speaking, of course, in learned phraseology; but others appealed to a larger audience, and spoke in language which they could understand. Mrs. Somerville's book on the "Connection of the Physical Sciences" was published in 1834 and had reached its eighth edition in 1849. This fact is enough to show that there already existed a widespread desire to be able to form some notion of physical science as a whole.

But when we examine her book in order to find out the nature of the connection of the physical sciences, we are at first tempted to suppose that it is due to the art of the bookbinder, who has bound into one volume such a quantity of information about each of them. What we find in fact is a series of expositions of different sciences, but hardly a word about their connection. The little that is said about this connection has reference to the mutual dependence of the different sciences on each other, a knowledge of the elements of one being essential to the successful prosecution of another. Thus physical astronomy requires a knowledge of dynamics, and the practical astronomer must learn a certain amount of optics in order to understand atmospheric refraction and the adjustment of telescopes. The sciences are also shown to have a common method, namely mathematical analysis; so that analytical methods invented for the investigation of one science are often useful in another.

The unity shadowed forth in Mrs. Somerville's book is therefore a unity of the method of science, not a unity of the processes of nature.

Sir W. Grove's essay may be fairly called a popular book, as it has reached its sixth edition. It is, therefore, not merely a record of the speculations of the author, but an index of the state of scientific thought among a large number of readers. It has not the universal facility and occasional felicity of exposition which distinguish Mrs. Somerville's writings. No one could use it as a text-book of any science, or even as an aid to the cultivation of the art of scientific conversation. The design of the book is to show that of the various forms of energy existing in nature, any one may be transformed into any other, the one form appearing as the other disappears. This is what is meant in the essay by the "correlation of the physical forces," and the whole essay is an exposition of this fact, each of the physical forces in turn being taken as the starting-point, and employed as the source of all the others.

We are sorry that we are not at present able to refer to the early reviews of the essay as indicating the reception given to the doctrine by the literary and scientific public at the time of its original publication. It has certainly exercised a very considerable effect in moulding the mass of what is called scientific opinion, that is to say the influence which determines what a scientific man shall say when he has to make a statement about a science which he does not understand. Many things in the essay which were then considered contrary to scientific opinion, and were therefore objected to, have since then become themselves part of scientific opinion, so that the objections now appear unintelligible to the rising generation of the scientific public.

Helmholtz's essay "On the Conservation of Force," published in 1847, undoubtedly masters a far greater step in science, but the immediate influence was confined to a small number of trained men of science, and it had little direct effect on the public mind.

The various papers of Mayer contain matter calculated to awaken an interest in the transformation of energy even in persons not exclusively devoted to science, but they were long unknown in this country, and produced little direct effect, even in Germany, at the time of their publication.

The rapid development of thermodynamics, and of other applications of the principle of the conservation of energy, at the beginning of the second half of this century, belongs to a later stage of the history of science than that with which we have to do.

To form a just estimate of the value of Sir W. Grove's work we must regard it as the instrument by which certain scientific ideas were diffused over a large area, in language sufficiently appropriate to prevent misapprehension, and yet sufficiently familiar to be listened to by persons who would recoil with horror from any statement in which literary convention is sacrificed to precision.

It is worth while, however, to take note of the progress of evolution by which the words of ordinary language are gradually becoming differentiated and rendered scientifically precise. The fathers of dynamical science found a number of words in common use expressive of action and the results of action, such as force, power, action, impulse, impetus, stress, strain, work, energy, &c. They also had in their minds a number of ideas to be expressed, and they appropriated these words as they best could to express these ideas. But the equivalent words Force, *Vis*, *Kraft*, came most easily to hand, so that we find them compelled to carry almost all the ideas above mentioned, while the other words which might have borne a portion of the load were long left out of scientific language, and retained only their more or less vague meanings as ordinary words.

Thus we have the expressions *Vis acceleratrix*, *Vis motrix*, *Vis viva*, *Vis mortua*, and even *Vis inertiæ*, in every one of which, except the second and fourth, the word *Vis* is used in a sense radically different from that in which it is used in the other expressions.

Confusion may perhaps be avoided in scientific works when read by scientific students, by means of a careful appropriation of epithets such as those which distinguish the meanings of the word *Vis*, but as soon as science becomes popularised, unless its nomenclature is reformed and arranged upon a better principle, the ideas of popular science will be more confused than those of so-called popular ignorance.

Thus the "Physical Forces," whose correlation is discussed in the essay before us, are Motion, Heat, Electricity, Light, Magnetism, Chemical Affinity, and "other modes of force." According to the definition of force, as it has been laid down during the last two centuries in treatises on dynamics, not one of these, except perhaps chemical affinity, can be admitted as a force. According to that definition, "force is that which produces change of motion, and is measured by the change of motion produced."

Newton himself reminds us that force exists only so long as it acts. Its effects may remain, but the force itself is essentially transitive. Hence, when we meet with such phrases as Conservation of Force, Persistence of Force, and the like, we must suppose the word Force to be used in a sense radically different from that adopted by scientific men from Newton downwards. In all these cases, and in the phrase "The Physical Forces" as applied to heat, we are now, thanks to Dr. Thomas Young, able to use the word Energy instead of Force, for this word, according to its scientific definition as "the capacity for performing work," is applicable to all these cases. The confusion has extended even to the metaphorical use of the word Force. Thus, it may be a legitimate metaphor to speak of the force of public opinion as being brought to bear on a statesman so as to exert an overpowering pressure upon him, because here we have an action tending to produce motion in a particular direction; but when we speak of "the Queen's Forces," we use the term in a sense as unscientific as when we speak of the Physical Forces. The author, in his concluding remarks, points out the confusion of terms which embarrassed him in his endeavours to enunciate scientific propositions, on account of the imperfection of scientific language. This, he tells us, "cannot be avoided without a neology which I have not the presumption to introduce or the authority to enforce."

Such a confession, proceeding from so great a master of the art of "putting things," is a most valuable testimony to the importance of the study and special cultivation of scientific language; and a comparison of many passages in the essay with the corresponding statements in more recent books of far inferior power, will show how much may be gained by the successful introduction of appropriate neologies. What appeared mysterious and even paradoxical to the giant, labouring among rough-hewn words, dwindles into a truism in the eyes of the child, born heir to the palace of truth, for the erection of which the giant has furnished the materials.

Thus the appropriation of the word "Mass" to denote the quantity of matter as defined by the amount of force required to produce a given acceleration, has placed the students of the present day on a very different level from those who had to puzzle out the meaning of the phrase *Vis Inertiæ* by combining the explanation of *Vis* as force, with that of *Inertia* as laziness. In the same way the word "stress" as an equivalent for "action and reaction," and as a generic name for pressure, tension, &c., will save future generations a great deal of trouble; and the distinction between the possession of energy and the act of doing work, which is now so familiar to us, would have obviated several objections to the doctrine of the essay, which are founded on statements in which the production of one form of energy and the maintenance of another are treated as if they were operations of the same kind. We read at p. 163:—Thus, "a voltaic battery, decomposing water in a voltameter, while the same current is employed at the same time to make (maintain) an electromagnet, gives nevertheless in the voltameter an equivalent of gas, or decomposes an equivalent of an electrolyte for each equivalent of decomposition in the battery cells, and will give the same ratios if the electro-magnet be removed."

Here the maintenance of a magnet is a thing of a different order from the decomposition of an electrolyte; the first is maintenance of energy, the other is doing work. This is well explained in the essay; but if appropriate language had been used from the first, the objection could never have been put into form.

J. C. CLERK-MAXWELL.

FIRST FORMS OF VEGETATION

First Forms of Vegetation. By the Rev. Hugh Macmillan, LL.D. Second edition, corrected and revised. (London: Macmillan and Co.)

DR. MACMILLAN explicitly informs his readers in his preface to his book, that his object is not so much to impart cut-and-dried information as to kindle their sympathy and awaken their interest "in a department of nature with which few, owing to the technical phraseology of botanical works, are familiar." Such a purpose is very laudable indeed, and the book which carried it into effect might have been a very valuable one. Science has great need of evangelists. Students of its various branches experience the keenest interest in following up the lines of research and investigating the problems which belong to their own departments. But to feel this interest it is necessary to be instructed ; and in an immense number of cases it is impossible to convey in non-technical language, so as to be understood by the uninstructed, in what the interest consists. Hence it follows that a large number of scientific workers have conceived a decided contempt for all attempts to popularise science. Their position is so far sound. Still, it is extremely important in the interests of science itself that its investigations should not be wholly withdrawn from the notice of the general community and confined to a small esoteric class. Here the function of the evangelists needs to be properly recognised ; we want men with Dr. Macmillan's sympathy with the subject-matter and liking for exposition to take a wider view of it in respect to general interest than it will ever be possible for the special student to take. If public funds are to be devoted to scientific purposes, it is absolutely necessary that the public mind should have some idea that they are being expended on something of more general importance than individual hobbies, as they will be too apt to believe, unless their sympathy with the work is occasionally kindled. It is not every branch of science which is capable of yielding results which can at once be turned to commercial profit, and though knowledge in every line of investigation may be expected to yield practical applications in the most unexpected directions, it would be an evil time for scientific advancement when the community determined to shut its eyes and close its ears to everything which could not be shown to pay. It is very likely, however, to begin to do this unless scientific men take measures to excite intelligent interest where there is no obvious suggestion of profit to gratify the natural cupidity of a commercial country.

It is worth while making these remarks, because it deserves to be borne in mind that the work—though apt to be contemned—is not easy to do ; nor is it easy to find men fit to do it. And the criticisms which we shall now proceed to make on Dr. Macmillan's book are made by no means from a desire to find fault, but rather to bring into prominence the inherent difficulty which exists in writing such a book as it should be written. If the author has not had a thorough drilling in the technicalities of the subject, then, as Dr. Macmillan has done, he will make some exceptionable statements and stray into sundry grievous pitfalls. If, on the other hand, he is quite and fully competent to write the book, it is tolerably certain he will never write it at all. The general reader wants his science skimmed for him—and this is an operation which a competent student particularly dislikes to perform.

It is a pity that some of Dr. Macmillan's friends "whose scientific position lends weight to their opinions" did not assist him in issuing the work in its new form. This in fact seems to be the only chance of doing the thing properly. The aid of those who would not actually write such books might at any rate be given for the purpose of keeping them free from glaring blunders.

Mosses, for example, we are told (p. 27) belong to the highest division of flowerless plants. This statement can only be met by a categorical negative. As to their being "prefigurations of the flowering plants, epitomes of archetypes in trees and flowers," if this is the alternative for technical language, the general reader can hardly be congratulated on the change. But the author seems not to have a very clear conception of the structural rank of mosses. He tells us on the next page that "through the cone-like spikes of the club-mosses they approximate to the pine tribe in their fructification." This is a *rapprochement* which no modern systematist would think of making. In fact, mosses and club-mosses have the same kind of relationship and no more that ants have with white ants or the albumen of an egg with the albumen of a seed.

On p. 37, it takes one's breath away to read, "*Besides* these curious capsules there are other organs of fructification which clearly demonstrate the sexuality of mosses." It hardly at first occurs to the reader that the author has no notion that the capsules are really the fertilised product derived from the sexual apparatus. The capsule—and this is one of the most remarkable things in the whole vegetable kingdom—is gradually developed from the oospore ; its being composed of modified leaves, as Dr. Macmillan explains on p. 40, is an antiquated idea. There is something indeed to strike an intelligent curiosity on almost every page. At p. 80 we are told of Lycopods "becoming slightly arborescent in tropical countries, *particularly* New Zealand." On p. 84 "some species" are said "to have little cone-like spikes at the tips of their branches under the scales of which, as in the pine tribe, lurk the reproductive embryos." This is simply utter nonsense. In so far as the process is understood we have spores borne in spore cases at the base of the upper surface of the fruiting scales, and these spores when disseminated undergo a further process of development, which results in the formation of an embryo.

Dr. Macmillan dismisses Schwenderer's theory of lichens in a very *ex cathedrâ* fashion. *En revanche*, he is equally decided in rejecting Dr. Bastian's views on heterogenesis.

We regret that this book has not been put into a more satisfactory shape, for the author has industriously collected a great deal of very interesting matter.

W. T. T. D.

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. No notice is taken of anonymous communications.*]

Bright Meteors

ON Saturday last I saw *two* very bright meteors, each coming from the Perseus radiant point, and isolated from smaller ones by such a length of time that my (possible) watch error of perhaps one minute will not prevent their being identified if they have been observed at other stations.

A very bright one, almost like a rocket, passed exactly over Vega at 10.35.

Another, nearly as bright, passed through the intersection of the diagonals of the quadrilateral of Monoceros at 10.55.

P. G. TAIT

St. Andrew's, N.B., Aug. 13

Mr. Herbert Spencer and Physical Axioms

I CANNOT help thinking that something of importance still remains to be said on the subject of the laws of motion, recently argued in your columns with so much ability by Spencer, Tait, and others.

There are three species of magnitude, viz., number, extended magnitude, and magnitude of degree. Magnitude of degree admits in itself no other mathematical comparison than that of equality and inequality, and no other mathematical treatment than simple increase or decrease, and in consequence it does not admit directly of ordinary mathematical investigation. Number and extended magnitude, such as length, duration, &c., admits of comparison by ratio, and of addition, subtraction, multiplication, division, &c. Magnitudes of degree are only brought under mathematical processes by means of conventional measurement. That is to say, some number or extended magnitude, which is found by experience to vary with the magnitude of degree, is adopted eventually as the measure of that magnitude, and mathematical processes are applied to the measure. It is incorrect, however, to say that we take an extended magnitude which varies in direct proportion with the magnitude of degree, as its measure, because direct proportion of magnitudes which vary together involves inequality of ratio of corresponding value, and, as already stated, the proportion of ratio does not really subsist between different values of a magnitude of degree, though from the intimate mental connection between certain magnitudes of degree and their measures, we often think it does.

When, for instance, we say that the brightness of two equal lights is double that of either, the statement is quite incapable of proof by experiment, and is certainly not intuitional; it is simply conventional. If we agreed that the brightness of a number of equal lights should be measured by the square root of the number, we should have to consider that the brightness of light varies inversely as its distance instead of as the square of its distance from its origin,—a result against which nothing could be urged but its practical inconvenience. Or, to take the example of a magnitude of degree whose conventional movement is somewhat less familiar to our minds: when we say that our expectation of an event which happens on an average three out of four times is double of our expectation of an event which happens once out of four times, we are clearly using words in a conventional way. The one belief is not really double of the other, but the average by which we agree to measure it is double.

Now with respect to force and mass, both magnitudes of degree, it so happens that there are two almost equally natural methods of measuring them consistent with, but nevertheless independent of, each other. Each of these may be conventionally adopted, but in either case its consistence with the other can only be demonstrated by experiment.

If you agree to measure force as directly proportionate to the acceleration it produces on a given mass, and mass as inversely proportionate to the acceleration produced by a given force, then, to that extent, the second law of motion, and the law which is sometimes adopted in place of Newton's third, are the results neither of experience nor intuition, but simply of convention; but then, on the other hand, it must be held that it is by experience we come to the conclusion that the mass of two bodies, *as above measured*, is the sum of their two masses, and the weight of two bodies the sum of their weights. If, on the other hand, you conventionally measure forces by the number of equal weights which will produce the same effect, and masses by the number of bodies of equal mass which make them up, then clearly the truth of the above portion of the laws of motion can only be proved by experience.

The mistake made by some mathematicians is that while ostensibly assuming the one conventional measure of force and mass they tacitly assume the other, and then illogically profess to demonstrate the necessary consequences of their own conventions by reference to experience founded on the other. They agree to measure force by the acceleration it produces in its own direction on a given mass, and then profess to prove forces do produce such proportionate acceleration by reference to experience, on the assumption that forces are to be measured by the number of equal weights or other forces which will produce the same effect.

In the case of the first law of motion, mathematicians often commit an error even more flagrant. To define force as that which affects motion, and then to profess that it is proved by experience that a body acted on by no force will remain at rest or move uniform, is on the face of it absurd. As well might Euclid, after defining a circle, have appealed to experience to show that a figure, every point of whose circumference is not equally distant from the centre, is not a circle. Or as well might a doctor begin by defining intoxication to be a state produced by taking alcohol, and then appeal to the experience of the Good Templars to prove that in the absence of alcohol there is no intoxication.

Herbert Spencer seems to me to be wrong, therefore, in concluding that our belief in the laws of motion is in the true sense (if it has any true sense) intuitive; but his error is the more excusable on account of the confusion of ideas involved in most mathematical explanations of these laws.

F. GUTHRIE

Graaff Reinet College, Cape of Good Hope, June 21

ORGANISATION OF THE FRENCH METEOROLOGICAL SERVICE

THE measures we alluded to in NATURE, vol. x. p. 294, with respect to the French Meteorological Service, have been partially adopted, and will be shortly followed by others. The Meteorological Service has been divided between two astronomers—M. Rayet, who has under his special care the magnetical map of France, the official observations taken at the observatory, and the several French stations; and M. Froat, who has been appointed to investigate the great disturbances of the atmosphere, to send warnings to the principal French seaports, to publish the atlas, and correspond with the several departmental commissions which have been already appointed. These departmental commissions are appointed by the prefect of each department, and funds are granted to them out of the departmental budget and voted by the Council-General of each department.

M. Leverrier issued, on August 5, a circular to these general commissions, informing them that the printing of the storm-maps, which had been stopped owing to the country's calamities, was to be resumed.

Special mention is made in this circular of the hailstorms which have been studied most carefully by MM. Becquerel, father and son. Nothing has been done yet to increase the efficiency of lightning conductors.

The several departmental commissions, numbering about ninety, including Algiers, have been grouped into six natural regions. M. Ch. Sainte-Clair Deville has been sent to Algiers to organise the meteorology of that country, from the sea to the remotest parts of the French possessions in the desert. He has not finished his tour yet. He is General Inspector for Meteorology, and had issued an order for altering the hours of observation, which order was cancelled by the Ministry.

Some arrangements have yet to be made with the navy for the storm warnings. Very likely French seaports will continue to receive warnings from England, which are very popular, as well as warnings from their own observatory.

NOTES

MR. BRIAN HODGSON, F.Z.S., has presented to the library of the Zoological Society a large collection of original drawings of Himalayan Mammals, made during his residence in Nepaul. They are of much scientific value, as being in many cases taken from the types on which his species are founded.

M. MAREY has recently published the results of experiments undertaken to determine by the graphic method what is the true movement of the legs in walking. His results prove convincingly that the brothers Weber were wrong in assuming that the oscillation of the leg which is not in contact with the ground is the same as that of a pendulum; for when it is represented on a uniformly moving plane, the line drawn is a straight and not a curved one. The movement of the suspended foot is therefore uniform, depending on muscular action, in combination with that of gravity.

DR. MORRISON WATSON, Senior Demonstrator of Anatomy in the University of Edinburgh, has been appointed Professor of Anatomy in the Owens College, Manchester.

A PARTICULARLY closely reasoned and valuable paper has just been published by Dr. William Marcet, F.R.S., entitled "An Experimental Inquiry into the Nutrition of Animal Tissues," in which the author argues out, and substantiates by careful analysis, his division of the constituents of animal tissues into the parts which constitute the working or ripe tissue, insoluble in water; the nutritive material of the tissue, colloid and soluble; and the products of tissue-destruction, crystalloid and soluble. We hope to be able to give an abstract of this paper on a future occasion.

Les Mondes announces the death, on July 21, of Count Gustave Doulcet de Pontécoulant, who was born in 1798.

THE seventh session of the International Congress of Anthropology and Prehistoric Archæology was closed at Stockholm on Sunday, after having fixed on Buda-Pesth as the next place of meeting. The number of members of this Association is upwards of 1,550: of these, 800 were present at the Stockholm meeting, which commenced on the 7th instant, when the following officials were chosen :—Patron, Oscar II., King of Sweden and Norway; president, Count Hammig Hamilton, Grand Chancellor of the Swedish Universities; honorary presidents, MM. Desor, Capellini, and Worsaae; vice-presidents, MM. Hildebrandt, sen., and Nilsson (Sweden), De Quatrefages (France), Franks (England), Virchow (Germany), Dupont (Belgium), Leemans and Bogdanow (Russia); general secretary, M. Hans Hildebrandt; secretaries, MM. Montelius, Retzius, Chantre, and Cazalis de Fondouce; assistant secretaries, MM. Stolpe and Landberg; council, MM. Bertrand, Berthelot, Evans, Von Quast, Schaffhausen, Pigorini, Van Beneden, Engelhardt, Rygh, Von Düben, Aspelin, Lerch, Romer, Whitney. The sittings were held at the *Riddarhus*, or "House of Knights," a house as old as the time of Gustavus Adolphus, which belongs to the Swedish nobility. Stockholm was very appropriately fixed upon as the place of meeting for this year's Congress, as the northern antiquaries and archæologists have done a great deal to form the departments of research with which the Congress deals; we need only mention the names of Bruzelius, Thomsen (Denmark), Nilsson, Retzius, and Hildebrandt. The magnificent museum of Stockholm was commenced in 1850, and finished in 1863, and the collection has been arranged by the Government Antiquary, M. Hildebrandt, and is one of the finest collections of prehistoric archæology in existence. Both the King and the city of Stockholm gave the antiquaries a splendid welcome.

THE British Medical Association meets next year in Edinburgh, the president elect being Prof. Sir Robert Christison, Bart.

A NEW physiological laboratory, and also an addition to the chemical laboratory of Westminster Hospital, are rapidly approaching completion.

AT the meeting of the Paris Academy of Sciences on the 10th inst., a letter from the Minister of Public Instruction was read, informing the Academy that in consequence of the proposition made to the National Assembly in the month of July last to establish in the neighbourhood of Paris a Physical Observatory independent of the Astronomical Observatory, it was decided to consult the Academy as to the appropriateness and utility of such an establishment. The Minister requested the Academy to consider the question and let him know what conclusion they came to.

WITH reference to Prof. Newcomb's investigation of the moon's motion, the superintendent of the U.S. Naval Observatory reports that the work has been nearly accomplished and prepared for the press according to the original plan; but on examining certain terms troublesome to calculate, which it was supposed were entirely unimportant, it was found that the work could not be properly completed without them. The preparations for observing the transit of Venus have interfered with the development of these important terms. The second part of the work, namely, the tables founded upon Prof. Newcomb's theory, has been carried as far as it can be without the data that will be attainable as soon as the preparations for observing the transit of Venus are completed.

ADMIRAL SANDS, in his annual report with reference to the work of the U.S. Naval Observatory, states that observations, to be of any value to the world, must be published. If they are not, the time and labour spent upon them are simply wasted; and yet they are so much more easily made than reduced, that nothing is more common than to see them lie for years before the computations necessary to fit them for publication are completed. The Naval Observatory has been enabled to resuscitate from its store-rooms the zones of stars observed by Capt. Gilliss, in Chili, in 1850-52, and their reductions are now in such a state of forwardness that the resulting star catalogue will appear in the volume of Washington Observations for 1873. Thus it will be seen that nearly all the valuable observations which were at one time locked up in the archives of the observatory have been given to the world.

WE notice with much pleasure that the Society of Arts has issued a prospectus of Examinations in the Technology of Agriculture and Rural Economy, proposed to be held annually by the Society, as a part of its excellent system of technological examinations in the various industries of the country. We sincerely hope that the proposed examinations will be largely the means of carrying out the object which the Society has in view in instituting them, viz., the promotion of a more extended and intelligent study of agriculture and of the sciences bearing upon it, by those intending to adopt farming as an occupation. The examinations will consist of three parts :—(1) General Science, in which a very wide knowledge of the various sciences which lie at the basis of successful agriculture is demanded from the candidates; there are three certificates in this department—the Elementary Certificate, the Advanced Certificate, and Honours. (2) Technology, in which a knowledge of the many points connected with agriculture and rural economy will be demanded from the candidates proportioned to the class in which they may have passed in the previous examinations; this examination looks very formidable on paper, and to pass creditably in it will demand extensive reading and hard work on the part of the candidates. (3) Practical Knowledge: under this head the candidate must forward to the Society of Arts a certificate, on a form supplied, signed by some agriculturist with whom he may have been practically engaged in farming operations, showing that he has a practical acquaintance with the subject. In order to render these examinations really useful, the Council are making application to the Agricultural Societies, local and general, for assistance in founding scholarships for successful candidates to undergo a regular course of instruction at an Agricultural College. We hope the scheme of the Society of Arts will be productive of excellent results on the agriculture of the country.

M. RÉNAN has brought out a new work, "La Mission de Phénicie," being an account of the scientific researches in Syria during the sojourn of the French army in 1860-61.

A COMMITTEE has been formed to consider what means ought to be taken for the construction of an aquarium at Herne Bay.

PROF. GERVAIS (U.S.) has made a communication upon the teeth of the American reptile known as *Heloderma*. A species of the genus is abundant in Southern Arizona, where it is called a scorpion, and is reputed by the natives to be extremely venomous, although experiments carefully prosecuted by Dr. B. J. D. Irwin, of the United States army, failed to exhibit any evidence of this fact. There is, as Gervais and others have found, a striking relationship between it and some of the poisonous serpents in the possession of a longitudinal furrow on the back part of the teeth, as if to carry poison from a gland. Whether the animal be actually poisonous or not, Gervais calls attention to the peculiar structure of the teeth (as shown by the microscope in a cross section), the basal part of which is filled by folds or plications directed outward toward the fine exterior coat of enamel.

Two new medical bi-monthly journals come to us from Paris; one, the *Paris Medical Record*, is in English, and in general appearance and arrangement resembles the *London Medical Record*; its declared intention is to supplement the efforts of other medical journals. The other, *Echo de la Presse Médicale*, is intended as the complement of the above, and is to be published every alternate week.

THE Wheeler U.S. expedition started from Washington to concentrate at Pueblo, Colorado, on July 15, leaving there as soon thereafter as the different parties can be got into shape. It will move in three separate divisions, which will occupy portions of South-western Colorado and Northern New Mexico. The principal localities to be examined are south of the thirty-eighth parallel of north latitude, in the neighbourhood of the Rio San Juan, and the northern tributaries of the Rio Grande, Rio Chamas, Pecos, and Canadian, a region extremely interesting, and which must shortly be opened up for mining purposes. There will be two separate astronomical parties, one in charge of Mr. John H. Clark, with one assistant, at the observatory, Ogden, Utah; the other in charge of Dr. F. L. Kampf, who will have two assistants, and will occupy stations at Las Vegas, Cimmaron, Sidney Barracks, Julesburgh, and the crossing of the Union Pacific Railroad at the one hundredth meridian. In New Mexico there will be a special party operating, consisting of Prof. E. D. Cope, palæontologist, and Dr. H. C. Yarrow, naturalist of the survey, and one assistant. These gentlemen will visit certain specified areas in the valley of the Rio Grande and Rio San Juan. The main division will be in charge of Lieut. Wheeler, assisted by Lieut. C. W. Whipple and six civilian assistants. The first party of the first division will be in charge of Lieut. W. L. Marshall, assisted by three civilian assistants. The second party consists of Lieut. Rogers Birnie and five civilian assistants. The second division of the first party, Lieut. P. M. Price and four civilian assistants; second party, Lieut. S. E. Blunt and three civilian assistants. There is also a special natural history party, at present operating in portions of Arizona and New Mexico, consisting of Dr. J. T. Rothrock, botanist, Prof. H. W. Henshaw, ornithologist, and James Rutter, general collector. Dr. Oscar Loew will acompany the expedition as chemist and mineralogist, and will be assigned to one of the above-named sections. The entire expedition is made up of nine different parties, and will cover a wide and interesting field; and it is hoped that our geographical knowledge, in the broadest sense of the word, will be greatly augmented by its labours and investigations. Mr. Henshaw and his associates of the special party, above referred to, have been heard from in the vicinity of Fort Wingate, New Mexico, where they were making the best of their way south. They have already secured extensive collections of specimens, and a box has been received at the Washington office containing a number of bird-skins, Indian crania, fish, reptiles, insects, plants, &c. This party will proceed south to near the Mexican boundary, and then retrace their steps, disbanding at Santa Fé in the fall.

IN a paper reprinted from the *American Journal of Science and Arts*, On the connection between isomorphism, molecular weight, and physiological action, by James Blake, M.D., the author gives the following results of investigations on the action of substances when introduced into the veins or arteries of living animals:—1. In the changes induced in living matter by inorganic compounds, the character of the change depends more on the physical properties of the reagent than on its more purely chemical properties. 2. That the character of the changes is determined by the isomorphous relations of the electro-positive element of the reagent. 3. That among the compounds of the more purely metallic elements, the quantity of substances in the same isomorphous group required to produce analogous changes in living matter, is less as the atomic weight of the electro-positive element increases. 4. That the action of inorganic compounds on living matter appears not to be connected with the changes they produce in the proximate elements of the solids and fluids, when no longer forming part of a living body, at least in so far as our present means of research enable us to judge. 5. That in living matter we possess a reagent capable of aiding us in our investigations on the molecular properties of substances.

THERE have been found in the Waiora district, Central India, in a coalfield of about 1,000 acres, two seams, one 15 ft. and the other 20 ft. thick, close together. In other parts the seam is from 50 ft. to 60 ft. thick. It is also said there are millions of tons of iron ore yielding 70 per cent. of metallic iron.

AMONG other recent interesting announcements is that by Mr. O. Harger of the discovery in the coal measures of Illinois of a fossil spider, to which the name *Arthrolycosa antiqua* has been applied.

THE telegraphic apparatus at the U.S. Naval Observatory at Washington is now connected with the main lines of the Western Union Telegraph Company, so that not only is the time-ball dropped daily at noon, but the same signal is widely distributed by the telegraph company. It goes directly from the observatory to the main office in New York city, and thence it is sent to nearly every State in the Union. The immediate object of these signals is to furnish accurate and uniform time to the railroads, and throughout the whole of the vast territory in question there is scarcely a train whose movements are not regulated by the observatory clocks. The clocks at the Navy Department, at the Army Signal Office, at the Treasury Department, and at the Western Union Telegraph Company's office are all constructed on the system known as Hamblett's, and are directly controlled by electric currents sent every second by the standard clock at the observatory.

THE additions to the Zoological Society's Gardens during the past week include a Puma (*Felis concolor*), and three Kinkajous (*Cercoleptes caudivolvulus*), from South America, presented by Mr. W. Delisle Powles; a Cuvier's Toucan (*Ramphastos cuvieri*), from Brazil, presented by Mr. Philip Harrington; a Macaque Monkey (*Macacus cynomolgus*), white variety, from India, presented by Sir Andrew Clarke; a West African Python (*Python sebæ*), deposited; a Crested Agouti (*Dasyprocta cristata*), from South America; five common Kingfishers (*Alcedo ispida*), British, purchased.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE forty-fourth Annual Meeting of the Association was opened yesterday at Belfast, when Prof. A. W. Williamson resigned the Presidency to Prof. Tyndall, who delivered the opening Address.

As in former years, we are able, by the courtesy of the officers of the Association, to publish this week the Address of the President of the Association, and the Addresses of some of the Presidents of Sections.

INAUGURAL ADDRESS OF PROF. JOHN TYNDALL, D.C.L., LL.D., F.R.S., PRESIDENT.

AN impulse inherent in primeval man turned his thoughts and questionings betimes towards the sources of natural phenomena. The same impulse, inherited and intensified, is the spur of scientific action to-day. Determined by it, by a process of abstraction from experience we form physical theories which lie beyond the pale of experience, but which satisfy the desire of the mind to see every natural occurrence resting upon a cause. In forming their notions of the origin of things, our earliest historic (and doubtless, we might add, our prehistoric) ancestors pursued, as far as their intelligence permitted, the same course. They also fell back upon experience, but with this difference—that the particular experiences which furnished the weft and woof of their theories were drawn, not from the study of nature, but from what lay much closer to them, the observation of men. Their theories accordingly took an anthropomorphic form. To supersensual beings, which, "however potent and invisible, were nothing but a species of human creatures, perhaps raised from among mankind, and retaining all human passions and appetites,"* were handed over the rule and governance of natural phenomena.

Tested by observation and reflection, these early notions failed in the long run to satisfy the more penetrating intellects of our race. Far in the depths of history we find men of exceptional power differentiating themselves from the crowd, rejecting these anthropomorphic notions, and seeking to connect natural phenomena with their physical principles. But long prior to these purer efforts of the understanding the merchant had been abroad, and rendered the philosopher possible; commerce had been developed, wealth amassed, leisure for travel and for speculation secured, while races educated under different conditions, and therefore differently informed and endowed, had been stimulated and sharpened by mutual contact. In those regions where the commercial aristocracy of ancient Greece mingled with its eastern neighbours, the sciences were born, being nurtured and developed by free-thinking and courageous men. The state of things to be displaced may be gathered from a passage of Euripides quoted by Hume. "There is nothing in the world; no glory, no prosperity. The gods toss all into confusion; mix everything with its reverse, that all of us, from our ignorance and uncertainty, may pay them the more worship and reverence." Now, as science demands the radical extirpation of caprice and the absolute reliance upon law in nature, there grew with the growth of scientific notions a desire and determination to sweep from the field of theory this mob of gods and demons, and to place natural phenomena on a basis more congruent with themselves.

The problem which had been previously approached from above was now attacked from below; theoretic effort passed from the super to the sub-sensible. It was felt that to construct the universe in idea it was necessary to have some notion of its constituent parts—of what Lucretius subsequently called the "First Beginnings." Abstracting again from experience, the leaders of scientific speculation reached at length the pregnant doctrine of atoms and molecules, the latest developments of which were set forth with such power and clearness at the last meeting of the British Association. Thought no doubt had long hovered about this doctrine before it attained the precision and completeness which it assumed in the mind of Democritus,† a philosopher who may well for a moment arrest our attention. "Few great men," says Lange, in his excellent "History of Materialism," a work to the spirit and the letter of which I am equally indebted, "have been so despitefully used by history as Democritus. In the distorted images sent down to us through unscientific traditions there remains of him almost nothing but the name of the 'laughing philosopher,' while figures of immeasurably smaller significance spread themselves at full length before us." Lange speaks of Bacon's high appreciation of Democritus—for ample illustrations of which I am indebted to my excellent friend Mr. Spedding, the learned editor and biographer of Bacon. It is evident, indeed, that Bacon considered Democritus to be a man of weightier metal than either Plato or Aristotle, though their philosophy "was noised and celebrated in the schools, amid the din and pomp of professors." It was not they, but Genseric and Attila and the barbarians, who destroyed the atomic philosophy. "For at a time when all human learning had suffered shipwreck, these planks of Aristotelian and Platonic philosophy, as being of a lighter and more inflated substance, were preserved and come down to us, while things more solid sank and almost passed into oblivion."

* Hume, "Natural History of Religion."
† Born 460 B.C.

The principles enunciated by Democritus reveal his uncompromising antagonism to those who deduced the phenomena of nature from the caprices of the gods. They are briefly these:—1. From nothing comes nothing. Nothing that exists can be destroyed. All changes are due to the combination and separation of molecules. 2. Nothing happens by chance. Every occurrence has its cause from which it follows by necessity. 3. The only existing things are the atoms and empty space; all else is mere opinion. 4. The atoms are infinite in number, and infinitely various in form; they strike together, and the lateral motions and whirlings which thus arise are the beginnings of worlds. 5. The varieties of all things depend upon the varieties of their atoms, in number, size, and aggregation. 6. The soul consists of free, smooth, round atoms, like those of fire. These are the most mobile of all. They interpenetrate the whole body, and in their motions the phenomena of life arise. Thus the atoms of Democritus are individually without sensation; they combine in obedience to mechanical laws; and not only organic forms, but the phenomena of sensation and thought are also the result of their combination.

That great enigma, "the exquisite adaptation of one part of an organism to another part, and to the conditions of life," more especially the construction of the human body, Democritus made no attempt to solve. Empedocles, a man of more fiery and poetic nature, introduced the notion of love and hate among the atoms to account for their combination and separation. Noticing this gap in the doctrine of Democritus, he struck in with the penetrating thought, linked, however, with some wild speculation, that it lay in the very nature of those combinations which were suited to their ends (in other words, in harmony with their environment) to maintain themselves, while unfit combinations, having no proper habitat, must rapidly disappear. Thus more than 2,000 years ago the doctrine of the "survival of the fittest," which in our day, not on the basis of vague conjecture, but of positive knowledge, has been raised to such extraordinary significance, had received at all events partial enunciation.*

Epicurus,† said to be the son of a poor schoolmaster at Samos, is the next dominant figure in the history of the atomic philosophy. He mastered the writings of Democritus, heard lectures in Athens, returned to Samos, and subsequently wandered through various countries. He finally returned to Athens, where he bought a garden, and surrounded himself by pupils, in the midst of whom he lived a pure and serene life, and died a peaceful death. His philosophy was almost identical with that of Democritus; but he never quoted either friend or foe. One main object of Epicurus was to free the world from superstition and the fear of death. Death he treated with indifference. It merely robs us of sensation. As long as we are, death is not; and when death is, we are not. Life has no more evil for him who has made up his mind that it is no evil not to live. He adored the gods, but not in the ordinary fashion. The idea of divine power, properly purified, he thought an elevating one. Still he taught, "Not he is godless who rejects the gods of the crowd, but rather he who accepts them." The gods were to him eternal and immortal beings, whose blessedness excluded every thought of care or occupation of any kind. Nature pursues her course in accordance with everlasting laws, the gods never interfering. They haunt

"The lucid interspace of world and world
Where never creeps a cloud or moves a wind,
Nor ever falls the least white star of snow,
Nor ever lowest roll of thunder moans,
Nor sound of human sorrow mounts to mar
Their sacred everlasting calm."‡

Lange considers the relation of Epicurus to the gods subjective; the indication probably of an ethical requirement of his own nature. We cannot read history with open eyes, or study human nature to its depths, and fail to discern such a requirement. Man never has been and he never will be satisfied with the operations and products of the understanding alone; hence physical science cannot cover all the demands of his nature. But the history of the efforts made to satisfy these demands might be broadly described as a history of errors—the error consisting in ascribing fixity to that which is fluent, which varies as we vary, being gross when we are gross, and becoming, as our capacities widen, more abstract and sublime. On one great point the mind of Epicurus was at peace. He neither sought

* Lange, 2nd edit., p. 23. † Born 342 B.C.
‡ Tennyson's "Lucretius."

nor expected, here or hereafter, any personal profit from his relation to the gods. And it is assuredly a fact that loftiness and serenity of thought may be promoted by conceptions which involve no idea of profit of this kind. "Did I not believe," said a great man to me once, "that an Intelligence is at the heart of things, my life on earth would be intolerable." The utterer of these words is not, in my opinion, rendered less noble but more noble, by the fact that it was the need of ethical harmony here, and not the thought of personal profit hereafter, that prompted his observation.

A century and a half after the death of Epicurus, Lucretius * wrote his great poem, "On the Nature of Things," in which he, a Roman, developed with extraordinary ardour the philosophy of his Greek predecessor. He wishes to win over his friend Memnius to the school of Epicurus; and although he has no rewards in a future life to offer, although his object appears to be a purely negative one, he addresses his friend with the heat of an apostle. His object, like that of his great forerunner, is the destruction of superstition; and considering that men trembled before every natural event as a direct monition from the gods, and that everlasting torture was also in prospect, the freedom aimed at by Lucretius might perhaps be deemed a positive good. "This terror," he says, "and darkness of mind must be dispelled, not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature." He refutes the notion that anything can come out of nothing, or that that which is once begotten can be recalled to nothing. The first beginnings, the atoms, are indestructible, and into them all things can be dissolved at last. Bodies are partly atoms and partly combinations of atoms; but the atoms nothing can quench. They are strong in solid singleness, and by their denser combination all things can be closely packed and exhibit enduring strength. He denies that matter is infinitely divisible. We come at length to the atoms, without which, as an imperishable substratum, all order in the generation and development of things would be destroyed.

The mechanical shock of the atoms being in his view the all-sufficient cause of things, he combats the notion that the constitution of nature has been in any way determined by intelligent design. The interaction of the atoms throughout infinite time rendered all manner of combinations possible. Of these the fit ones persisted, while the unfit ones disappeared. Not after sage deliberation did the atoms station themselves in their right places, nor did they bargain what motions they should assume. From all eternity they have been driven together, and after trying motions and unions of every kind, they fell at length into the arrangements out of which this system of things has been formed. His grand conception of the atoms falling silently through immeasurable ranges of space and time suggested the nebular hypothesis to Kant, its first propounder. "If you will apprehend and keep in mind these things, Nature, free at once, and rid of her haughty lords, is seen to do all things spontaneously of herself, without the meddling of the gods."†

During the centuries between the first of these three philosophers and the last, the human intellect was active in other fields than theirs. The Sophists had run through their career. At Athens had appeared the three men, Socrates, Plato, and Aristotle, whose yoke remains to some extent unbroken to the present hour. Within this period also the School of Alexandria was founded, Euclid wrote his "Elements," and he and others made some advance in optics. Archimedes had propounded the theory of the lever and the principles of hydrostatics. Pythagoras had made his experiments on the harmonic intervals, while astronomy was immensely enriched by the discoveries of Hipparchus, who was followed by the historically more celebrated Ptolemy. Anatomy had been made the basis of scientific medicine; and it is said by Draper ‡ that vivisection then began. In fact, the science of ancient Greece had already cleared the world of the fantastic images of divinities operating capriciously through natural phenomena. It had shaken itself free from that fruitless scrutiny "by the internal light of the mind alone," which had vainly sought to transcend experience and reach a knowledge of ultimate causes. Instead of accidental observation, it had introduced observation with a purpose; instruments were employed to aid the senses; and scientific method was rendered in a great measure complete by the union of induction and experiment.

What, then, stopped its victorious advance? Why was the scientific intellect compelled, like an exhausted soil, to lie fallow for nearly two millenniums before it could regather the elements necessary to its fertility and strength? Bacon has already let us know one cause; Whewell ascribes this stationary period to four causes—obscurity of thought, servility, intolerance of disposition, enthusiasm of temper; and he gives striking examples of each.* But these characteristics must have had their causes, which lay in the circumstances of the time. Rome and the other cities of the empire had fallen into moral putrefaction. Christianity had appeared, offering the gospel to the poor, and by moderation if not asceticism of life, practically protesting against the profligacy of the age. The sufferings of the early Christians and the extraordinary exaltation of mind which enabled them to triumph over the diabolical tortures to which they were subjected,† must have left traces not easily effaced. They scorned the earth, in view of that "building of God, that house not made with hands, eternal in the heavens." The Scriptures which ministered to their spiritual needs were also the measure of their science. When, for example, the celebrated question of antipodes came to be discussed, the Bible was with many the ultimate court of appeal. Augustine, who flourished A.D. 400, would not deny the rotundity of the earth, but he would deny the possible existence of inhabitants at the other side, "because no such race is recorded in Scripture among the descendants of Adam." Archbishop Boniface was shocked at the assumption of a "world of human beings out of the reach of the means of salvation." Thus reined in, science was not likely to make much progress. Later on, the political and theological strife between the Church and civil governments, so powerfully depicted by Draper, must have done much to stifle investigation.

Whewell makes many wise and brave remarks regarding the spirit of the Middle Ages. It was a menial spirit. The seekers after natural knowledge had forsaken that fountain of living waters, the direct appeal to nature by observation and experiment, and had given themselves up to the remanipulation of the notions of their predecessors. It was a time when thought had become abject, and when the acceptance of mere authority led, as it always does in science, to intellectual death. Natural events, instead of being traced to physical, were referred to moral causes, while an exercise of the phantasy, almost as degrading as the spiritualism of the present day, took the place of scientific speculation. Then came the mysticism of the Middle Ages, magic, alchemy, the Neo-platonic philosophy, with its visionary though sublime attractions, which caused men to look with shame upon their own bodies as hindrances to the absorption of the creature in the blessedness of the Creator. Finally came the scholastic philosophy, a fusion, according to Lange, of the least mature notions of Aristotle with the Christianity of the west. Intellectual immobility was the result. As a traveller without a compass in a fog may wander long, imagining he is making way, and find himself, after hours of toil at his starting-point, so the schoolmen, having tied and untied the same knots, and formed and dissipated the same clouds, found themselves at the end of centuries in their old position.

With regard to the influence wielded by Aristotle in the Middle Ages, and which, though to a less extent, he still wields, I would ask permission to make one remark. When the human mind has achieved greatness and given evidence of extraordinary power in any domain, there is a tendency to credit it with similar power in all other domains. Thus theologians have found comfort and assurance in the thought that Newton dealt with the question of revelation, forgetful of the fact that the very devotion of his powers, through all the best years of his life, to a totally different class of ideas, not to speak of any natural disqualification, tended to render him less instead of more competent to deal with theological and historic questions. Goethe, starting from his established greatness as a poet, and indeed from his positive discoveries in natural history, produced a profound impression among the painters of Germany when he published his "Farbenlehre," in which he endeavoured to overthrow Newton's theory of colours. This theory he deemed so obviously absurd, that he considered its author a charlatan, and attacked him with a corresponding vehemence of language. In the domain of natural history Goethe had made really considerable discoveries; and we have high authority for assuming that

* Born 99 B.C.

† Monro's translation. In his criticism of this work (*Contemporary Review*, 1867) Dr. Hayman does not appear to be aware of the really sound and subtile observations on which the reasoning of Lucretius, though erroneous, sometimes rests.

‡ "History of the Intellectual Development of Europe," p. 295.

* "History of the Inductive Sciences," vol. i.

† Depicted with terrible vividness in Renan's "Antichrist."

had he devoted himself wholly to that side of science, he might have reached in it an eminence comparable with that which he attained as a poet. In sharpness of observation, in the detection of analogies, however apparently remote, in the classification and organisation of facts according to the analogies discerned, Goethe possessed extraordinary powers. These elements of scientific inquiry fall in with the discipline of the poet. But, on the other hand, a mind thus richly endowed in the direction of natural history, may be almost shorn of endowment as regards the more strictly called physical and mechanical sciences. Goethe was in this condition. He could not formulate distinct mechanical conceptions; he could not see the force of mechanical reasoning; and in regions where such reasoning reigns supreme he became a mere *ignis fatuus* to those who followed him.

I have sometimes permitted myself to compare Aristotle with Goethe, to credit the Stagirite with an almost superhuman power of amassing and systematising facts, but to consider him fatally defective on that side of the mind in respect to which incompleteness has been justly ascribed to Goethe. Whewell refers the errors of Aristotle, not to a neglect of facts, but to "a neglect of the idea appropriate to the facts; the idea of mechanical cause, which is force, and the substitution of vague or inapplicable notions, involving only relations of space or emotions of wonder." This is doubtless true; but the word "neglect" implies mere intellectual misdirection, whereas in Aristotle, as in Goethe, it was not, I believe, misdirection, but sheer natural incapacity which lay at the root of his mistakes. As a physicist, Aristotle displayed what we should consider some of the worst attributes of a modern physical investigator—indistinctness of ideas, confusion of mind, and a confident use of language, which led to the delusive notion that he had really mastered his subject, while he as yet had failed to grasp even the elements of it. He put words in the place of things, subject in the place of object. He preached induction without practising it, inverting the true order of inquiry by passing from the general to the particular, instead of from the particular to the general. He made of the universe a closed sphere, in the centre of which he fixed the earth, proving from general principles, to his own satisfaction and that of the world for near 2,000 years, that no other universe was possible. His notions of motion were entirely unphysical. It was natural or unnatural, better or worse, calm or violent—no real mechanical conception regarding it lying at the bottom of his mind. He affirmed that a vacuum could not exist, and proved that if it did exist motion in it would be impossible. He determined *à priori* how many species of animals must exist, and showed on general principles why animals must have such and such parts. When an eminent contemporary philosopher, who is far removed from errors of this kind, remembers these abuses of the *à priori* method, he will be able to make allowance for the jealousy of physicists as to the acceptance of so-called *à priori* truths. Aristotle's errors of detail were grave and numerous. He affirmed that only in man we had the beating of the heart, that the left side of the body was colder than the right, that men have more teeth than women, and that there is an empty space, not at the front, but at the back of every man's head.

There is one essential quality in physical conceptions which was entirely wanting in those of Aristotle and his followers. I wish it could be expressed by a word untainted by its associations; it signifies a capability of being placed as a coherent picture before the mind. The Germans express the act of picturing by the word *vorstellen*, and the picture they call a *vorstellung*. We have no word in English which comes nearer to our requirements than *imagination*, and, taken with its proper limitations, the word answers very well; but, as just intimated, it is tainted by its associations, and therefore objectionable to some minds. Compare, with reference to this capacity of mental presentation, the case of the Aristotelian, who refers the ascent of water in a pump to Nature's abhorrence of a vacuum, with that of Pascal when he proposed to solve the question of atmospheric pressure by the ascent of the Puy de Dome. In the one case the terms of the explanation refuse to fall into place as a physical image; in the other the image is distinct, the fall and rise of the barometer being clearly figured as the balancing of two varying and opposing pressures.

During the drought of the Middle Ages in Christendom, the Arabian intellect, as forcibly shown by Draper, was active. With the intrusion of the Moors into Spain, cleanliness, order, learning, and refinement took the place of their opposites. When smitten with the disease, the Christian peasant resorted to a shrine; the Moorish one to an instructed physician. The Arabs encouraged translations from the Greek philosophers, but not from the Greek poets. They turned in disgust "from the lewdness of our classical mythology, and denounced as an unpardonable blasphemy all connection between the impure Olympian Jove and the Most High God." Draper traces still further than Whewell the Arab elements in our scientific terms, and points out that the under garment of ladies retains to this hour its Arab name. He gives examples of what Arabian men of science accomplished, dwelling particularly on Alhazen, who was the first to correct the Platonic notion that rays of light are emitted by the eye. He discovered atmospheric refraction, and points out that we see the sun and moon after they have set. He explains the enlargement of the sun and moon, and the shortening of the vertical diameters of both these bodies, when near the horizon. He is aware that the atmosphere decreases in density with increase of height, and actually fixes its height at 58½ miles. In the Book of the Balance Wisdom, he sets forth the connection between the weight of the atmosphere and its increasing density. He shows that a body will weigh differently in a rare and a dense atmosphere: he considers the force with which plunged bodies rise through heavier media. He understands the doctrine of the centre of gravity, and applies it to the investigation of balances and steelyards. He recognises gravity as a force, though he falls into the error of making it diminish at the distance, and of making it purely terrestrial. He knows the relation between the velocities, spaces, and times of falling bodies, and has distinct ideas of capillary attraction. He improves the hydrometer. The determination of the densities of the bodies as given by Alhazen approach very closely to our own. "I join," says Draper, in the pious prayer of Alhazen, "that in the day of judgment the All-Merciful will take pity on the soul of Abur-Raihân, because he was the first of the race of men to construct a table of specific gravities." If all this be historic truth (and I have entire confidence in Dr. Draper), well may he "deplore the systematic manner in which the literature of Europe has contrived to put out of sight our scientific obligations to the Mahommedans." *

Towards the close of the stationary period a word-weariness, if I may so express it, took more and more possession of men's minds. Christendom had become sick of the school philosophy and its verbal wastes, which led to no issue, but left the intellect in everlasting haze. Here and there was heard the voice of one impatiently crying in the wilderness, "Not unto Aristotle, not unto subtle hypotheses, not unto Church, Bible, or blind tradition, must we turn for a knowledge of the universe, but to the direct investigation of nature by observation and experiment." In 1543 the epoch-making work of Copernicus on the paths of the heavenly bodies appeared. The total crash of Aristotle's closed universe with the earth at its centre followed as a consequence; and "the earth moves" became a kind of watchword among intellectual freemen. Copernicus was the Canon of the Church of Frauenburg, in the diocese of Ermeland. For three-and-thirty years he had withdrawn himself from the world and devoted himself to the consolidation of his great scheme of the solar system. He made its blocks eternal; and even to those who feared it and desired its overthrow it was so obviously strong that they refrained from meddling with it. In the last year of the life of Copernicus his book appeared: it is said that the old man received a copy of it a few days before his death, and then departed in peace.

The Italian philosopher Giordano Bruno was one of the earliest converts to the new astronomy. Taking Lucretius as his exemplar, he revived the notion of the infinity of worlds; and combining with it the doctrine of Copernicus, reached the sublime generalisation that the fixed stars are suns, scattered numberless through space and accompanied by satellites, which bear the same relation to them as the earth does to our sun, or our moon to our earth. This was an expansion of transcendent import; but Bruno came closer than this to our present line of thought. Struck with the problem of the generation and maintenance of organisms, and duly pondering it, he came to the conclusion that nature in her productions does not imitate the technic of man. Her process is one of unravelling and unfolding. The infinity of forms under which matter appears were not imposed upon it by an external artificer; by its own intrinsic force and virtue it brings these forms forth. Matter is not the mere naked, empty *capacity* which philosophers have pictured her to be, but

* "Intellectual Development of Europe," p. 359.

the universal mother, who brings forth all things as the fruit of her own womb.

This outspoken man was originally a Dominican monk. He was accused of heresy and had to fly, seeking refuge in Geneva, Paris, England, and Germany. In 1592 he fell into the hands of the Inquisition at Venice. He was imprisoned for many years, tried, degraded, excommunicated, and handed over to the civil power, with the request that he should be treated gently and "without the shedding of blood." This meant that he was to be burnt; and burnt accordingly he was, on Feb. 16, 1600. To escape a similar fate, Galileo, thirty-three years afterwards, abjured, upon his knees and with his hand on the holy gospels, the heliocentric doctrine. After Galileo came Kepler, who from his German home defied the power beyond the Alps. He traced out from pre-existing observations the laws of planetary motion. The problem was thus prepared for Newton, who bound those empirical laws together by the principle of gravitation.

During the Middle Ages the doctrine of atoms had to all appearance vanished from discussion. In all probability it held its ground among sober-minded and thoughtful men, though neither the Church nor the world was prepared to hear of it with tolerance. Once, in the year 1348, it received distinct expression. But retractation by compulsion immediately followed, and thus discouraged, it slumbered till the 17th century, when it was revived by a contemporary of Hobbes and Descartes, the Père Gassendi.

The analytic and synthetic tendencies of the human mind exhibit themselves throughout history, great writers ranging themselves sometimes on the one side, sometimes on the other. Men of lofty feelings, and minds open to the elevating impressions produced by nature as a whole, whose satisfaction, therefore, is rather ethical than logical, have leaned to the synthetic side; while the analytic harmonises best with the more precise and more mechanical bias which seeks the satisfaction of the understanding. Some form of pantheism was usually adopted by the one, while a detached Creator, working more or less after the manner of men, was often assumed by the other.* Gassendi is hardly to be ranked with either. Having formerly acknowledged God as the first great cause, he immediately drops the idea, applies the known laws of mechanics to the atoms, and thence deduces all vital phenomena. God who created earth and water, plants and animals, produced in the first place a definite number of atoms, which constituted the seed of all things. Then began that series of combinations and decompositions which goes on at the present day, and which will continue in the future. The principle of every change resides in matter. In artificial productions the moving principle is different from the material worked upon; but in nature the agent works within, being the most active and mobile part of the material itself. Thus this bold ecclesiastic, without incurring the censure of the Church or the world, contrives to outstrip Mr. Darwin. The same cast of mind which caused him to detach the Creator from his universe led him also to detach the soul from the body, though to the body he ascribes an influence so large as to render the soul almost unnecessary. The aberrations of reason were in his view an affair of the material brain. Mental disease is brain-disease; but then the immortal reason sits apart, and cannot be touched by the disease. The errors of madness are errors of the instrument, not of the performer.

It may be more than a mere result of education, connecting itself probably with the deeper mental structure of the two men, that the idea of Gassendi, above enunciated, is substantially the same as that expressed by Prof. Clerk Maxwell at the close of the very noble lecture delivered by him at Bradford last year. According to both philosophers, the atoms, if I understand aright, are the *prepared materials*, the "manufactured articles," which, formed by the skill of the Highest, produce by their subsequent interaction all the phenomena of the material world. There seems to be this difference, however, between Gassendi and Maxwell. The one *postulates*, the other *infers* his first cause. In his manufactured articles, Prof. Maxwell finds the basis of an induction which enables him to scale philosophic heights considered inaccessible by Kant, and to take the logical step from the atoms to their Maker.

The atomic doctrine, in whole or in part, was entertained by Bacon, Descartes, Hobbes, Locke, Newton, Boyle, and their successors, until the chemical law of multiple proportions enabled Dalton to confer upon it an entirely new significance. In our day there are secessions from the theory, but it still stands firm. Only a year or two ago Sir William Thomson, with characteristic penetration, sought to determine the sizes of the atoms, or rather to fix the limits between which their sizes lie; while only last year the discourses of Williamson and Maxwell illustrate the present hold of the doctrine upon the foremost scientific minds. What these atoms, self-moved and self-posited, can and cannot accomplish in relation to life, is at the present moment the subject of profound scientific thought. I doubt the legitimacy of Maxwell's logic; but it is impossible not to feel the ethic glow with which his lecture concludes. There is, moreover, a Lucretian grandeur in his description of the stedfastness of the atoms:—"Natural causes, as we know, are at work, which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred and may yet occur in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built, the foundation stones of the material universe, remain unbroken and unworn."

Ninety years subsequent to Gassendi the doctrine of bodily instruments, as it may be called, assumed immense importance in the hands of Bishop Butler, who, in his famous "Analogy of Religion," developed, from his own point of view, and with consummate sagacity, a similar idea. The bishop still influences superior minds; and it will repay us to dwell for a moment on his views. He draws the sharpest distinction between our real selves and our bodily instruments. He does not, as far as I remember, use the word soul, possibly because the term was so hackneyed in his day, as it had been for many generations previously. But he speaks of "living powers," "perceiving" or "percipient powers," "moving agents," "ourselves," in the same sense as we should employ the term soul. He dwells upon the fact that limbs may be removed and mortal diseases assail the body, while the mind, almost up to the moment of death, remains clear. He refers to sleep and to swoon, where the "living powers" are suspended but not destroyed. He considers it quite as easy to conceive of an existence out of our bodies as in them; that we may animate a succession of bodies, the dissolution of all of them having no more tendency to dissolve our real selves, or "deprive us of living faculties—the faculties of perception and action—than the dissolution of any foreign matter which we are capable of receiving impressions from, or making use of, for the common occasions of life." This is the key of the bishop's position: "Our organised bodies are no more a part of ourselves than any other matter around us." In proof of this he calls attention to the use of glasses, which "prepare objects" for the "percipient power" exactly as the eye does. The eye itself is no more percipient than the glass, and is quite as much the instrument of the true self, and also as foreign to the true self, as the glass is. "And if we see with our eyes only in the same manner as we do with glasses, the like may justly be concluded from analogy of all our senses."

Lucretius, as you are aware, reached a precisely opposite conclusion; and it certainly would be interesting, if not profitable, to us all, to hear what he would or could urge in opposition to the reasoning of the bishop. As a brief discussion of the point will enable us to see the bearings of an important question, I will here permit a disciple of Lucretius to try the strength of the bishop's position, and then allow the bishop to retaliate, with the view of rolling back, if he can, the difficulty upon Lucretius. Each shall state his case fully and frankly; and you shall be umpire between them. The argument might proceed in this fashion:—

"Subjected to the test of mental presentation (*Vorstellung*) your views, most honoured prelate, would present to many minds a great, if not an insuperable difficulty. You speak of 'living powers,' 'percipient or perceiving powers,' and 'ourselves;' but can you form a mental picture of any one of these apart from the organism through which it is supposed to act? Test yourself honestly, and see whether you possess any faculty that would enable you to form such a conception. The true self has a local habitation in each of us; thus localised, must it not possess a form? If so, what form? Have you ever for a moment realised it? When a leg is amputated the body is divided into two parts; is the true self in both of them or in one? Thomas Aquinas might say in both; but not you, for you appeal to the consciousness associated with one of the two parts to prove that the other is foreign matter. Is conscious-

* Boyle's model of the universe was the Strasburg clock with an outside artificer. Goethe, on the other hand, sang

"Ihm ziemt's die Welt im Innern zu bewegen,
Natur in sich, sich in Natur zu hegen."

The same repugnance to the clockmaker conception is manifest in Carlyle.

ness, then, a necesary element of the true self? If so, what do you say to the case of the whole body being deprived of consciousness? If not, then on what grounds do you deny any portion of the true self to the severed limb? It seems very singular that, from the beginning to the end of your admirable book (and no one admires its sober strength more than I do), you never once mention the brain or nervous system. You begin at one end of the body, and show that its parts may be removed without prejudice to the perceiving power. What if you begin at the other end, and remove, instead of the leg, the brain? The body, as before, is divided into two parts; but both are now in the same predicament, and neither can be appealed to to prove that the other is foreign matter. Or, instead of going so far as to remove the brain itself, let a certain portion of its bony covering be removed, and let a rhythmic series of pressure and relaxations of pressure be applied to the soft substance. At every pressure 'the faculties of perception and of action' vanish; at every relaxation of pressure they are restored. Where, during the intervals of pressure, is the perceiving power? I once had the dischage of a Leyden battery passed unexpectedly through me: I felt nothing, but was simply blotted out of conscious existence for a sensible interval. Where was my true self during that interval? Men who have recovered from lightning-stroke have been much longer in the same state; and indeed in cases of ordinary concussion of the brain, days may elapse during which no experience is registered in consciousness. Where is the man himself during the period of insensibility? You may say that I beg the question when I assume the man to have been unconscious, that he was really conscious all the time, and has simply forgotten what had occurred to him. In reply to this, I can only say that no one need shrink from the worst tortures that superstition ever invented if only so felt and so remembered. I do not think your theory of instruments goes at all to the bottom of the matter. A telegraph operator has his instruments, by means of which he converses with the world; our bodies possess a nervous system, which plays a similar part between the perceiving powers and external things. Cut the wires of the operator, break his battery, demagnetise his needle: by this means you certainly sever his connection with the world; but inasmuch as these are real instruments, their destruction does not touch the man who uses them. The operator survives, *and he knows that he survives*. What is it, I would ask, in the human system that answers to this conscious survival of the operator when the battery of the brain is so disturbed as to produce insensibility, or when it is destroyed altogether?

"Another consideration, which you may consider slight, presses upon me with some force. The brain may change from health to disease, and through such a change the most exemplary man may be converted into a debauchee or a murderer. My very noble and approved good master had, as you know, threatenings of lewdness introduced into his brain by his jealous wife's philter; and sooner than permit himself to run even the risk of yielding to these base promptings he slew himself. How could the hand of Lucretius have been thus turned against himself if the real Lucretius remained as before? Can the brain or can it not act in this distempered way without the intervention of the immortal reason? If it can, then it is a prime mover which requires only healthy regulation to render it reasonably self-acting, and there is no apparent need of your immortal reason at all. If it cannot, then the immortal reason, by its mischievous activity in operating upon a broken instrument, must have the credit of committing every imaginable extravagance and crime. I think, if you will allow me to say so, that the gravest consequences are likely to flow from your estimate of the body. To regard the brain as you would a staff or an eyeglass—to shut your eyes to all its mystery, to the perfect correlation that reigns between its condition and our consciousness, to the fact that a slight excess or defect of blood in it produces that very swoon to which you refer, and that in relation to it our meat and drink and air and exercise have a perfectly transcendental value and significance—to forget all this does, I think, open a way to innumerable errors in our habits of life, and may possibly in some cases initiate and foster that very disease, and consequent mental ruin, which a wiser appreciation of this mysterious organ would have avoided."

I can imagine the bishop thoughtful after hearing this argument. He was not the man to allow anger to mingle with the consideration of a point of this kind. After due consideration, and having strengthened himself by that honest contemplation of the facts which was habitual with him, and which includes the desire to give even adverse facts their due weight, I can suppose the bishop to proceed thus:—"You will remember that in the 'Analogy of Religion,' of which you have so kindly spoken, I did not profess to prove anything absolutely, and that I over and over again acknowledged and insisted on the smallness of our knowledge, or rather the depth of our ignorance, as regards the whole system of the universe. My object was to show my deistical friends who set forth so eloquently the beauty and beneficence of Nature and the Ruler thereof, while they had nothing but scorn for the so-called absurdities of the Christian scheme, that they were in no better condition than we were, and that for every difficulty they found upon our side, quite as great a difficulty was to be found on theirs. I will now with your permission adopt a similar line of argument. You are a Lucretian, and from the combination and separation of atoms deduce all terrestrial things, including organic forms and their phenomena. Let me tell you in the first instance how far I am prepared to go with you. I admit that you can build crystalline forms out of this play of molecular force; that the diamond, amethyst, and snow-star are truly wonderful structures which are thus produced. I will go further and acknowledge that even a tree or flower might in this way be organised. Nay, if you can show me an animal without sensation, I will concede to you that it also might be put together by the suitable play of molecular force.

"Thus far our way is clear, but now comes my difficulty. Your atoms are individually without sensation, much more are they without intelligence. May I ask you, then, to try your hand upon this problem. Take your dead hydrogen atoms, your dead oxygen atoms, your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless; observe them running together and forming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to arise? You speak of the difficulty of mental presentation in my case; is it less in yours? I am not all bereft of this *Vorstellungs-kraft* of which you speak. I can follow a particle of musk until it reaches the olfactory nerve; I can follow the waves of sound until their tremors reach the water of the labyrinth, and set the otoliths and Corti's fibres in motion; I can also visualise the waves of ether as they cross the eye and hit the retina. Nay, more, I am able to follow up to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processss. What baffles me, what I find unimaginable, transcending every faculty I possess—transcending, I humbly submit, every faculty *you* possess—is the notion that out of those physical tremors you can extract things so utterly incongruous with them as sensation, thought, and emotion. You may say, or think, that this issue of consciousness from the clash of atoms is not more incongruous than the flash of light from the union of oxygen and hydrogen. But I beg to say that it is. For such incongruity as the flash possesses is that which I now force upon your attention. The flash is an affair of consciousness, the objective counterpart of which is a vibration. It is a flash only by our interpretation. *You* are the cause of the apparent incongruity; and *you* are the thing that puzzles me. I need not remind you that the great Leibnitz felt the difficulty which I feel, and that to get rid of this monstrous deduction of life from death he displaced your atoms by his monads, and which were more or less perfect mirrors of the universe, and out of the summation and integration of which he supposed all the phenomena of life—sentient, intellectual, and emotional—to arise.

"Your difficulty, then, as I see you are ready to admit, is quite as great as mine. You cannot satisfy the human understanding in its demand for logical continuity between molecular processes and the phenomena of consciousness. This is a rock on which materialism must inevitably split whenever it pretends to be a complete philosophy of life. What is the moral, my Lucretian? You and I are not likely to indulge in ill-temper in the discussion of these great topics, where we see so much room for honest differences of opinion. But there are people of less wit, or more bigotry (I say it with humility) on both sides, who are ever ready to mingle anger and vituperation with such discussions. There are, for example, writers of note and influence at the present day who are not ashamed to assume the 'deep personal sin' of a great logician to be the cause of his unbelief in a theologic dogma. And there are others who hold that we, who cherish our noble Bible, wrought as it has been into the constitution of our foreathers, and by inheritance into us, must necessarily be hypocritical and insincere. Let us disavow and discountenance such people, cherishing the unswerving faith that what is good and true in both our arguments will be preserved for the benefit of humanity, while all that is bad or false will disappear."

It is worth remarking that in one respect the bishop was a product of his age. Long previous to his day the nature of the soul had been so favourite and general a topic of discussion, that when the students of the University of Paris wished to know the leanings of a new professor, they at once requested him to lecture upon the soul. About the time of Bishop Butler the question was not only agitated but extended. It was seen by the clear-witted men who entered this arena that many of their best arguments applied equally to brutes and men. The bishop's arguments were of this character. He saw it, admitted it, accepted the consequences, and boldly embraced the whole animal world in his scheme of immortality.

Bishop Butler accepted with unwavering trust the chronology of the Old Testament, describing it as "confirmed by the natural and civil history of the world, collected from common historians, from the state of the earth, and from the late inventions of arts and sciences." These words mark progress: they must seem somewhat hoary to the bishop's successors of to-day.* It is hardly necessary to inform you that since his time the domain of the naturalist has been immensely extended—the whole science of geology, with its astounding revelations regarding the life of the ancient earth, having been created. The rigidity of old conceptions has been relaxed, the public mind being rendered gradually tolerant of the idea that not for six thousand, nor for sixty thousand, nor for six thousand thousand, but for æons embracing untold millions of years, this earth has been the theatre of life and death. The riddle of the rocks has been read by the geologist and palæontologist, from sub-cambrian depths to the deposits thickening over the sea-bottoms of to-day. And upon the leaves of that stone book are, as you know, stamped the characters, plainer and surer than those formed by the ink of history, which carry the mind back into abysses of past time compared with which the periods which satisfied Bishop Butler cease to have a visual angle. Everybody now knows this; all men admit it; still, when they were first broached these verities of science found loud-tonged denunciators, who proclaimed not only their baselessness considered scientifically, but their immorality considered as questions of ethics and religion: the Book of Genesis had stated the question in a different fashion; and science must necessarily go to pieces when it clashed with this authority. And as the seed of the thistle produces a thistle, and nothing else, so these objectors scatter their germs abroad, and reproduce their kind, ready to play again the part of their intellectual progenitors, to show the same virulence, the same ignorance, to achieve for a time the same success, and finally to suffer the same inexorable defeat. Sure the time must come at last when human nature in its entirety, whose legitimate demands it is admitted science alone cannot satisfy, will find interpreters and expositors of a different stamp from those rash and ill-informed persons who have been hitherto so ready to hurl themselves against every new scientific revelation, lest it should endanger what they are pleased to consider theirs.

The lode of discovery once struck, those petrified forms in which life was at one time active, increased to multitudes and demanded classification. The general fact soon became evident that none but the simplest forms of life lie lowest down, that as we climb higher and higher among the superimposed strata more perfect forms appear. The change, however, from form to form was not continuous—but by steps, some small, some great. "A section," says Mr. Huxley, "a hundred feet thick will exhibit at different heights a dozen species of ammonite, none of which passes beyond its particular zone of limestone, or clay, into the zone below it, or into that above it." In the presence of such facts it was not possible to avoid the question, Have these forms, showing, though in broken stages and with many irregularities, this unmistakable general advance, been subjected to no continuous law of growth or variation? Had our education been purely scientific, or had it been sufficiently detached from influences which, however ennobling in another domain, have always proved hindrances and delusions when introduced as factors into the domain of physics, the scientific mind never could have werved from the search for a law of growth, or allowed itself to accept the anthropomorphism which regarded each successive stratum as a kind of mechanic's bench for the manufacture of new species out of all relation to the old.

Biassed, however, by their previous education, the great majority of naturalists invoked a special creative act to account for the appearance of each new group of organisms. Doubtless there were numbers who were clear-headed enough to see that this was no explanation at all, that in point of fact it was an attempt, by the introduction of a greater difficulty, to account for a less. But having nothing to offer in the way of explanation, they for the most part held their peace. Still the thoughts of reflecting men naturally and necessarily simmered round the question. De Maillet, a contemporary of Newton, has been brought into notice by Prof. Huxley as one who "had a notion of the modifiability of living forms." In my frequent conversations with him, the late Sir Benjamin Brodie, a man of highly philosophic mind, often drew my attention to the fact that, as early as 1794, Charles Darwin's grandfather was the pioneer of Charles Darwin. In 1801, and in subsequent years, the celebrated Lamarck, who produced so profound an impression on the public mind through the vigorous exposition of his views by the author of "Vestiges of Creation," endeavoured to show the development of species out of changes of habit and external condition. In 1813, Dr. Wells, the founder of our present theory of dew, read before the Royal Society a paper in which, to use the words of Mr. Darwin, "he distinctly recognises the principle of natural selection; and this is the first recognition that has been indicated." The thoroughness and skill with which Wells pursued his work, and the obvious independence of his character, rendered him long ago a favourite with me; and it gave me the liveliest pleasure to alight upon this additional testimony to his penetration. Prof. Grant, Mr. Patrick Matthew, Von Buch, the author of the "Vestiges," D'Halloy, and others,* by the enunciation of views more or less clear and correct, showed that the question had been fermenting long prior to the year 1858, when Mr. Darwin and Mr. Wallace simultaneously but independently placed their closely concurrent views upon the subject before the Linnean Society.

These papers were followed in 1859 by the publication of the first edition of "The Origin of Species." All great things come slowly to the birth. Copernicus, as I informed you, pondered his great work for thirty-three years. Newton for nearly twenty years kept the idea of Gravitation before his mind; for twenty years also he dwelt upon his discovery of Fluxions, and doubtless would have continued to make it the object of his private thought had he not found that Leibnitz was upon his track. Darwin for two-and-twenty years pondered the problem of the origin of species, and doubtless he would have continued to do so had he not found Wallace upon his track.† A concentrated but full and powerful epitome of his labours was the consequence. The book was by no means an easy one; and probably not one in every score of those who then attacked it had read its pages through, or were competent to grasp their significance if they had. I do not say this merely to discredit them; for there were in those days some really eminent scientific men, entirely raised above the heat of popular prejudice, willing to accept any conclusion that science had to offer, provided it was duly backed by fact and argument, and who entirely mistook Mr. Darwin's views. In fact the work needed an expounder; and it found one in Mr. Huxley. I know nothing more admirable in the way of scientific exposition than those early articles of his on the origin of species. He swept the curve of discussion through the really significant points of the subject, enriched his exposition with profound original remarks and reflections, often summing up in a single pithy sentence an argument which a less compact mind would have spread over pages. But there is one impression made by the book itself which no exposition of it, however luminous, can convey; and that is the impression of the vast amount of labour, both of observation and of thought, implied in its production. Let us glance at its principles.

It is conceded on all hands that what are called varieties are continually produced. The rule is probably without exception. No chick and no child is in all respects and particulars the counterpart of its brother or sister; and in such differences we have "variety" incipient. No naturalist could tell how far this vari-

* Only to some; for there are dignitaries who even now speak of the earth's rocky crust as so much building material prepared for man at the Creation. Surely it is time that this loose language should cease.

* In 1855 Mr. Herbert Spencer ("Principles of Psychology," 2nd edit. vol. i. p. 465) expressed "the belief that life under all its forms has arisen by an unbroken evolution, and through the instrumentality of what are called natural causes."

† The behaviour of Mr. Wallace in relation to this subject has been dignified in the highest degree.

ation could be carried; but the great mass of them held that never by any amount of internal or external change, nor by the mixture of both, could the offspring of the same progenitor so far deviate from each other as to constitute different species. The function of the experimental philosopher is to combine the conditions of nature and to produce her results; and this was the method of Darwin.* He made himself acquainted with what could, without any manner of doubt, be done in the way of producing variation. He associated himself with pigeon-fanciers—bought, begged, kept, and observed every breed that he could obtain. Though derived from a common stock, the diversities of these pigeons were such that "a score of them might be chosen which, if shown to an ornithologist, and he were told that they were wild birds, would certainly be ranked by him as well-defined species." The simple principle which guides the pigeon-fancier, as it does the cattle-breeder, is the selection of some variety that strikes his fancy, and the propagation of this variety by inheritance. With his eye still upon the particular appearance which he wishes to exaggerate, he selects it as it reappears in successive broods, and thus adds increment to increment until an astonishing amount of divergence from the parent type is effected. Man in this case does not produce the *elements* of the variation. He simply observes them, and by selection adds them together until the required result has been obtained. "No man," says Mr. Darwin, "would ever try to make a fantail till he saw a pigeon with a tail developed in some slight degree in an unusual manner, or a pouter until he saw a pigeon with a crop of unusual size." Thus nature gives the hint, man acts upon it, and by the law of inheritance exaggerates the deviation.

Having thus satisfied himself by indubitable facts that the organisation of an animal or of a plant (for precisely the same treatment applies to plants) is to some extent plastic, he passes from variation under domestication to variation under nature. Hitherto we have dealt with the adding together of small changes by the conscious selection of man. Can Nature, thus select? Mr. Darwin's answer is, "Assuredly she can." The number of living things produced is far in excess of the number that can be supported; hence at some period or other of their lives there must be a struggle for existence; and what is the infallible result? If one organism were a perfect copy of the other in regard to strength, skill, and agility, external conditions would decide. But this is not the case. Here we have the fact of variety offering itself to nature, as in the former instance it offered itself to man; and those varieties which are least competent to cope with surrounding conditions will infallibly give way to those that are competent. To use a familiar proverb, the weakest comes to the wall. But the triumphant fraction again breeds to over-production, transmitting the qualities which secured its maintenance, but transmitting them in different degrees. The struggle for food again supervenes, and those to whom the favourable quality has been transmitted in excess will assuredly triumph. It is easy to see that we have here the addition of increments favourable to the individual still more rigorously carried out than in the case of domestication; for not only are unfavourable specimens not selected by nature, but they are destroyed. This is what Mr. Darwin calls "natural selection," which "acts by the preservation and accumulation of small inherited modifications, each profitable to the preserved being." With this idea he interpenetrates and leavens the vast store of facts that he and others have collected. We cannot, without shutting our eyes through fear or prejudice, fail to see that Darwin is here dealing, not with imaginary, but with true causes; nor can we fail to discern what vast modifications may be produced by natural selection in periods sufficiently long. Each individual increment may resemble what mathematicians call a "differential" (a quantity indefinitely small); but definite and great changes may obviously be produced by the integration of these infinitesimal quantities through practically infinite time.

If Darwin, like Bruno, rejects the notion of creative power acting after human fashion, it certainly is not because he is unacquainted with the numberless exquisite adaptations on which this notion of a supernatural artificer has founded. His book is a repository of the most startling facts of this description. Take the marvellous observation which he cites from Dr. Crüger, where a bucket with an aperture, serving as a spout, is formed in an orchid. Bees visit the flower: in eager search of material for their combs they push each other into the bucket, the drenched ones escaping from their involuntary bath by the spout. Here they rub their backs against the viscid stigma of the flower and obtain glue; then against the pollen-masses, which are thus stuck to the back of the bee and carried away. "When the bee, thus provided, flies to another flower, or to the same flower a second time, and is pushed by its comrades into the bucket, and then crawls out by the passage, the pollen-mass upon its back necessarily comes first into contact with the viscid stigma," which takes up the pollen; and this is how that orchid is fertilised. Or take this other case of the *Catasetum*. "Bees visit these flowers in order to gnaw the labellum; on doing this they inevitably touch a long, tapering, sensitive projection. This, when touched, transmits a sensation or vibration to a certain membrane, which is instantly ruptured, setting free a spring, by which the pollen-mass is shot forth like an arrow in the right direction, and adheres by its viscid extremity to the back of the bee." In this way the fertilising pollen is spread abroad.

It is the mind thus stored with the choicest materials of the teleologist that rejects teleology, seeking to refer these wonders to natural causes. They illustrate, according to him, the method of nature, not the "technic" of a man-like artificer. The beauty of flowers is due to natural selection. Those that distinguish themselves by vividly contrasting colours from the surrounding green leaves are most readily seen, most frequently visited by insects, most often fertilised, and hence most favoured by natural selection. Coloured berries also readily attract the attention of birds and beasts, which feed upon them, spread their manured seeds abroad, thus giving trees and shrubs possessing such berries a greater chance in the struggle for existence.

With profound analytic and synthetic skill, Mr. Darwin investigates the cell-making instinct of the hive-bee. His method of dealing with it is representative. He falls back from the more perfectly to the less perfectly developed instinct—from the hive-bee to the humble-bee, which uses its own cocoon as a comb, and to classes of bees of intermediate skill, endeavouring to show how the passage might be gradually made from the lowest to the highest. The saving of wax is the most important point in the economy of bees. Twelve to fifteen pounds of dry sugar are said to be needed for the secretion of a single pound of wax. The quantities of nectar necessary for the wax must therefore be vast; and every improvement of constructive instinct which results in the saving of wax is a direct profit to the insect's life. The time that would otherwise be devoted to the making of wax is now devoted to the gathering and storing of honey for winter food. He passes from the humble-bee with its rude cells, through the Melipona with its more artistic cells, to the hive-bee with its astonishing architecture. The bees place themselves at equal distances apart upon the wax, sweep and excavate squal spheres round the selected points. The spheres intersect, and the planes of intersection are built up with thin laminæ. Hexagonal cells are thus formed. This mode of treating such questions is, as I have said, representative. He habitually retires from the more perfect and complex, to the less perfect and simple, and carries you with him through stages of *perfecting*, adds increment to increment of infinitesimal change, and in this way gradually breaks down your reluctance to admit that the exquisite climax of the whole could be a result of natural selection.

Mr. Darwin shirks no difficulty; and, saturated as the subject was with his own thought, he must have known, better than his critics, the weakness as well as the strength of his theory. This of course would be of little avail were his object a temporary dialectic victory instead of the establishment of a truth which he means to be everlasting. But he takes no pains to disguise the weakness he has discerned; nay, he takes every pains to bring it into the strongest light. His vast resources enable him to cope with objections started by himself and others, so as to leave the final impression upon the reader's mind that if they be not completely answered they certainly are not fatal. Their negative force being thus destroyed, you are free to be influenced by the vast positive mass of evidence he is able to bring before you. This largeness of knowledge and readiness of resource render Mr. Darwin the most terrible of antagonists. Accomplished naturalists have levelled heavy and sustained criticisms against him—not always with the view of fairly weighing his theory, but with the express intention of exposing its weak points only. This does not irritate him. He treats every objection with a soberness and thoroughness which even Bishop Butler might be proud to imitate, surrounding each fact with its

* The first step only towards experimental demonstration has been taken. Experiments now begun might, a couple of centuries hence, furnish data of incalculable value, which ought to be supplied to the science of the future.

appropriate detail, placing it in its proper relations, and usually giving it a significance which, as long as it was kept isolated, failed to appear. This is done without a trace of ill-temper. He moves over the subject with the passionless strength of a glacier; and the grinding of the rocks is not always without a counterpart in the logical pulverisation of the objector. But though in handling this mighty theme all passion has been stilled, there is an emotion of the intellect incident to the discernment of new truth which often colours and warms the pages of Mr. Darwin. His success has been great; and this implies not only the solidity of his work, but the preparedness of the public mind for such a revelation. On this head a remark of Agassiz impressed me more than anything else. Sprung from a race of theologians, this celebrated man combated to the last the theory of natural selection. One of the many times I had the pleasure of meeting him in the United States was at Mr. Winthrop's beautiful residence at Brookline, near Boston. Rising from luncheon, we all halted as if by a common impulse in front of a window, and continued there a discussion which had been started at table. The maple was in its autumn glory; and the exquisite beauty of the scene outside seemed, in my case, to interpenetrate without disturbance the intellectual action. Earnestly, almost sadly, Agassiz turned and said to the gentlemen standing round, "I confess that I was not prepared to see this theory received as it has been by the best intellects of our time. Its success is greater than I could have thought possible."

In our day great generalisations have been reached. The theory of the origin of species is but one of them. Another, of still wider grasp and more radical significance, is the doctrine of the Conservation of Energy, the ultimate philosophical issues of which are as yet but dimly seen—that doctrine which "binds nature fast in fate" to an extent not hitherto recognised, exacting from every antecedent its equivalent consequent, from every consequent its equivalent antecedent, and bringing vital as well as physical phenomena under the dominion of that law of causal connection which, as far as the human understanding has yet pierced, asserts itself everywhere in nature. Long in advance of all definite experiment upon the subject, the constancy and indestructibility of matter had been affirmed; and all subsequent experience justified the affirmation. Later researches extended the attribute of indestructibility to force. This idea, applied in the first instance to inorganic, rapidly embraced organic nature. The vegetable world, though drawing almost all its nutriment from invisible sources, was proved incompetent to generate anew either matter or force. Its matter is for the most part transmuted air; its force transformed solar force. The animal world was proved to be equally uncreative, all its motive energies being referred to the combustion of its food. The activity of each animal as a whole was proved to be the transferred activities of its molecules. The muscles were shown to be stores of mechanical force, potential until unlocked by the nerves, and then resulting in muscular contractions. The speed at which messages fly to and fro along the nerves was determined, and found to be, not as had been previously supposed, equal to that of light or electricity, but less than the speed of a flying eagle.

This was the work of the physicist: then came the conquests of the comparative anatomist and physiologist, revealing the structure of every animal, and the function of every organ in the whole biological series, from the lowest zoophyte up to man. The nervous system had been made the object of profound and continued study, the wonderful and, at bottom, entirely mysterious controlling power which it exercises over the whole organism, physical and mental, being recognised more and more. Thought could not be kept back from a subject so profoundly suggestive. Besides the physical life dealt with by Mr. Darwin, there is a psychical life presenting similar gradations, and asking equally for a solution. How are the different grades and orders of mind to be accounted for? What is the principle of growth of that mysterious power which on our planet culminates in Reason? These are questions which, though not thrusting themselves so forcibly upon the attention of the general public, had not only occupied many reflecting minds, but had been formally broached by one of them before the "Origin of Species" appeared.

With the mass of materials furnished by the physicist and physiologist in his hands, Mr. Herbert Spencer, twenty years ago, sought to graft upon this basis a system of psychology; and two years ago a second and greatly amplified edition of his work appeared. Those who have occupied themselves with the beautiful experiments of Plateau, will remember that when two spherules of olive-oil suspended in a mixture of alcohol and water of the same density as the oil, are brought together, they do not immediately unite. Something like a pellicle appears to be formed around the drops, the rupture of which is immediately followed by the coalescence of the globules into one. There are organisms whose vital actions are almost as purely physical as that of these drops of oil. They come into contact and fuse themselves thus together. From such organisms to others a shade higher, and from these to others a shade higher still, and on through an ever-ascending series, Mr. Spencer conducts his argument. There are two obvious factors to be here taken into account—the creature and the medium in which it lives, or, as it is often expressed, the organism and its environment. Mr. Spencer's fundamental principle is, that between these two factors there is incessant interaction. The organism is played upon by the environment, and is modified to meet the requirements of the environment. Life he defines to be "a continuous adjustment of internal relations to external relations.

In the lowest organisms we have a kind of tactual sense diffused over the entire body; then, through impressions from without and their corresponding adjustments, special portions of the surface become more responsive to stimuli than others. The senses are nascent, the basis of all of them being that simple tactual sense which the sage Democritus recognised 2,300 years ago as their common progenitor. The action of light, in the first instance, appears to be a mere disturbance of the chemical processes in the animal organism, similar to that which occurs in the leaves of plants. By degrees the action becomes localised in a few pigment-cells, more sensitive to light than the surrounding tissue. The eye is here incipient. At first it is merely capable of revealing differences of light and shade produced by bodies close at hand. Followed as the interception of the light is in almost all cases by the contact of the closely adjacent opaque body, sight in this condition becomes a kind of "anticipatory touch." The adjustment continues; a slight bulging out of the epidermis over the pigment-granules supervenes. A lens is incipient, and, through the operation of infinite adjustments, at length reaches the perfection that it displays in the hawk and the eagle. So of the other senses; they are special differentiations of a tissue which was originally vaguely sensitive all over.

With the development of the senses the adjustments between the organism and its environment gradually extend in *space*, a multiplication of experiences and a corresponding modification of conduct being the result. The adjustments also extend in *time*, covering continually greater intervals. Along with this extension in space and time, the adjustments also increase in speciality and complexity, passing through the various grades of brute life and prolonging themselves into the domain of reason. Very striking are Mr. Spencer's remarks regarding the influence of the sense of touch upon the development of intelligence. This is, so to say, the mother-tongue of all the senses, into which they must be translated to be of service to the organism. Hence its importance. The parrot is the most intelligent of birds, and its tactual power is also greatest. From this sense it gets knowledge unattainable by birds which cannot employ their feet as hands. The elephant is the most sagacious of quadrupeds—its tactual range and skill, and the consequent multiplication of experiences, which it owes to its wonderfully adaptable trunk, being the basis of its sagacity. Feline animals, for a similar cause, are more sagacious than hoofed animals—atonement being to some extent made, in the case of the horse, by the possession of sensitive prehensile lips. In the *Primates* the evolution of intellect and the evolution of tactual appendages go hand in hand. In the most intelligent anthropoid apes we find the tactual range and delicacy greatly augmented, new avenues of knowledge being thus opened to the animal. Man crowns the edifice here, not only in virtue of his own manipulatory power, but through the enormous extension of his range of experience, by the invention of instruments of precision, which serve as supplemental senses and supplemental limbs. The reciprocal action of these is finely described and illustrated. That chastened intellectual emotion to which I have referred in connection with Mr. Darwin is, I should say, not absent in Mr. Spencer. His illustrations possess at times exceeding vividness and force, and from his style on such occasions it is to be inferred that the ganglia of this apostle of the understanding are sometimes the seat of a nascent poetic thrill.

It is a fact of supreme importance that actions, the performance of which at first requires even painful effort and deliberation, may by habit be rendered automatic. Witness the slow learning of its letters by a child, and the subsequent facility of reading in a man, when each group of letters which forms a word is instantly and without effort fused to a single perception. Instance the billiard-player, whose muscles of hand and eye, when he reaches the perfection of his art, are unsconsciously co-ordinated. Instance the musician, who by practice is enabled to fuse a multitude of arrangements, auditory, tactual, and muscular, into a process of automatic manipulation. Combining such facts with the doctrine of hereditary transmission, we reach a theory of instinct. A chick, after coming out of the egg, balances itself correctly, runs about, picks up food, thus showing that it possesses a power of directing its movements to definite ends. How did the chick learn this very complex co-ordination of eye, muscles, and beak? It has not been individually taught; its personal experience is *nil;* but it has the benefit of ancestral experience. In its inherited organisation are registered all the powers which it displays at birth. So also as regards the instinct of the hive-bee, already referred to. The distance at which the insects stand apart when they sweep their hemispheres and build their cells is "organically remembered." Man also carries with him the physical texture of his ancestry, as well as the inherited intellect bound up with it. The defects of intelligence during infancy and youth are probably less due to a lack of individual experience than to the fact that in early life the cerebral organisation is still incomplete. The period necessary for completion varies with the race and with the individual. As a round shot outstrips a rifled one on quitting the muzzle of the gun, so the lower race in childhood may outstrip the higher. But the higher eventually overtakes the lower, and surpasses it in range. As regards individuals, we do not always find the precocity of youth prolonged to mental power in maturity, while the dulness of boyhood is sometimes strikingly contrasted with the intellectual energy of after years. Newton, when a boy, was weakly, and he showed no particular aptitude at school; but in his eighteenth year he went to Cambridge, and soon afterwards astonished his teachers by his power of dealing with geometrical problems. During his quiet youth his brain was slowly preparing itself to be the organ of those energies which he subsequently displayed.

By myriad blows (to use a Lucretian phrase) the image and superscription of the external world are stamped as states of consciousness upon the organism, the depth of the impression depending upon the number of the blows. When two or more phenomena occur in the environment invariably together, they are stamped to the same depth or to the same relief, and are indissolubly connected. And here we come to the threshold of a great question. Seeing that he could in no way rid himself of the consciousness of space and time, Kant assumed them to be necessary "forms of thought," the moulds and shapes into which our intuitions are thrown, belonging to ourselves solely and without objective existence. With unexpected power and success Mr. Spencer brings the hereditary experience theory, as he holds it, to bear upon this question. "If there exist certain external relations which are experienced by all organisms at all instants of their waking lives—relations which are absolutely constant and universal—there will be established answering internal relations that are absolutely constant and universal. Such relations we have in those of space and time. As the substratum of all other relations of the Non-Ego, they must be responded to by conceptions that are the substrata of all other relations in the Ego. Being the constant and infinitely repeated elements of thought, they must become the automatic elements of thought—the elements of thought which it is impossible to get rid of—the 'forms of intuition.'"

Throughout this application and extension of the "law of inseparable association," Mr. Spencer stands on totally different ground from Mr. John Stuart Mill, invoking the registered experiences of the race instead of the experiences of the individual. His overthrow of Mr. Mill's restriction of experience is, I think, complete. That restriction ignores the power of organising experience furnished at the outset to each individual; it ignores the different degrees of this power possessed by different races and by different individuals of the same race. Were there not in the human brain a potency antecedent to all experience, a dog or cat ought to be as capable of education as a man. These predetermined internal relations are independent of the experiences of the individual. The human brain is the "organised register of infinitely numerous experiences received during the evolution of life, or rather during the evolution of that series of organisms through which the human organism has been reached. The effects of the most uniform and frequent of these experiences have been successively bequeathed, principal and interest, and have slowly mounted to that high intelligence which lies latent in the brain of the infant. Thus it happens that the European inherits from twenty to thirty cubic inches more of brain than the Papuan. Thus it happens that faculties, as of music, which scarcely exist in some inferior races, become congenital in superior ones. Thus it happens that out of savages unable to count up to the number of their fingers, and speaking a language containing only nouns and verbs, arise at length our Newtons and Shakespeares."

At the outset of this address it was stated that physical theories which lie beyond experience are derived by a process of abstraction from experience. It is instructive to note from this point of view the successive introduction of new conceptions. The idea of the attraction of gravitation was preceded by the observation of the attraction of iron by a magnet, and of light bodies by rubbed amber. The polarity of magnetism and electricity appealed to the senses; and thus became the substratum of the conception that atoms and molecules are endowed with definite, attractive, and repellent poles, by the play of which definite forms of crystalline architecture are produced. Thus molecular force becomes *structural.* It required no great boldness of thought to extend its play into organic nature, and to recognise in molecular force the agency by which both plants and animals are built up. In this way out of experience arise conceptions which are wholly ultra-experiential.

The *origination* of life is a point lightly touched upon, if at all, by Mr. Darwin and Mr. Spencer. Diminishing gradually the number of progenitors, Mr. Darwin comes at length to one "primordial form;" but he does not say, as far as I remember, how he supposes this form to have been introduced. He quotes with satisfaction the words of a celebrated author and divine who had "gradually learnt to see that it is just as noble a conception of the Deity to believe He created a few original forms, capable of self-development into other and needful forms, as to believe that He required a fresh act of creation to supply the voids caused by the action of His laws." What Mr. Darwin thinks of this view of the introduction of life I do not know. Whether he does or does not introduce his "primordial form" by a creative act, I do not know. But the question will inevitably be asked, "How came the form there?" With regard to the diminution of the number of created forms, one does not see that much advantage is gained by it. The anthropomorphism, which it seemed the object of Mr. Darwin to set aside, is as firmly associated with the creation of a few forms as with the creation of a multitude. We need clearness and thoroughness here. Two courses, and two only, are possible. Either let us open our doors freely to the conception of creative acts, or, abandoning them, let us radically change our notions of matter. If we look at matter as pictured by Democritus, and as defined for generations in our scientific text-books, the absolute impossibility of any form of life coming out of it would be sufficient to render any other hypothesis preferable; but the definitions of matter given in our text-books were intended to cover its purely physical and mechanical properties. And taught as we have been to regard these definitions as complete, we naturally and rightly reject the monstrous notion that out of *such* matter any form of life could possibly arise. But are the definitions complete? Everything depends on the answer to be given to this question. Trace the line of life backwards, and see it approaching more and more to what we call the purely physical condition. We reach at length those organisms which I have compared to drops of oil suspended in a mixture of alcohol and water. We reach the *protogenes* of Haeckel, in which we have "a type distinguishable from a fragment of albumen only by its finely granular character." Can we pause here? We break a magnet and find two poles in each of its fragments. We continue the process of breaking, but however small the parts, each carries with it, though enfeebled, the polarity of the whole. And when we can break no longer, we prolong the intellectual vision to the polar molecules. Are we not urged to do *something* similar in the case of life? Is there not a temptation to close to some extent with Lucretius, when he affirms that "Nature is seen to do all things spontaneously of herself without the meddling of the gods?" or with Bruno, when he declares that matter is not "that mere empty *capacity* which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her own womb?" The questions here raised are inevitable. They are approaching us with accelerated speed, and it is not a matter of indifference whether they are introduced with reverence or irreverence. Abandoning all disguise, the confession that I feel bound to make before you is that I prolong the vision backward across the boundary of the experimental evidence, and discern in that matter, which we in our ignorance, and notwithstanding our professed reverence for its Creator have hitherto covered with opprobrium, the promise and potency of every form and quality of life.

The "materialism" here enunciated may be different from what you suppose, and I therefore crave your gracious patience to the end. "The question of an external world," says Mr. J. S. Mill, "is the great battle-ground of metaphysics." * Mr. Mill himself reduces external phenomena to "possibilities of sensation." Kant, as we have seen, made time and space "forms" of our own intuitions. Fichte, having first by the inexorable logic of his understanding proved himself to be a mere link in that chain of eternal causation which holds so rigidly in nature, violently broke the chain by making nature, and all that it inherits, an apparition of his own mind.† And it is by no means easy to combat such notions. For when I say I see you, and that I have not the least doubt about it, the reply is, that what I am really conscious of is an affection of my own retina. And if I urge that I can check my sight of you by touching you, the retort would be that I am equally trangressing the limits of fact; for what I am really conscious of is, not that you are there, but that the nerves of my hand have undergone a change. All we hear, and see, and touch, and taste, and smell, are, it would be urged, mere variations of our own condition, beyond which, even to the extent of a hair's breadth, we cannot go. That anything answering to our impressions exists outside of ourselves is not a *fact*, but an *inference*, to which all validity would be denied by an idealist like Berkeley, or by a sceptic like Hume. Mr. Spencer takes another line. With him, as with the uneducated man, there is no doubt or question as to the existence of an external world. But he differs from the uneducated, who think that the world really *is* what consciousness represents it to be. Our states of consciousness are mere *symbols* of an outside entity which produces them and determines the order of their succession, but the real nature of which we can never know.‡ In fact the whole process of evolution is the manifestation of a Power absolutely inscrutable to the intellect of man. As little in our day as in the days of Job can man by searching find this Power out. Considered fundamentally, it is by the operation of an insoluble mystery that life is evolved, species differentiated, and mind unfolded from their prepotent elements in the immeasurable past. There is, you will observe, no very rank materialism here.

The strength of the doctrine of evolution consists, not in an experimental demonstration (for the subject is hardly accessible to this mode of proof), but in its general harmony with the method of nature as hitherto known. From contrast, moreover, it derives enormous relative strength. On the one side we have a theory (if it could with any propriety be so called) derived, as were the theories referred to at the beginning of this address, not from the study of nature, but from the observation of men—a theory which converts the Power whose garment is seen in the visible universe into an Artificer, fashioned after the human model, and acting by broken efforts as man is seen to act. On the other side we have the conception that all we see around us, and all we feel within us—the phenomena of physical nature as well as those of the human mind—have their unsearchable roots in a cosmical life, if I dare apply the term, an infinitesimal span of which only is offered to the investigation of man. And even this span is only knowable in part. We can trace the development of a nervous system, and correlate with it the parallel phenomena of sensation and thought. We see with undoubting certainty that they go hand in hand. But we try to soar in a vacuum the moment we seek to comprehend the connection between them. An Archimedean fulcrum is here required which the human mind cannot command; and the effort to solve the problem, to borrow an illustration from an illustrious friend of mine, is like the effort of a man trying to lift himself by his own waistband. All that has been here said is to be taken in connection with this fundamental truth. When "nascent senses" are spoken of, when "the differentiation of a tissue at first vaguely sensitive all over" is spoken of, and when these processes are associated with "the modification of an organism by its environment," the same parallelism, without contact, or even approach to contact, is implied. There is no fusion possible between the two classes of facts—no motor energy in the intellect of man to carry it without logical rupture from the one to the other.

Further, the doctrine of evolution derives man, in his totality, from the interaction of organism and environment through countless ages past. The human understanding, for example—the faculty which Mr. Spencer has turned so skilfully round upon its own antecedents—is itself a result of the play between organism and environment through cosmic ranges of time. Never surely did prescription plead so irresistible a claim. But then it comes to pass that, over and above his understanding, there are many other things appertaining to man whose prescriptive rights are quite as strong as that of the understanding itself. It s a result, for example, of the play of organism and environment that sugar is sweet and that aloes are bitter, that the smell of henbane differs from the perfume of a rose. Such facts of consciousness (for which, by the way, no adequate reason has ever yet been rendered) are quite as old as the understanding itself; and many other things can boast an equally ancient origin. Mr. Spencer at one place refers to that most powerful of passions—the amatory passion—as one which, when it first occurs, is antecedent to all relative experience whatever; and we may pass its claim as being at least as ancient and as valid as that of the understanding itself. Then there are such things woven into the texture of man as the feeling of awe, reverence, wonder—and not alone the sexual love just referred to, but the love of the beautiful, physical and moral, in nature, poetry, and art. There is also that deep-set feeling which, since the earliest dawn of history, and probably for ages prior to all history, incorporated itself in the religions of the world. You who have escaped from these religions in the high-and-dry light of the understanding may deride them; but in so doing you deride accidents of form merely, and fail to touch the immovable basis of the religious sentiment in the emotional nature of man. To yield this sentiment reasonable satisfaction is the problem of problems at the present hour. And grotesque in relation to scientific culture as many of the religions of the world have been and are—dangerous, nay, destructive, to the dearest privileges of freemen as some of them undoubtedly have been, and would, if they could, be again—it will be wise to recognise them as the forms of force, mischievous, if permitted to intrude on the region of *knowledge*, over which it holds no command, but capable of being guided by liberal thought to noble issues in the region of *emotion*, which is its proper sphere. It is vain to oppose this force with a view to its extirpation. What we should oppose, to the death if necessary, is every attempt to found upon this elemental bias of man's nature a system which should exercise despotic sway over his intellect. I do not fear any such consummation. Science has already to some extent leavened the world, and it will leaven it more and more. I should look upon the mild light of science breaking in upon the minds of the youth of Ireland, and strengthening gradually to the perfect day, as a surer check to any intellectual or spiritual tyranny which might threaten this island, than the laws of princes or the swords of emperors. Where is the cause of fear? We fought and won our battle even in the Middle Ages: why should we doubt the issue of a conflict now?

The impregnable position of science may be described in a few words. All religious theories, schemes, and systems, which embrace notions of cosmogony, or which otherwise reach into its domain, must, in so far as they do this, submit to the control of science, and relinquish all thought of controlling it. Acting otherwise proved disastrous in the past, and it is simply fatuous to-day. Every system which would escape the fate of an organism too rigid to adjust itself to its environment, must be plastic to the extent that the growth of knowledge demands. When this truth has been thoroughly taken in, rigidity will be relaxed, exclusiveness diminished, things now deemed essential will be dropped, and elements now rejected will be assimilated. The lifting of the life is the essential point; and as long as dogmatism, fanaticism, and intolerance are kept out, various modes of leverage may be employed to raise life to a higher level. Science itself not unfrequently derives motive power from an ultra-scientific source. Whewell speaks of enthusiasm of temper as a hin-

* "Examination of Hamilton," p. 154.

† "Bestimmung des Menschen."

‡ In a paper, at once popular and profound, entitled "Recent Progress in the Theory of Vision," contained in the volume of lectures by Helmholtz, published by Longmans, this symbolism of our states of consciousness is also dwelt upon. The impressions of sense are the mere *signs* of external things. In this paper Helmholtz contends strongly against the view that the consciousness of space is inborn; and he evidently doubts the power of the chick to pick up grains of corn without some preliminary lessons. On this point, he says, further experiments are needed. Such experiments have been since made by Mr. Spalding, aided, I believe, in some of his observations by the accomplished and deeply lamented Lady Amberley: and they seem to prove conclusively that the chick does not need a single moment's tuition to teach it to stand, run, govern the muscles of its eyes, and peck. Helmholtz, however, is contending against the notion of pre-established harmony; and I am not aware of his views as to the organisation of experiences of race or breed.

drance to science; but he means the enthusiasm of weak heads. There is a strong and resolute enthusiasm in which science finds an ally; and it is to the lowering of this fire, rather than to a diminution of intellectual insight, that the lessening productiveness of men of science in their mature years is to be ascribed. Mr. Buckle sought to detach intellectual achievement from moral force. He gravely erred; for without moral force to whip it into action, the achievements of the intellect would be poor indeed.

It has been said that science divorces itself from literature: The statement, like so many others, arises from lack of knowledge. A glance at the less technical writings of its leaders—of its Hehmholtz, its Huxley, and its Du Bois-Reymond—would show what breadth of literary culture they command. Where among modern writers can you find their superiors in clearness and vigour of literary style? Science desires no isolation, but freely combines with every effort towards the bettering of man's estate. Single-handed, and supported not by outward sympathy, but by inward force, it has built at least one great wing of the many-mansioned home which man in his totality demands. And if rough walls and protruding rafter-ends indicate that on one side the edifice is still incomplete, it is only by wise combination of the parts required with those already irrevocably built that we can hope for completeness. There is no necessary incongruity between what has been accomplished and what remains to be done. The moral glow of Socrates, which we all feel by ignition, has in it nothing incompatible with the physics of Anaxagoras which he so much scorned, but which he would hardly scorn to-day. And here I am reminded of one amongst us, hoary, but still strong, whose prophet-voice some thirty years ago, far more than any other of this age, unlocked whatever of life and nobleness lay latent in its most gifted minds—one fit to stand beside Socrates or the Maccabean Eleazar, and to dare and suffer all that they suffered and dared—fit, as he once said of Fichte, "to have been the teacher of the Stoa, and to have discoursed of beauty and virtue in the groves of Academe." With a capacity to grasp physical principles which his friend Goethe did not possess, and which even total lack of exercise has not been able to reduce to atrophy, it is the world's loss that he, in the vigour of his years, did not open his mind and sympathies to science, and make its conclusions a portion of his message to mankind. Marvellously endowed as he was—equally equipped on the side of the heart and of the understanding—he might have done much towards teaching us how to reconcile the claims of both, and to enable them in coming times to dwell together in unity of spirit and in the bond of peace.

And now the end is come. With more time, or greater strength and knowledge, what has been here said might have been better said, while worthy matters here omitted might have received fit expression. But there would have been no material deviation from the views set forth. As regards myself, they are not the growth of a day; and as regards you, I thought you ought to know the environment which, with or without your consent, is rapidly surrounding you, and in relation to which some adjustment on your part may be necessary. A hint of Hamlet's, however, teaches us all how the troubles of common life may be ended; and it is perfectly possible for you and me to purchase intellectual peace at the price of intellectual death. The world is not without refuges of this description; nor is it wanting in persons who seek their shelter and try to persuade others to do the same. I would exhort you to refuse such shelter, and to scorn such base repose—to accept, if the choice be forced upon you, commotion before stagnation, the leap of the torrent before the stillness of the swamp. In the one there is at all events life, and therefore hope; in the other, none. I have touched on debatable questions, and led you over dangerous ground—and this partly with the view of telling you, and through you the world, that as regards these questions science claims unrestricted right of search. It is not to the point to say that the views of Lucretius and Bruno, of Darwin and Spencer, may be wrong. Here I should agree with you, deeming it indeed certain that these views will undergo modification. But the point is, that, whether right or wrong, we claim the freedom to discuss them. The ground which they cover is scientific ground; and the right claimed is one made good through tribulation and anguish, inflicted and endured in darker times than ours, but resulting in the immortal victories which science has won for the human race. I would set forth equally the inexorable advance of man's understanding in the path of knowledge, and the unquenchable claims of his emotional nature which the understanding can never satisfy. The world embraces not only a Newton, but a Shakespeare—not only a Boyle, but a Raphael—not only a Kant, but a Beethoven—not only a Darwin, but a Carlyle. Not in each of these, but in all, is human nature whole. They are not opposed, but supplementary—not mutually exclusive, but reconcilable. And if, still unsatisfied, the human mind, with the yearning of a pilgrim for his distant home, will turn to the mystery from which it has emerged, seeking so to fashion it as to give unity to thought and faith, so long as this is done, not only without intolerance or bigotry of any kind, but with the enlightened recognition that ultimate fixity of conception is here unattainable, and that each succeeding age must be held free to fashion the mystery in accordance with its own needs—then, in opposition to all the restrictions of Materialism, I would affirm this to be a field for the noblest exercise of what, in contrast with the *knowing* faculties, may be called the *creative* faculties of man. Here, however, I must quit a theme too great for me to handle, but which will be handled by the loftiest minds ages after you and I, like streaks of morning cloud, shall have melted into the infinite azure of the past.

SECTION A

Mathematical and Physical

Opening Address by the President, the Rev. Prof. J. H. Jellett, M.A., M.R.I.A.

In opening the business of the Section, my first duty is, as you will naturally anticipate, to return my warmest thanks to the British Association for the honour which they have conferred upon me by inviting me to occupy this chair. I do it, I assure you, with all sincerity, fully sensible how high the compliment is; and if I do not dwell further upon the subject, it is, as I hope you will believe, because the president of a Section ought to occupy your time, not by speaking of himself or his own feelings, but by a review, more or less extensive, of those branches of science which form the proper business of the Section.

I say "more or less extensive;" for in determining what kind of review he will present to you, the president of this Section has a very wide range of choice. He may give you a rapid but (in its outline) complete sketch of the progress of mathematical science during the past year. He may select some one special subject, probably (and rightly) the subject with which he is himself especially conversant, giving of that a more detailed account; or he may take a middle course, neither so extensive as the first nor quite so limited as the second. It is this latter course which I wish now to take, proposing to direct your attention, during the short time which I can allow myself, to the relations, becoming every day more fully developed, not only among the branches of science which properly belong to us, but between our Section and the other Sections of the Association, or, in other words, between the sciences which we ordinarily call mathematical or physical and some of the other sciences to which the British Association is devoted. I am the more anxious to direct your attention to this class of subjects, because recent investigation has shown how fertile for discovery the "border land," if I may so call it, between sciences hitherto considered distinct has been found to be. Instances in proof of this will present themselves as we go on; some have no doubt suggested themselves to you already.

We are called, in ordinary language, the Mathematical Section. The adjective must indeed be understood in a very wide sense—too wide perhaps for strict propriety of language, if it be meant to include every thing to which our labours here are devoted; still the use of the term "mathematical" indicates, and truly indicates, the preponderance which in this Section we give to mathematics and to those sciences which are at present capable of mathematical treatment; and therefore the first question which in the consideration of our present subject naturally presents itself is, Does this list of sciences show any prospect of increase? Are we making, are we likely to make, an increased use of mathematics as an instrument of physical investigation? Are we trying to improve its use in those sciences which are already recognised as belonging to its legitimate province? Are we trying to perfect the mathematical treatment of such sciences as optics or electricity, which have been already brought under the sway of mathematics? Are we trying to extend its sway by bringing under it sciences (chemistry, for example, or biology) in which as yet its power has been but little felt? Or have we come to the conclusion, to which some writers would lead us, that we have already pushed the use of mathematics too far?

Is it true, for example, and do we feel it to be true, that in our anxiety to being physical optics completely under the power of mathematical science, we have abandoned the principles of the inductive philosophy, and substituted mere hypotheses for true knowledge? And are we convinced, at least, that every chemist is bound, as he values the truth and reality of his science, to resist the introduction into chemistry of the methods of mathematical analysis, if any such attempt should be made?

This latter is the opinion of Comte, whose severe strictures on the application of mathematical analysis to physical optics I shall have to consider further on; for the present I would confine your attention to the inquiry, What indications on this subject are presented by the actual progress of physical science? Does its history exhibit a tendency to widen or to contract the field of mathematical analysis?

In reviewing, with this purpose, the history of physical science, we may leave out of sight those sciences, or parts of a science, to which the methods and language of mathematics are applicable without the aid of hypotheses. No scientific man doubts the advantage of applying, as far as our analytic powers enable us so to do, the methods of mathematical analysis to such sciences as plain optics or plain astronomy. Even physical astronomy, although in strict logical precision not wholly independent of hypothesis, has been long recognised as, in the most proper sense of the word, a mathematical science. Wherever, in fact, the fundamental equations rest either on direct observation (as in plain optics) or (as in physical astronomy) upon an hypothesis, if we may venture to call it an hypothesis, so entirely accepted as universal gravitation, the extension of the methods of mathematics is only limited by the weakness of mathematical analysis itself. But there are other sciences, as, for example, physical optics, to which mathematical analysis cannot be applied without the intervention of hypotheses more or less uncertain. And if we would appreciate the true character of scientific progress, the question which we must put to scientific history is this, Is science becoming more or less tolerant of such hypotheses? A principle is assumed, possessing in itself a certain amount of plausibility, and capable of mathematical expression, from which we are able to deduce, as consequences and by mathematical reasoning, phenomena whose reality may afterwards be proved by direct experiment. And from this experimental verification we infer, with more or less probability, the truth of the original assumption. The question, then, which we have to put to scientific history is this, Do the records of science indicate a greater or a less tolerance of this kind of logic? Is the mode of physical investigation which I have shortly sketched gaining or losing the favour of scientific men?

Passing over sciences like astronomy, which, though not wholly free from hypothesis, do not give us very extended information on this point, I come to a part of scientific history to which we may put the question with every probability of obtaining (so far, at least, as one science is concerned) a decisive answer —I mean, the history of physical optics.

We have here a science whose basis is purely hypothetical. The definition of light is an hypothesis, the nature of the ethereal motion is an hypothesis, even the very existence of the ether is an hypothesis—hypotheses, indeed, which have led to conclusions amply verified by experiment, but hypotheses still. Does the history of optical science indicate a desire to discard this hypothetical base? Does the history of this science betray a tendency on the part of scientific men to abandon or neglect mechanical theories of light? Have physicists given up as hopeless, or perhaps unphilosophical, the attempt to reduce, by the intervention of a supposed ether, the phenomena of light under the mathematical laws which govern motion? Are they even abandoning the reasoning or the phraseology of the undulatory system? The answer to these questions is not doubtful. Commencing with Fresnel, more than half a century ago, the history of physical optics is a history of efforts, constantly repeated, to frame what M. de St. Venant has called "a really rational theory of light."

Take, for example, the repeated attempts to reconcile the mechanical principle of continuity with the optical phenomenon of double refraction. When the movement which we call light passes from one medium to another, if the molecular movement be continuous, it is hard to see how the elastic force of the ether can be different at different sides of the plane of separation. It would seem, then, that the principle requires that the elastic force of the ether should be the same in all media. But if it be the same in a crystalline as in an uncrystalline medium, it ought to be the same in every direction; and if it be the same in every direction, how are we to account for the phenomenon of double refraction? The effort to overcome this difficulty may be said to have engaged the attention of Cauchy during all the latter part of his life. The same question was taken up after his death by other writers, among whom I may mention M. Boussinesq as the most recent, and is to this day a question of great interest to mathematical physicists. I am not now inquiring whether the reasoning which I have just stated be valid, or whether the difficulty, which some writers do not appear to have felt, be real. I allude to it only as a proof of the anxiety felt by men who have borne the greatest names in optical science to have a complete mechanical theory of light. It would be easy to multiply instances, affecting all the great phenomena of optics, which evince the same anxiety.

Another and even stronger proof of the firm footing which the undulatory theory has obtained in the world of science, is the familiarity with which we use the terms of that theory, as if they denoted actual physical realities. When, not long since, much labour was expended in calculating the wave-lengths for the several rays of the spectrum, there does not appear to have been among physicists any consciousness that they were discussing, and even professing to measure, things which had no existence but in the fancy of mathematicians. On the contrary, we have come to speak of wave-lengths quite as freely and as familiarly as we speak of indices of refraction. Nor is this true only of detached memoirs, which might be supposed to represent only individual opinion. The language and the principles of the undulatory theory have found their way into our ordinary text-books—a sure proof that these principles have been generally accepted by the scientific world. I am not now discussing the question whether, regarded as an indication of scientific progress, this fact is favourable or unfavourable. I only say that it *is* a fact. M. Comte has done all that the hard words of a man of great genius could do to banish theories of light from the domain of science, but his greatest admirer will hardly say that he has been successful.

I pass to the consideration of another branch of science, closely connected with, and indeed including, physical optics, and exemplifying, even more strongly, the desire of scientific men to extend the sway of mathematics over physical science—I mean, Molecular Mechanics. This branch of mechanical science (if, indeed, it be not more correct to say, this science), is altogether modern. Fifty years ago it had hardly begun to exist, and even now it is in a very imperfect condition. Imperfect as it is, however, it has advanced far enough to mark the progress of science in the direction which I have indicated. And as it is a science more general than physical optics, the indications which we can gather from it are more important. Physical optics does not take us outside our own Section; molecular mechanics shows a marked tendency to carry mathematical analysis into the domain of chemistry. If it shall ever be possible to establish an intimate connection between this latter science and theoretical mechanics, it is probably here that we shall find the connecting link. In truth, it is impossible to contemplate the ever-growing tendency of science to see in so many natural phenomena varieties of motion, without anticipating a time when mathematical dynamics (the science which has already reduced so many of the phenomena of motion beneath the power of mathematical analysis) shall be admitted to be the universal interpreter of nature, as completely as it is now admitted to be the interpreter of the motions of the planets. I do not say that it will ever be. I do not even say that it is possible. It is no true philosophy which dogmatises on the future of science. But it is certain that the current of scientific thought is setting strongly in that direction. The constant tendency of scientific thought is, as I have said, to increase the number of those phenomena which are regarded as mere varieties of motion. Sound—that we have placed on the list long since. Light, though here our conclusions are more hypothetical, we have also long regarded as belonging to the same category; and heat may now be fairly added; and we have almost learned, under the guidance of Professor Williamson, to regard chemical combination as a phenomenon of the same kind. All these phenomena (of sound, of light, of heat, and perhaps even of chemical combination) we now regard as produced by the movements of systems of exceedingly small particles—whether of known particles, as in the case of sound, or of the hypothetical ether, as in the case of light; and a science which proposes to itself the mathematical discussion of the laws which govern the movements of such systems can hardly fail to play an important part in the future history of physical science. I shall not then, I hope, be thought to misemploy the time of the Section by offering some observations on the science of molecular dynamics.

When we have to deal with a science which professes to be more than a mathematical abstraction—a science which assumes to itself the function of representing, with at least approximate truth, the realities of nature—our first question will naturally be, What is the basis on which it rests? Is it built upon a pure hypothesis, not derived from experiment, but seeking to justify its claim to reality by the truth of the results which may be deduced from it?

The word "molecule," as Prof. Maxwell has told us, is modern, embodying an idea derived from modern chemistry. It denotes a material particle so small as to be incapable of subdivision into parts similar in their nature to itself. Thus a drop of water may be divided into smaller drops, each of which is also water; but a *molecule* of water is regarded as incapable of such division. Not that we regard it as absolutely indivisible; but we assume that a further division, could it be effected, would produce molecules, not of water, but of its component gases, hydrogen and oxygen.

Now this conception of a molecule undoubtedly involves an hypothesis. Are there such ultimate particles of matter, not only resisting all the dividing forces which we can command, but absolutely indivisible, by *any force*, into particles similar to each other, or perhaps into particles of any kind? Or are we to suppose that, if we had instruments of sufficient delicacy, the process of division might be carried on without limit? Experiment gives us no means of deciding between these alternatives; and if the exigencies of our method of investigation force us to make a decision, we can make it only by an hypothesis. But we may fairly ask, Does the logic of molecular dynamics absolutely require this decision? And on this point I wish to offer one or two remarks. When we propose to determine the motion of a body, solid or fluid, we ought, as indeed in all scientific problems, to form in the first place a clear conception of the meaning of the question which we propose to ourselves. We wish to discover the laws which govern the motion—of what? Not certainly of the body taken as a whole. That is, no doubt, part of the information which we seek, but a very small part of it. When we have learned to determine by a fixed mathematical rule, or formula as we generally call it, the position occupied at any instant by the centre of gravity of the body and by its principal axes, we have learned something, but the investigation is far from being complete. There are, as you know, large classes of movements of which such knowledge would tell us nothing. Thus, to take a familiar instance, you see a man (to use our ordinary language) "sitting quiet." He is at rest, so far as the movement of the body, taken as a whole, is concerned. He is neither turning on his chair nor walking about the room; and yet there is probably not a single particle of his body which is absolutely quiescent. You see, then, how ignorant we are of the vital movements of the human body, if we know only that the individual is "sitting quiet."

But suppose that we push the inquiry a little further and propose to investigate the motion of the blood. We obtain an answer to this question in one sense by determining the rate at which the blood, taken as a whole, is moving—that is to say, suppose the number of ounces of blood which pass through the mitral valve in the space of one minute; but having learned this, we are still very far from knowing completely the motion of the blood. But suppose that we are able to assign at any instant the position of each one of the blood-globules considered as a unit —that is to say, suppose we could assign for each of these globules the position of its centre of gravity and the positions of its principal axes, we should then know the motion of the blood, not, indeed, perfectly (for we should still be ignorant of the motion of the *serum* as well as of the internal movements which take place in each globule), but very much more completely than before.

Further (and this is the point to which I wish especially to direct your attention), the results would be equally true, whether the globules were really units, incapable of further subdivision, or really aggregates of still smaller particles. In the former case we should know perfectly the motion of that part of the blood which consists of the red globules; in the latter, we should know the same motion, but not perfectly; that is to say, our results, though true as far as they go, would leave us still in ignorance of one or more classes of motions which are really exhibited by the globules of the blood. We should then be obliged to imagine a still further subdivision. If, for example, we divided, in imagination, each globule into a thousand parts, and could determine the motion of each part considered as a unit, our results would still further approximate to completeness; and so on for further subdivisions. The logic of molecular dynamics may then be shortly stated as follows:—

In seeking to form the equations of motion of a body, solid or fluid, we commence by an imaginary division of the body into elements of any arbitrary magnitude, and we form the equations of motion for each of these elements considered as a unit. The results so obtained are true, but, as long as the elements retain a finite magnitude, incomplete. They do not give us full information as to the movement of the system. But suppose now, adopting the spirit of the differential calculus, that the magnitude of these elements is constantly diminished; then it will be found that, as in the differential calculus, these equations tend towards a certain limiting form, constantly approaching it as the magnitude of the elements is continually diminished; and in this limiting form these equations are not only true but complete.

Stated in this general form, the principles of molecular dynamics are not only perfectly logical, but wholly free from hypothesis. Hypotheses have, no doubt, been freely introduced for the purpose of forming the actual equations in any given case; but molecular dynamics, as such, is not an hypothetical science. The word molecular is in some respects unfortunate, as tending to identify the science with a particular hypothesis as to the constitution of matter. But molecular dynamics as a science has no necessary connection with the molecular hypothesis. In truth, the methods of this science harmonise quite as readily with the supposition of the infinite divisibility of matter as with the supposition of ultimate molecules.

Molecular dynamics may fairly be called the differential calculus of physical science. It is, in its relation to physical science, what the differential calculus is in its relation to geometry. As in geometry, when we would pass from the small and exceptional class of rectilinear figures to the infinite varieties of curve-lines, we must invoke the aid of the differential calculus, so when we would pass from the abstractions of rigid solids and unbending surfaces to the contemplation of bodies as they really exist in nature, must we, if we would fully investigate their phenomena, invoke the aid of molecular dynamics. It is the science of that phenomenon which is gradually drawing all others within its sway; it is the science of that phenomenon which, "changed in all and yet in all the same," we have learned to see in every part of nature. Molecular dynamics is the science of Motion in its widest and truest sense—of the motion which passes along in the sweep of the tempest or the fierce throb of the earthquake—of the motion (no less real) which breathes in the gentlest whisper or thrills along the minutest nerve.

I have dealt thus long upon the subject of molecular dynamics because the amount of attention which in the present century it has commanded, and the great advance which it has made, mark most distinctly the tendency of scientific thought to the introduction of mathematical analysis into all parts of physical science; for molecular dynamics is the key to this introduction. It is to the perfection of this science that we must look for an increased use of the mathematical instrument; and when we combine the indications afforded by the history of this science with those which we may derive from the history of its principal application (Physical Optics), we have at least this partial answer to our question—Mathematical analysis shows no sign of relaxing its grasp upon any of the sciences which have been hitherto considered to belong to its domain; nay, more, the desire to extend that domain is indicated by the efforts to perfect the instrument by which that extension must be made. We may now ask, Is this indication confirmed by the history of any of those sciences which have been hitherto regarded as lying wholly without our Section?

And first, what shall we say of Section B? Does chemical science show any indications pointing to a future union with the group already collected under the *genus* (if I may so call it) Theoretical Mechanics? Take, for example, the great problem of chemical combination. Does the treatment of this problem now show any signs pointing in the direction of dynamical science? I desire here to speak with all reserve and even hesitation, being conscious that I am no longer on familiar ground. Still there are signs which even an outside spectator may read. And we may, I think, speak confidently of their direction, although the goal to which they point is far distant and may perhaps be unattainable.

One of these signs is the appearance of *time* as one of the elements of a chemical problem. And in recognising the necessity of a certain time for the production of a chemical effect, chemists are now pointing not obscurely to the analogy of mechanical science. "Time," says Berthelot, "is necessary for the accomplishment of chemical reactions, as it is for all the other mechanical phenomena." This might not in itself be very significant; but chemists have not merely recognised the necessity of time as a condition for the production of chemical phenomena, they have also undertaken to measure it; or rather, taking the converse problem, they have undertaken to measure the amount of chemical effect produced in the unit of time; and the law of this phenomenon announced by Berthelot takes (necessarily, indeed) a mathematical form quite analogous to equations which present themselves in dynamical science. The next step has followed as a matter of course, and chemists now speak as familiarly of the *velocity* of chemical reactions as engineers do of the velocity of a cannon-ball.

Still more important in its bearing on the future of chemistry, and tending distinctly in the same direction, is the theory of chemical combination, which science owes to Prof. Williamson, and according to which this phenomenon, like so many others, ought to be regarded as in great measure a mode of motion. We suppose the normal condition of the atomic constituents of a body to be *motion*, not rest; and when we say that a molecule of one substance enters into *combination* with a molecule of another substance, we do not mean that the same molecules constantly adhere together, but that the union between the molecules, whatever be its nature, is continually dissolved and as continually re-formed. According to this theory, chemical equilibrium does not denote molecular rest, but a system of molecular motion, in which these decompositions and recompositions balance each other.

If I may venture to add anything to that which comes from such an authority, I would say that this theory leads us naturally to regard the chemical properties of bodies as, if not wholly modes of motion, yet largely dependent upon the nature of the movements which take place among their constituent atoms. Hence, if two bodies incapable of chemical action are brought into chemical presence of each other, we may suppose that their atomic movements, and therefore their properties, remain unaltered. If, on the other hand, these bodies be capable of acting chemically on each other, their atomic movements are modified by their mutual chemical presence; and therefore the chemical properties of the compound, as we call it, may be wholly different from those of either of the bodies which have entered into combination.

Now we are not yet prepared to consider chemical combination as a problem of molecular dynamics. We have not sufficiently clear ideas (even hypothetical ideas) of these atomic movements, and of the modifications which are caused by the chemical presence of another body, to place the investigation of these phenomena in the same category with the investigation of the phenomena of physical optics; and I am sure that any attempt to hasten unduly the affiliation of chemistry to theoretical dynamics would be productive of serious mischief. The drift of the remarks which I have made has been only to show that the current of scientific thought is setting in that direction; and while we may not predict such an affiliation, still less should we be justified in pronouncing it to be beyond the possibilities or even the probabilities of science.

Time will only allow me to notice very briefly another important application of mathematics to a branch of science considered hitherto to be altogether beyond the limits of our Section,—I refer to the application of the methods of geometry and theoretical mechanics to biological science recently made by Prof. Haughton.

The first example which I shall notice is the establishment of a principle governing the animal frame, and quite analogous to the principle of "least action" in dynamics. This principle asserts that every muscle is so framed as to perform the greatest amount of work under the given external circumstances. If this principle be admitted as an *à priori* truth, the arrangement of any given muscle may be mathematically deduced from it; but many, no doubt, will prefer to regard it as an inductive truth established by the number of instances which Professor Haughton has adduced and discussed. Among these the work done by the human heart is considered; and in order more fully to exemplify the principle of the economy of work, Professor Haughton has imagined a very obvious construction of the heart in which the principle would be violated, contrasting this with the actual construction in which, as he has shown, the principle is preserved.

Prof. Haughton has also made much use of the geometry of curved surfaces in estimating the action of the non-plane muscles.

On the whole the work of Prof. Haughton is a remarkable example of the increasing use of mathematical methods in the investigation of physical problems.

We have put to scientific history the important question, Is it probable that the dominion of mathematics over physical science will be more widely extended than it is at present? Is it probable, not only that we shall improve the mathematical instrument as applied to those sciences which are already recognised as belonging to the legitimate province of mathematical analysis, but also that we shall learn to apply the same instrument to sciences which are now wholly or partially independent of its authority? And to this question I think that scientific history must answer, Yes, it *is* probable. It is probable, because physical science is learning more and more every day to see in the phenomena of nature modifications of that one phenomenon which is peculiarly under the power of mathematics. It is probable, because science already indicates the path by which that advance will be made, because we already possess in molecular dynamics a method (the creation, I may almost say, of our own age, and still very imperfect) whose proper subject is motion, not in any limited or abstract sense, but as widely as it really exists in nature. And it is probable, because we cannot look back on the history of science for the last fifty years without becoming conscious how large is the advance which has been already made.

I have thus far endeavoured to show to you the light which is thrown on the connection between physical science and mathematical analysis by actual scientific history; and I have given you some reasons for believing, so far as it is permitted to us to read the future, that this connection is likely to extend still more widely.

But before we pass from this part of the subject, we are bound to ask the question, Are we to regard this indication as being favourable to the cause of scientific progress? Shall we regard the tendency to use, as far as possible, the mathematical instrument in physical investigation as being likely to extend our real knowledge of nature? Or will its result be merely to encourage the formation of vain hypotheses, recommended only by their capability of mathematical expression, and deeply injuring the cause of science by means of the facility with which men accept such speculations as real knowledge? This latter opinion seems to be, on the whole, that of Comte, whose severe strictures upon physical theories of light I have noticed before.

Now, I believe that the advocate of the mathematical method of investigation might be, and would be, perfectly content to fight the battle of mathematical physics on the ground which Comte himself has chosen. We have put one important question to the history of science, let us put another.

Has the effect of theories of light upon the progress of real optical knowledge (knowledge which Comte himself would admit to be real) been beneficial or injurious?

This question belongs to a class to which the answer is never easy. It is never an easy task to abstract one from a group of causes which concur in the production of an effect, and then determine how the effect would have been changed by such removal. Still we may succeed in obtaining at least a partial answer to the question.

It has been frequently remarked as one of the benefits conferred upon physical science by theory, that it suggests experiment. Nowhere is this principle more strongly exemplified than in the history of perhaps the greatest name in optical science—I mean Fresnel. He is an experimentalist, certainly; but he is an experimentalist because he is a theorist. His most valuable experiments had their origin in the desire to test the truth of a theory. The experiment with the two mirrors were devised to test Young's principle of interference. His diffraction experiments were devised at first to test the truth of Young's theory; and when that had been found to be inconsistent with fact, then to test the truth of his own. And, not to multiply instances, the experiments by which he established the existence of circular polarisation, and ascertained the true nature of the light which passes along the axis of a quartz crystal, were suggested by theory.

Among the motives which induced Jamin to undertake the experimental researches which have given to science such valuable results, not the least was the desire to test the truth of an hypothetical principle of Fresnel and of a theoretic formula of Cauchy. And quite recently M. Abria has made an elaborate examination of uniaxial refraction for the purpose of testing the truth of the construction of Huyghens. I may here remark that it is much to be desired that some competent observer would undertake the yet more difficult task of verifying experimentally the wave-surface of Fresnel.

But to revert to the general subject. If any physicist is inclined to agree with the views of Comte upon this subject, let me propose to him the following test:—Let him strike out of physical optics everything which that science owes to theories of light, and then let him try to write a treatise on the subject, excluding the language and the ideas of theory. Finally, let him compare his work with some treatise in which these aids have not been neglected, and judge himself of their relative value. Theoretic science need not be afraid of the result.

Naturally suggested by the subject which we have been considering, namely, the tendency of scientific progress to a reduction of all physical science under the power of mathematical analysis, is the gradual development of connections between the different members of that great group to which we give the name of physical science. And among the instances of such growing relationship I take, also suggested by the topics which have engaged us, the connection between optics and chemistry. I only say "suggested" by our former subject, for I do not desire to attach any undue significance to the fact that of these connected sciences one may already be called a mathematical science. As yet the connection between these sciences has consisted principally in the introduction into chemistry of an analysis in some respects more refined than any which has been hitherto known. And this fact does not in itself indicate the extension to chemistry of the mathematical character which belongs to physical optics. Still, if we hold the assumption of this character by any science to be the mark of perfection, we shall be inclined to regard every improvement in its instruments of research as tending in that direction.

In speaking of the connection between optics and chemistry, the topic which will occur first to everyone is the Spectroscope; but on this part of the subject it is not necessary that I should dwell. It has so largely occupied the attention of physicists, and has been so fully treated by those who have made it their special study, that I could not hope to add anything to what they have said. I would only observe that the spectroscope has enabled chemistry to overleap a barrier which Comte pronounced to be insurmountable, and which would have excluded from the objects of chemical research anything lying without the limits of our earth. Comte warned us that our knowledge of the planetary worlds was necessarily limited to their geometrical and mechanical properties—to the nature of their movements, and the forces by which they are produced,—and that all inquiry into the constituent elements of the planets or their atmospheres was for ever, and by the necessities of the case, interdicted to us. But the spectroscope has told quite another story.

But there is another point of contact between optics and chemistry,—another spot on the border-land between these two sciences which, I think, promises also to be fertile in discovery,—I mean the use of polarised light as an instrument of chemical analysis. It is true that the application of this instrument is limited in its extent. The physical property on which this application depends (namely, the power possessed by certain liquids to change the plane of polarisation of a transmitted ray, or, as it is commonly called, the rotatory power) is altogether confined to the organic world, and is not universal even there. Still, within this limited range, the application of polarised light is capable of solving, or aiding to solve, chemical problems which chemistry proper would probably find very difficult. Let me give you two examples.

1. Is it true that an acid salt is decomposed by solution? Or, taking the question in another form: If to a solution of a neutral salt there be added, atom for atom, a quantity of its own acid, does that additional atom of acid enter into combination, or does it remain free? It has been usually inferred from the thermic researches of Dr. Andrews, followed up by Favre, Silbermann, Berthelot, and others, that the second alternative is the true one, the solvent being water. Now, if the problem be varied a little by making the solvent spirit, the application of polarised light gives us this important information:—

If to an alcoholic solution of the ordinary nitrate of quinia there be added an additional equivalent of acid, this additional equivalent *does* enter into combination with the nitrate.

This information leaves to us the alternative of supposing that the ordinary nitrate, sulphate, &c., of quinia are not neutral but basic salts, or of admitting that an acid salt is not always decomposed by solution, at least in spirit.

2. When an acid is added to a solution containing two bases, the salts formed being also soluble, does the acid divide itself between the bases? and if so, what is the law which governs the division?

The application of polarised light enables us to solve this question for some of the organic bases, proving that there is a continuous partition of the acid, and enabling us in one case, and probably in many others, to assign the law according to which the partition is made.

One more instance may suffice to exemplify the advantage which chemistry proper has already derived from its union with optics. I take this instance from the general problem of saccharometry.

We have long known how to analyse, both optically and chemically, a solution which contains two kinds of sugar, one of which is sucrose? But as each of these methods gives but two equations, it is plain that neither is sufficient where the unknown quantities are more than two. If, then, as is very commonly the case, there are present in the solution three kinds of sugar, we cannot obtain a complete analysis, either from optics or from chemistry. But, as Dr. Apjohn has recently shown, this problem, insoluble by either method taken alone, is readily solved by a combination of both methods. An important step is thus made in the application of optics to chemistry. Instead of merely giving to chemistry a new solution of a problem which chemistry could solve without any assistance, optics has aided chemistry to solve a problem which chemistry unaided might have found very difficult.

But it is time that I should bring these remarks to a close, and I recur, in conclusion, to a thought which my subject has already suggested.

Let none presume to fix the bounds of Science. "Hitherto shalt thou come, but no further"—that sentence is not for man. Not by our own powers, not by the powers of our generation, not even by the conceptions of possibility, may we limit the march of scientific discovery. To us, labourers in that great field, it is given to see but a few steps in advance. And when at times a thicker darkness has seemed to gather before them, men have recoiled as from an impassable barrier, and for a while that path, has been closed. But only for a while. Some happy accident some more daring adventurer, it may be time itself, has shown that the darkness was but a cloud. The light of Science has pierced it; the march of Science has left it behind; and the impossibility of one generation is for the next but the record of a new triumph.

If seeming plausibility could give to man the right to draw across any path of scientific discovery an impassable line, surely Comte might be justified in the line which he drew across the path of chemistry. Fifty years ago it might seem no unjust restriction to say to the chemist, Your field of discovery lies within the bounds of our own earth. You must not hope to place in your laboratory the distant planet or the scarce-visible nebula. You must not hope to determine the constituents of their atmospheres as you would analyse the air which is around your own door; and you will never do it. Fifty years ago no chemist would have complained that chemical discovery was unjustly limited by such a sentence; perhaps no chemist would have refused to join in the prediction. Yet even those who heard it uttered have lived to see the prediction falsified. They have seen the barrier of distance vanish before the chemist, as it has long since vanished before the astronomer. They have seen the chemist, like the astronomer, penetrate the vast abyss of space and bring back tidings from the worlds beyond. Comte might well think it impossible. We know is to be true.

We have learned from this episode of scientific history that the attempt to draw an impassable line between the domain of the chemist and the domain of the astronomer was not justified by the result. Another generation may learn to obliterate as completely the line between the domain of the chemist and the domain of the mathematician. When that shall be, when Science shall have subjected all natural phenomena to the laws of Theoretical Mechanics, when she shall be able to predict the result of every combination as unerringly as Hamilton predicted conical refraction or Adams revealed to us the existence of Neptune—that we cannot say. That day may never come, and it is certainly far in the dim future. We may not anticipate it—

we may not even call it possible. But not the less are we bound to look to that day, and to labour for it as a crowning triumph of Science, when Theoretical Mechanics shall be recognised as the key to every physical enigma—the chart for every traveller through the dark infinite of Nature.

SECTION C

GEOLOGY

OPENING ADDRESS OF THE PRESIDENT, PROF. EDWARD HULL, F.R.S.

On the Volcanic Phenomena of County Antrim and adjoining Districts.

FOLLOWING the example of several Presidents of the Geological Section of the British Association, I purpose commencing our proceedings by an address, selecting for my subject the volcanic phenomena of the district in which we are assembled. But before entering upon this subject, I am sure it will be equally in accordance with your feelings and my own if I give expression to the general and deep regret which is felt at the death (so little expected) of the late President of this Section, Prof. John Phillips, of Oxford, on April 24, in the 74th year of his age.

The late Prof. Phillips.—As the nephew and pupil of Mr. William Smith, "the Father of English Geology," Prof. Phillips was nurtured in an atmosphere of geological science which accorded well with his own tastes; and in his youth was the companion and assistant of his uncle in many a surveying-tour in the east and north of England. His subsequent appointment as Keeper of the Museum at York, and one of the secretaries of the Yorkshire Philosophical Society, gave him opportunities and scope for pursuing his inquiries—ultimately resulting in the publication of his laborious work on "The Geology of Yorkshire," a work not only abounding in local details, but containing the germs of several generalisations on questions relating to physical geology.

Of his connection with the Geological Survey of Great Britain, Prof. Phillips has left two enduring monuments in his work on "The Palæozoic Fossils of Cornwall, Devon, and West Somerset," and that on "The Malvern Hills and surrounding districts"*—one dealing with the organic structures, and the other more especially with the physical conditions of the south and west of England.

To his future career as Professor of Geology in the University of Dublin, afterwards, on the death of Dr. Buckland, in the University of Oxford, or as President of the Geological Society of London in 1859 and of the British Association at Birmingham in 1865, it is unnecessary for me in this brief notice to do more than allude. Through these years and down to the time of his decease his fertile brain and ready pen were ever at work. But the scope of his investigations was not limited to purely geological subjects; he was a man of many parts, and astronomical questions largely engaged his attention in his later years. In 1868 he visited Italy and Vesuvius, and subsequently published a little work on the history and structure of that mountain in a form very acceptable to that large portion of the travelling British public which at one time or another makes the delightful pilgrimage to the workshop of Vulcan and the Phlegræan Fields.

The loss of Prof. Phillips' presence at the meetings of the British Association, of which he was one of the founders, is irreparable. His genial face and lucid words brought sunshine wherever he appeared, and threw light on every topic he handled; to him might well be applied the words—"quidquid tetigit ornavit." While lamenting his loss, let us endeavour to imitate the example of his untiring industry, his patient pursuit of the beautiful and noble in nature, his honesty of character, his purity of life. †

The Volcanic District of the North-east of Ireland.—I have now to direct your attention to the district of County Antrim and its neighbourhood as one claiming our special investigation, and presenting a multitude of interesting problems connected with the volcanic phenomena of the Tertiary period. By the labours of Berger, Weaver, Portlock, Griffith, Bryce, Tate, Holden, and other geologists, many of these problems have received a solution; others remain for further discussion. It shall be my endeavour to give you a brief summary of the facts and inferences arrived at up to this time, and to present you with a connected history of the operations carried on by terrestrial agents in this island, from the commencement of the volcanic era to its close.

This era, though short as compared with the sum of geologic time, was in reality vastly extended, and comprised within its limits several stages or divisions characterised by special physical conditions. Speaking in geological terms, it probably included the latter part of the Eocene and the whole of the Miocene periods, interrupted by long pauses in the outburst of volcanic products.

But before entering upon the narrative of events which occupied this space of time, let us first endeavour to determine the physical limits of the theatre of these operations; for it may well be asked, considering the great extent to which the volcanic products have been cleared from off the surface of the country by denudation, with what degree of precision can we define the original limits of the volcanic area?

Let us for a moment, when replying to this question, turn to a still more recent volcanic district for an illustration. When we ascend the cone of Vesuvius, and from that commanding station sweep with our eyes the surrounding region, we find ourselves in the centre of a plain—the Campagna of Naples—formed of the products of volcanic eruptions, but limited through three quarters of a circle by calcareous hills of older date, and along the other portion by the sea.

I believe that similarly, but on a far more extended scale, we can trace out the original limits of the volcanic district of the north-east of Ireland, and that from some elevated stations rising from the central plateau of Antrim these limits may be almost descried by the uprising of ridges of more ancient rocks in several directions. Taking our stand on Tardree Hill, or Sleamish, we see to the southward the granitic and schistose ridge of Slieve Croob, projected against a background of the mountains of Mourne, culminating in Slieve Donard. Westward the eye rests on the rugged masses of Slieve Gullion and the Silurian hills of Newtown Hamilton. Towards the north, after passing the depression of the southern shore of Lough Neagh and the valley of the river Blackwater, the enclosing ridge of old rocks, forming from this distance an apparently unbroken line, ranges northward into Donegal and the northern shores of Lough Foyle. The ocean now intervenes; but a comparison of the physical characters of the Donegal mountains with those of Islay, Jura, Cantyre, and the Western Islands leaves the impression on my mind that the volcanic region of Antrim was limited northwards along the line of a submarine ridge, and that there is little reason for supposing that the volcanic rocks of Mull were superficially connected with those of this country,—on the contrary, the probability seems to be that the old crystalline rocks of the Western Highlands were interposed between the two regions.

Turning to the eastward, the sea overflows an area at one time occupied by volcanic products, but now only partially so, and we are unable strictly to define their easterly limits; but it is tolerably certain that the sheets of lava did not reach the shores of Galloway or those of the Isle of Man. Basaltic dykes, however, as is well known, traverse the north of England and the south of Scotland; but if referable, as Prof. Geikie concludes, to the Miocene period, they cannot be included in the volcanic region as here described and understood.

Thus the volcanic plateau of Antrim, like the Campagna of Naples, is washed on one side by the sea, and its limits become indefinable in consequence; but to the south, the west, and to some extent to the north, the limits of the region are marked out by mountains of considerable elevation. Within this region craters poured forth lavas or other volcanic products, which extended in great sheets until they were intercepted by the uprising of these natural barriers.

The floor of the area thus partially circumscribed was formed of various materials, as the accidents of denudation admitted. Over the central portions it was chiefly Cretaceous limestone (or Chalk), but to the southward it was New Red Sandstone and Lower Silurian, and to the north, Chalk, Lias, Carboniferous, and Lower Silurian beds in different directions. The whole region composed of rocks thus distributed was probably converted into dry land towards the close of the Eocene period—when, at various points, highly silicated felspathic lavas burst forth, consolidating into sheets of trachyte porphyry, rhyolite, and more rarely pitchstone, such as are found at Brown Dod Hill and Tardree, near Antrim, and west of Hillsborough. These trachytic lavas were therefore the oldest of the volcanic eruptions of the north of Ireland, and seem to have been represented by the newer granitoid rocks recently described by Zirkel, Geikie, and

* "The Malvern Hills compared with the Palæoic districts of Abberley, Woolhope, May Hill, Tortworth, and Usk," Mem. Geol. Survey, 1849.

† An interesting memoir of the late Prof. Phillips will be found in the *Geological Magazine*, vol. vii. p. 301 (1870).

Judd in the Island of Mull on the one hand, and by the trachytes of Mont Dore in Central France on the other. They have been described in this district by Berger and Bryce; but it is only recently that their relations to the other lavas have been clearly determined; and as such rocks are exceedingly rare in the British Isles, I trust the members of the Association will take this opportunity of paying a visit to the quarries near Antrim, where they are fully opened to view. In composition, both at Hillsborough and at Antrim, they present a felspathic base, enclosing crystals of sanidine (or glassy felspar) and grains of quartz. At Brown Dod Hill they are disposed in sheets, showing lines of viscous flow and dipping beneath the overlying beds of basalt.

As I have already stated, the outpouring of these trachytic lavas may, with every probability, be referred back to the later Eocene period. At any rate, a considerable interval probably elapsed before the eruption of the next series of lavas of Miocene age, which are essentially augitic, and may be comprehended under the heads of basalt and dolerite with their amygdaloidal varieties. Sheets of these lavas were formed, from various vents, over the uneven surface of the older rocks, and to a far greater extent, both as to area and thickness, than in the case of the preceding eruptions of trachyte.* These beds, which are often vesicular, attain in some places a thickness of 600 feet, and are surmounted by decomposed lava and volcanic ashes, which mark the close of the second period of eruption.

The sheets of augitic lava which were poured forth during this stage are remarkable for their vesicular character and the numerous thin bands of red ochre (bole or laterite) which separate the different lava-flows, and which have been recognised by Sir C. Lyell as probably ancient soils formed by the decomposition of the beds of lava, similar to those in Madeira and the Canary Islands, resulting from streams of sub-aërial origin. Microscopic examination bears out this view; for a thin slice of one of the more compact beds of bole from the north coast showed that the felspar-prisms retained their form, while the augite and magnetite ingredients had passed into the state of an ochreous paste.

The vesicular and amygdaloidal character of these older beds of lava shows the probability that they have been poured forth under no greater pressure than that of the atmosphere, and together with the evidence derived from the bands of ochre leads to the conclusion that they have been erupted over land-surfaces. Some of the vents of eruption are now visible, either in the form of amorphous masses of trap protruded through the sheets, or of great funnels filled by bombs, broken pieces of rock, and ashes, such as the rock on which is perched the venerable ruin of Dunluce Castle (the ancient stronghold of the MacDonnells), or the neck erupted through the chalk in the coast-cliffs near Portrush.† One of these old funnels was found by the late Mr. Du Noyer near this place: it forms a portion of the crest of the ridge overlooking Belfast Lough, to the east of Cave Hill, and is within easy reach of members of the Association.

The period of the formation of the older sheets appears to have been brought to a close by the discharge of volcanic ashes and the formation of an extensive lake, or series of lakes, over the region extending at least from the shores of Belfast Lough to the northern coast of Antrim, in which the remarkable beds of pisolitic iron-ore were ultimately deposited. This is the only mode of origin of these ores which seems to me at all probable; and I am consequently unable to accept the views advanced by Messrs. Tate and Holden regarding their origin from basaltic lava by a process of metamorphism. That water was present, and that the beds of ash which underlie the pisolitic ore were stratified, at least in some instances, is abundantly evident upon an examination of the sections at Ballypalidy, Ballymena, and the northern coast. In some places they are seen to be perfectly laminated in a manner that could only take place by the agency of water.‡ It would seem, therefore, that by the combination of slight terrestrial movements, a shallow basin was formed over the area indicated, which received the streams charged with iron in solution, draining the upland margins, from the waters of which were precipitated the iron, possibly by the agency of confervoid algæ, as in the case of the Swedish lakes of the present day (a view maintained by Mr. D. Forbes, F.R.S.), or by the escape of carbonic acid, owing to which the iron became oxidised and was precipitated.

Upon these uplands grew the plants whose remains occur amongst the ash-beds of Ballypalidy, the Causeway, and elsewhere, and which have enabled Mr. Baily to refer the strata in which they occur to the Miocene period.* In some places the vegetation crept over the surface of the former lake-bottom as it became shallower or was drying up, and gave rise to beds of lignite similar to those described by the Duke of Argyll as occurring at intervals amongst the basalts of Mull.† The beds of ore, wherever they are found, belong to one and the same geological horizon, and enable us to separate the basaltic series into two great divisions—one below and the other above the position of the pisolitic ore; and which, on maps of the Geological Survey, will for the future be represented by two different shades of colouring.

The ore itself is now laid open in numerous adits driven into the hill-sides, or in open works at Island Magee, Shane's Hill, Broughshane, Red Bay, Portfad, and other places,‡ whence it is transported to the furnaces of Scotland, Cumberland, Lancashire, and Wales. A new source of industry and wealth is rapidly springing up over the already prosperous county of Antrim, and ere many years are over we may expect to see furnaces established at several points for smelting the ores at the mines from which they are extracted.

The period of volcanic inaction just described was brought to a close by fresh eruptions of augitic lavas, which spread in massive sheets over the beds of ore, bole, and even lignite, without materially altering their constitution. Thus on the north coast a band of lignite is interposed between the pisolitic ore below and a massive bed of columnar basalt above, which can be followed and identified by the size and regularity of its columns for several square miles over that district. That this molten rock has not utterly reduced the lignite to ashes, or even entirely obliterated the impressions of the plant-remains, has been doubtless due to the rapidity with which a hard crust, of low conducting power, consolidates on the outside of a lava-stream, as has been frequently observed on Vesuvius and other active volcanoes.

Above this peculiarly massive bed were piled fresh sheets of basalt and dolerite to a total depth of at least 400 ft., each flow of lava being consolidated in a somewhat different manner from those above and below it, and probably separted from them by considerable intervals of time, as bands of ochre intervene in most instances between successive beds indicating subaërial soils of decomposed lava.

The maximum thickness of the basaltic sheets of Antrim has been estimated by Mr. Duffin and myself at 1,100 ft., to which must be added perhaps 200 ft. for the subordinate trachytic beds, giving a total of 1,300 ft. for the whole volcanic series. This is rather more than originally assigned by Dr. Berger, who places it at 900 ft.,§ but it falls far short of the enormous accumulations of Mull, estimated by Prof. Geikie at from 3,000 to 4,000 ft.; in neither district, however, have we the data for determining the original thickness of volcanic *ejecta*, as in both large masses of material have been wasted away by denudation, and not a single volcanic cone or crater remains behind out of all those which, probably in numbers corresponding to those of Central France, were planted over the entire volcanic region.

The basaltic dykes which traverse not only the geological formations subordinate to the bedded traps, but also the latter themselves, are, in some districts, both remarkable and exceedingly numerous. To the south of Belfast Lough we find at Scrabo Hill an outlying mass of bedded dolerite resting on New Red Sandstone, and far beyond the limits of the main masses which rise in a fine escarpment to the north of the Lough. There is every probability that Scrabo Hill is the site of a distinct focus of eruption; but it is also remarkable for the dykes of trap, as well as intrusive sheets, which have been squeezed in between the beds of sandstone themselves. Admirable and instructive sections are laid open in the freestone-quarries of this

* In this respect they resemble the corresponding rocks in Central France, where, as Mr. Scrope has shown, the trachytes have a more restricted range than the basalts ("Volcanoes of Central France").

† A sketch of this old rock is given by Prof Geikie in Jukes's "Manual of Geology," 3rd edit. p. 271.

‡ The authors referred to, while admitting the stratified character of the beds at Ballipalidy and their formation in presence of water, consider that in all other cases the iron ore has been formed on a terrestrial surface; but sections seen at Ballymena and the north coast have led me to conclude that these beds are all more or less stratified, and due to aqueous deposition.

* Quart. Jour. Geol. Soc., vol. xxv. p. 357, pls. 14 and 15 The plants determined by Mr. Baily, from Ballypalidy, belong to the genera *Sequoia*, *Cupressites*, *Rhamnus*, *Quercus*, *Pinus*, &c. They were originally detected by the late Mr. Du Noyer.

† Jukes's "Manual of Geology," 3rd edit. p. 690.

‡ At Pleaskin Head it was originally observed by the Rev. Dr. Hamilton (1790).

§ Trans. Geol. Soc., 1st Series, vol. iii.

hill, which will amply repay a visit. Another district remarkable for such intrusions is that of Ballycastle, where dykes and sheets are seen traversing the carboniferous rocks, as described by Sir R. Griffith in his admirable report on the geology of that coal-field;* while the well-known Giants' Causeway is itself a tesselated pavement of columnar basalt, traversing in the form of a dyke the horizontal sheets of older formation.

The intrusion of the thousands of dykes of the north-east of Ireland is unaccompanied by crumplings or contortions of the strata; and if it were possible to place the dykes side by side, their aggregate breadth would cover a space several thousand feet in breadth. How, then, has this additional space amongst strata of given horizontal dimensions been obtained? Has it been by lateral tension outwards owing to inflation by means of elastic gases or vapours, or by a general bulging of the surface consequent on lateral pressure? The former view, I am told by physicists, is untenable; the latter is one which will probably prove more consonant with modern views of terrestrial dynamics.

The results of the microscopic examination of a considerable number of specimens of augitic lavas from various parts of the volcanic district are of a generally uniform character. Whether we take specimens from the largely crystalline granular dolerites of Portrush or Fair Head, or the very dense micro-crystalline basalts of Shane's Castle, the structure and composition are found to be nearly uniform.

The lava is, with very few exceptions, an amorphous or sub-crystalline paste of augite, enclosing long prisms or plates of labradorite felspar, crystalline grains of titano-ferrite, and often of olivine. Chlorite is also sometimes present as a "secondary" mineral. It will be observed that this diagnosis differs essentially from that assigned by Dr. Zirkel as the normal structure of basalt, in which the base is "a glass," and the other minerals (the augite, felspar, and olivine) are individually crystallised out.† This, indeed, is the case with the carboniferous melaphyres of the south of Ireland,‡ and probably with all the rocks in which augite is deficient; but the basalts of Antrim contain augite so largely in excess of the felspar that it has, in nearly every case, formed the base of the rock.§

The basalt itself is often so rich in iron as to become an impure iron-ore. This is owing to the presence of the metal in the form of minute grains of titaniferous iron-ore, which is the principal cause of the black appearance of the rock and also as one of the components of the augite.

From the above general review of the volcanic history of Tertiary times in the north of Ireland it will be evident that it presents us with three distinct periods, similar to those which Mr. Judd has recognised in the succession of events in the Island of Mull:—

The earliest, possibly extending as far back as the later Eocene period, characterised by the trachytic lavas.

The middle, referable to the Miocene period, characterised by vesicular augitic lavas, tuffs, and plant-beds.

The latest, referable to a still later stage of the Miocene period, characterised by more solid sheets of basalt and numerous vertical dykes.

These three stages were probably separated from each other by long intervals of repose and the cessation of volcanic action. The succeeding Pliocene period seems to have been characterised by considerable terrestrial movements, resulting in the production of fractures in the earth's crust, and (as my colleague, Mr. Hardman, supposes) in the formation of that large depression which was filled with waters having a greater area than the Lough Neagh of the present day. Some of the faults which traverse the upper sheets of basalt, and are therefore of later date, have vertical dislocation amounting to 500 or 600 ft., as, for instance, that which runs along the valley under Shane's Hill near Larne. Such great fractures must necessarily have been accompanied by denudation, and it is probable that many of the present physical features had their origin at this (Pliocene) period. The extent to which the original plateau of volcanic rocks has been broken up and carried away within such comparatively recent times is vaster than is generally supposed. As there is evidence that the sheets of lava to the north of Belfast Lough were originally connected with those of Scrabo Hill to the south, we must suppose that this arm of the sea and the valley of the Lagan have been excavated since the Miocene period; while on the north-west the high elevation to which the escarpment of the basalt reaches, leads to the supposition that the basaltic sheets spread over the ground now occupied by Lough Foyle. Both along the west and along the eastern seaboard the sheets of lava are abruptly truncated, and must have extended far beyond their present bounds; while many deep valleys, such as those of Glenarm, Cushendall, and Red Bay, have been excavated.

But the most remarkable result of the denudation, as bearing upon the subject before us, is the complete obliteration of the volcanic cones which we may well suppose studded the plateau. Some of these cones, at least, were contemporaneous with those now standing upon the granitic plateau of Central France, and which are but little altered in elevation since the fires which once burst forth from them became extinct. But since then the north of Ireland has been subjected to vicissitudes from which Central France has been exempted. The surface of the country has been overspread by the great ice-sheet of the earliest stage of the Glacial period, which appears to have stretched across from the Argyleshire Highlands, if we are to judge by the direction of the glacial *striæ* at Fair Head.*

At a later stage the country was submerged beneath the waters of the Inter-glacial sea which deposited the sands and gravels which overlie the Lower Boulder-clay; and subsequent emergences during the stage of the Upper Boulder-clay, together with atmospheric agencies constantly at work, whenever land has been exposed, have moulded the surface into the form we now behold.

It will thus be seen that the physical geologist, whether a Vulcanist or a Neptunist, has in this region abundant materials on which to concentrate his attention.

Volcanic Energy.—In connection with this subject it may not unnaturally be expected that I should make some allusion to the views of Mr. Robert Mallet on "Volcanic Energy," which he has recently unfolded in the "Philosophical Transactions of the Royal Society."† My limits, however, forbid more than a cursory glance at this subject. Stated in a few words, volcanic energy, according to Mr. Mallet, has its origin primarily in the contraction of the earth's crust, due to secular cooling and the tendency of the interior molten matter to fall inwards and thus leave the exterior solid shell unsupported. The lateral pressure arising therefrom (which, as Mr. Mallet shows, is vastly greater than the vertical weight of the crust) is expended in crushing portions of the solid crust together, along lines of fracture which are supposed to correspond to those of the volcanic cones which are distributed over the earth's surface. Each successive crush produces an earthquake-shock, and is converted into heat sufficient to melt the rocks which line the walls of the fissure or lie beneath at high temperatures, and which, in presence of elastic steam and gases, are erupted at intervals both of time and place.

In the words of the author of these views, "The secular cooling of the globe is always going on, though in a very slowly descending ratio. Contraction is therefore constantly providing a store of energy to be expended in crushing parts of the crust, and through that providing for the volcanic heat. But the crushing itself does not take place with uniformity; it necessarily acts *per saltum* after accumulated pressure has reached the necessary amount at a given point, where some of the unequally pressed mass gives way, and is succeeded perhaps by a time of repose or by the transfer of the crushing action elsewhere to some weaker point."

It cannot be denied that Mr. Mallet's theory seems to be consistent with many observed facts connected with volcanic action. It has for its foundation an incontestable physical hypothesis, the secular cooling of the earth, and it seems to throw considerable light upon several observed phenomena of volcanic action—such as the distribution of cones and craters along great lines, the intermittent character of eruptions, and the connection of earthquake-shocks with volcanic outbursts. There are some statements in Mr. Mallet's paper which few physical geologists will be inclined to accept, such as the non-existence of true

* "Geological and Mining Survey of the Coal Districts of Tyrone and Antrim" (1829). Some of the sheets in this district may be of older date than the Miocene age.

† "Untersuchungen über d. mikrosk. Zusammensetzung und Structur der Basaltgesteine" (1870).

‡ E. Hull, "On the Microscopic Structure of the Limerick Carboniferous Melaphyres," Journ. Roy. Geol. Soc. Ireland, vol. iii. p. 112 (with plates).

§ Mr. Allport, F.G.S., states (Geol. Mag. 1873) that he has found the augite individually crystallised out in a specimen from near the Causeway. Such a case, however, must be exceptional; but the rule as stated above certainly holds good.

* A view also held by Mr. James Geikie and Mr. Campbell of Islay.

† 3, vol. clxiii. p. 147.

volcanoes before the Secondary or Mesozoic period. The Silurian volcanic districts of North Wales and of the west of Ireland, and the Carboniferous volcanic districts of Limerick and Scotland, bear witness against the soundness of such a view. This statement, however, does not necessarily invalidate the general views of the author; and I cannot but think that the publication of Mr. Mallet's paper has enabled us to take a very long stride in the direction of a true theory of volcanic energy.

SECTION D

BIOLOGY

OPENING ADDRESS BY PROF. PETER REDFERN, M.D., PRESIDENT

I CONSENTED to allow myself to be nominated President of this Section in compliance with the kindly-expressed wishes of scientific friends, notwithstanding that I felt that the duties of the Chair would have been more fitly discharged by many who have attended the meetings of the Association more regularly and laboured to promote its objects more continuously than I have been able to do.

Fortunately the increasing importance and the vast extent of the subjects comprised under the head of Biology have led to a division of the business of this Section into the separate departments of Anatomy and Physiology, Botany and Zoology, and Anthropology; and it is a great relief to me that the departments of Botany and Zoology, and of Anthropology, respectively, will be presided over by gentlemen of the highest eminence in those subjects, and that Anatomy and Physiology, in which I am more immediately interested, will alone come under my direct supervision. It has occurred to me that, in attempting to give a stronger impulse and a more systematic direction to scientific inquiry, the time ordinarily devoted to an introductory address could not be more profitably occupied than by bringing into as great prominence as possible some of the great revolutions in our knowledge of Anatomy and Physiology which have taken place in my own time and under my own immediate observation.

I remember, as if it were yesterday, the elucidation in the Museum of the Royal College of Surgeons of Edinburgh, of the newly discovered cell-theory by the late distinguished Professor of Anatomy in Edinburgh, John Goodsir—his account of the production of ulceration by cell-growth, of the characters of the corpuscles of bone, of the structure of lymphatic glands, and of the germinal centres of basement membranes as they were then understood. This was the time when the teaching of Histology was first established in Great Britain. Two students, of whom I was one, formed the first class under the most enthusiastic of teachers, my old friend Dr. Hughes Bennett. The University of Edinburgh has just passed through what was probably the most brilliant period in its history. The race of the last of the Munros was well-nigh run; the great discoverer of the difference in the motor and sensory nerves, Sir Charles Bell, was still living; the aristocracy of Scotland had only just ceased to crowd the classroom and witness the brilliant and successful experiments of Dr. Hope. The day of Cullen, of Home, and Duncan, and Macintosh was over; but there still remained in the University the most loved and revered of teachers, the benevolent Dr. Alison, Sir Robert Christison, Sir George Ballinghall, and Mr. Syme, Dr. Abercrombie still practising his profession in the city.

At this period the great discoveries of Schleiden and Schwann seemed likely to upset all that had previously constituted Physiology. The idea that all tissues were either composed of cells or had been formed of cells—that nucleated cells elaborated all the secretions and formed the excretions—that their energy lay at the very root of the formation, the reproduction, and the function of every tissue and organ, was a revelation of such astounding simplicity as might well upset men's minds and prevent their seeing beyond.

No one, who did not live through that time, will, I believe, ever realise the eagerness and anxiety with which every new statement of the action of cells was received and added to the previous knowledge of their amazing power—or, on the other hand, be able to judge of the feeling, half akin to disappointment, which was experienced as each succeeding attack was made on this charming theory, showing it to be really human, very human indeed.

Cells were then understood to constitute the mass of all organs (the liver, spleen, kidney, and brain), and to be the main agents in the discharge of their functions—to exist and grow upon the definite membranous walls of the glandular vesicles and ducts—to be fed by blood brought to the attached surface of membranes which seemed almost everywhere to form an absolute separation of the cellular part (the potential gland) from the non-essential blood and lymph-vessels, the nerves, and framework of the organ. It seemed almost a pity that these little microscopic deities should be hampered by the necessities of their own existence, that they should need such base things as blood-vessels, nerves, and packing materials. Now how strangely are matters changed! What if it should turn out that these apparently independent little beings are not independent at all—that they are only the dilated ending of nerves? To this subject I shall refer again by and by.

This great cell-theory has now given place to what I think is certain knowledge, that living matter may move, perform all the functions of assimilation and nutrition, and reproduce its like without having any of the essential characters of a cell. A living mass of protoplasm may change its shape, alter its position, feed and nourish itself, and form other matter having the same properties as it has, and yet be perfectly devoid of any structure recognisable by the highest powers of the microscope.

Mr. Lister showed that the contraction of pigment-cells in the skin changes the position of the pigment-granules, driving them alternately into the processes and the body of the cell. Kühne, Golubew, and Stricker observed changes of form in amœbæ (white blood-corpuscles and embryonal capillaries, respectively) after the application of electrical stimuli; and Brücke observed contraction in the pigment-cells of the skin of the chameleon after excitation of the sensory nerves; whilst Kühne noticed contraction in corneal cells after excitation of the corneal nerves.

Thus obvious movements in fixed cells or masses of protoplasm are proved to result from the operation of various stimuli, including nervous stimuli.

But all cells are not fixed. The blood-cells, fixed, as cells of organs, at an early period, become free in the blood-fluid and are moved along by the forces which circulate it until a second time they enter into the composition of the solid tissues by penetrating the walls of the blood-vessels and moving along the substance of the tissues for purposes which are not yet wholly explicable.

What naturalist will not at once suggest how frequently this process of alternate fixation and movement of animal forms occurs low down in the scale? and yet how startling is it in man! how impossible to reconcile with our former ideas of the existence of membranous coverings, of cells, surfaces, and of gland-ducts! But, with or without explanation, the facts must be recognised; the floating blood-cells are really the very cells which once formed the substance of the lymphatic glands, the spleens, and other organs; and they do, in fact, move through the walls of the blood-passages, and wander about freely in what we call solid tissues.

Our knowledge of this circulating fluid has marvellously increased. The duration of the life of any of its particles is but short; they die and their places are occupied by others, as was the case with our forefathers, and will be the case with ourselves. It is now a matter of observation, which commenced with Hirt of Zittau, that after every meal an amazing number of white corpuscles are added to the blood: breakfast doubles their proportion to the coloured corpuscles in half an hour; supper increases their proportion three times; and dinner makes it four times as great. They come from such solid glands as the spleen. In the blood going to the spleen, their proportion is one to two thousand two hundred and sixty; in that returning from the spleen it is one to sixty. Every organ and every tissue changes this fluid; and, to my mind, perhaps the most stupendous miracle of organisation is the steady maintenance of but slightly variable characters in the living and moving blood which is every moment undergoing changes of different kinds as it circulates through each tissue and organ in the body.

Yet with all this change there is an invariable transmission of the parental characters by continual descent from particle to particle as each takes the place of a former one; and thus each organ continues to discharge the same function from year to year. Animals of the same kind retain the old number of organs, the same shape of body, and similar modes of life. There is no sign of commencing life, no coining of new vital power, no production of living out of dead matter. The original life extends its limits; it operates in a more extended sphere; but it is the same life, it operates in the same way, it never fails to be recognisable in the individual by the same characters as it had when it was first known. Whatever other functions it discharges, it acts continually in obedience to the first great law ; it increases and multiplies, and replenishes the earth.

Let us now for a few moments compare our former views of the structure of animal membranes with the present ones. The skin (covering the outer surface of the body), the mucous membranes, the serous linings of the great internal cavities and of the blood- and lymph-vessels, and the lining membranes of joints were all alike viewed as if formed of a definite membrane covered on one side by cells, and on the other supplied by blood- and lymph-vessels and by nerves—the membrane covering in the latter parts and affecting an absolute separation of the cells from the vessels and nerves, which were universally believed never to penetrate into the cellular layer. The cells were regarded as the parts actively engaged in the performance of the functions, the vessels and nerves aiding thereto supplying materials to be acted on by the cells, and the nerves regulating the amount of action at particular times for special purposes. The diseased conditions, like the functions, were kept perfectly distinct; and we had one set of diseases of the epithelial or cellular parts, and another and a different set of diseases of the membranes and of the parts below.

I think the first occasion on which the public faith in these views was seriously shaken was when the late distinguished Professor of Medicine in St. Andrew's, Dr. John Reid, died of what was called an epithelial cancer of the tongue. Microscopical examinations showed that the disease existed in the cellular covering of the tongue. A sufficient cause for it was supposed to exist in the irritation caused by sharp points of the teeth, to cover which a protecting silver plate was constructed. The diseased parts were removed with the greatest skill and care by Sir William Fergusson, and subsequently by the late Dr. James Duncan, assisted by Mr. Goodsir and Mr. Spence, now Professor of Surgery in the University of Edinburgh. Every conceivable care was taken by these attached friends of the poor sufferer to remove every trace of the disease ; but it progressed steadily and destroyed his valuable life.

At this period no one could understand the extension of an epithelial disease through a basement membrane ; and therefore the affection of the adjacent lymphatic glands was explained by supposing the diseased action to have been propagated from cell to cell along the epithelial surface of the lymphatic vessels.

Not long afterwards the sternly truthful and accurate Sir James Paget declared, in terms of terrible significance, to the sufferers from this disease, that epithelial cancer takes a little longer time than ordinary cancer to do its fatal work.

And it soon became thoroughly well known that the glands of the skin, the hair-bulbs, and the teeth are produced by a local development of the deep cells of the cuticle, extending far below the line of the basement membrane or cutis, and through the position which it was supposed to occupy, as though no membrane were there to hinder them.

Thus the basement membrane, which was supposed so arbitrarily to separate the cells on one surface of membranes from the vessels and nerves on the other, gives way at once before an increased development of the cells, whether in the formation of new organs or the extension of disease. And the membranous walls of capillary blood-vessels allow the corpuscles of the blood to pass through them much in the same way as solid particles enter into and traverse the substance of the protoplasm of an amœba or other mass of sarcode.

Whilst physiologists were engaged in these observations, the late Master of the Mint, Mr. Graham, was conducting a series of experiments of the most remarkable kind, and of the utmost importance to physiology as well as to chemistry and physics. He found it necessary to separate the two sets of substances as crystalloids and colloids,—the colloids being penetrable by the crystalloids as readily as water, the crystalloids (such as hydrochloric acid and common salt) passing through organic membranes with great freedom, whilst many of the colloids, such as albumen and gum, will not penetrate them at all. This discovery has enabled the chemist to separate crystalloids from colloids by dialysis, even when they occur in the most minute proportions—for instance, to separate 80 or 90 per cent. of a ten-thousandth part of arsenious acid in twenty-four hours from porter, milk, or infusions of viscera, substances notoriously difficult to analyse. And it has enabled physiologists to explain how animal membranes are traversed by various substances which could not pass through them without being changed from the colloidal into the crystalloidal form. Thus the colloidal starch and albumen of our food scarcely admit of absorption until in the process of digestion the starch becomes sugar and the albumen albuminose, crystalloidal bodies which pass through animal membranes with great facility. And again, this crystalloidal albuminose, after having passed into the tissues through the membranous walls of the vessels, may become a second time a colloid, and be deposited and fixed as tissue-substance, ready in its turn to be permeated by crystalloids either for temporary or more durable purposes in the economy.

The effect of this great discovery of Mr. Graham's shows how impossible is the advance of physiology without a corresponding advance in our knowledge of chemistry and physics.

If basement membranes, the walls of blood-vessels, and of cells are made up of colloidal matter, we can easily understand how they are penetrated by crystalloids ; and in like manner it is perfectly possible that they may be traversed by other substances in solid forms—as, for instance, the walls of blood-vessels by the corpuscles of the blood. No wonder that there is a continual deposition and removal of the constituents of the tissues, if so slight a change as that from the crystalloidal to the colloidal form, and the reverse, makes such perfectly marvellous differences in the relations of these substances to each other.

We must look upon the tissues of an animal body as we do upon the substance of an amœba, and recollect how penetrable the surfaces and tissues of animals are ; then we shall cease to be startled when we see these parts become the seat of entirely new deposits, or find them traversed by migrating blood-corpuscles as freely as a colloid is penetrated by a crystalloid.

It is impossible to foresee what may be the result to physiology of this great advance in our knowledge of the varying relations of substances to each other according as they present themselves at different times in the opposite physical conditions which were described by Mr. Graham as crystalloidal and colloidal. But it is plain that we cannot continue to look upon animal membranes as forming such decided barriers against the penetration of one tissue by another, or by foreign matters, as was once supposed.

Let me now direct your attention to the present aspect of the question how far basement membranes limit the distribution of vessels and nerves, and separate them from the cells of glands and membranes.

Mr. Bowman, in his admirable researches into the anatomy of the organs of sense, discovered that the filaments of the nerves of smell have a remarkable structure—that they are nucleated, finely granular, contain no white substance of Schwann, and resemble the gelatinous nerve-fibres. The epithelial surface, too, of the olfactory region Mr. Bowman described as differing greatly from that of the adjacent parts of the nasal mucous membrane, and as being of a dark sepia tint. Subsequent examinations by Hoyer, Max Schultze, and Lockhart Clarke confirmed these statements ; and those of Schultze demonstrated that the cells are of two kinds, one elongated and filled with yellowish granular protoplasm, exposed at the outer end of each cell and containing a clear oval nucleus in clear protoplasm in its deeper part, which is first attenuated and then expanded into a broad flattened process, apparently connected with the connective tissue ; the other cell, the proper olfactory cell, a thin, fibrous, rod-like body, is moniliform or varicose, connected below with the out-runners of a nerve-cell, and in birds and amphibia furnished with one or more hair-like processes, which at the free end come directly into contact with odorous particles. Exner in 1872 denied the distinctness of these two forms of cells, stating that there are all intermediate forms, and that both forms are connected with a deep network continuous with filaments of the olfactory nerve. But Dr. Newell Martin, in a paper published in the November number of the *Journal of Anatomy and Physiology*, maintains that the two kinds of cell are distinct, though their characters approximate very closely in the instance of the frog. He inclines to the belief that, as both forms of cell are so distinct from ordinary epithelium, they are all olfactory cells.

The only conclusion which can be drawn from these observations is, that in this situation the olfactory nerves divide into myriads of small finger-like processes, which, exposed on the free surface of the membrane, are actually engaged in feeling at the odorous particles to inform us of their characters.

This single instance, so thoroughly proved, would be sufficient to destroy our former ideas that nerves are spread out under basement membranes and never penetrate an epithelial layer.

But this is not the only case of the kind. The general relations of the gustatory nerves to the epithelial cells of the tongue have been described by Axel Key as similar in the fungiform papillæ of the frog, and by Schwalbe and Lovén in the gustatory cells of the circumvallate and of some of the fungiform papilæ in men and animals. On the protected sides of the circumvallate papillæ a peculiarity in the shape and arrangement of the epithelial cells produces a series of taste-cones, the central cells of which are furnished with hair-like prolongations similar to those of the olfactory cells.

In the otolith sacs and the ampullæ of the semicircular canals of the ear, the nerve-filaments, having lost their white substance, become connected with peculiar auditory cells and end in hair-like processes between the epithelial cells. In the cochlea, too, notwithstanding the complication of the examination produced by the rods of Corti, there is reason to believe that the cells supporting hairs which project beyond the epithelial surface are connected with the primitive nerve-fibrils of the plexus below.

Of the recorded instances in which nerves pass through basement membranes to get into direct contact or continuity with the superjacent epithelial cells, none is so striking as that of the salivary and other glands, if there be the least ground for the remarkably detailed observations and suggestions of Pflüger. They are of so much importance and interest in connection with the whole process of secretion, that I offer no excuse for directing your attention to them, even though it may be proved that the act of secretion is not attended with such marvellous and extensive changes of structure as Pflüger supposes. Up to a certain point his observations may be easily and abundantly confirmed; beyond that there is much greater difficulty; but this meeting offers one of the most favourable opportunities for extending our knowledge by bringing different observers into easy communication with each other, and enabling each to help the rest by stating the means by which he had overcome what seemed at first to be insuperable difficulties in the progress of an investigation.

Pflüger calls attention to the very variable characters of the alveoli, the secreting cells, and the excretory ducts of the salivary glands. These parts, which were believed to have very determinate sizes and characters, he declares to differ very greatly in different parts of the same gland. The alveoli, occupied by what we understand as secreting or glandular epithelial cells, and the excretory ducts, lined by columnar epithelium, he thinks he can prove to be but different stages of development of the same structures, produced on the ends of the myriad nervous filaments supplied to these glands.

On this view glandular epithelial cells must be regarded as special organs of termination of nerve-fibrils, like the auditory cells, touch-corpuscles, olfactory cells, muscular fibre-cells, and the like; the relation between such structures and the nerves becoming so close that it may be difficult, perhaps impossible, to define their respective limits. Pflüger has figured the nuclei of the cells of the alveoli of the salivary glands, the salivary cells, connected with a delicate fibre, which often pierces the surface of the cell in contact with the *membrana propria*, and gives the cell the appearance of being stalked. This appearance has also been seen by Schlüter, Otto Weber, Gianuzzi, Boll, and Kölliker; and indeed the appearance which Pflüger has figured may be seen by anyone who will take the trouble to examine the salivary glands of the common cockroach (*Blatta orientalis*). This process was shown to me by my friend and pupil, Mr. Charles Workman; and I have several preparations which show a similar process to that which Pflüger has observed and figured; but that it is as clearly connected with the nucleus of the cell as he describes it I am not prepared to affirm. Pflüger says it is hollow, and often discharges a large quantity of tenacious material which clearly proceeds from the nucleus.

In the interior of the gland there are ducts lined with a thick but single layer of columnar epithelium, the cells of which are clear and nucleated near their free end, but furnished with a large number of extremely fine varicose hairs at the end connected with the *membrana propria*. This epithelium becomes thicker as the ducts proceed towards their connection with the alveoli; and as transparent drops can be seen transuding from the ends of the cells when saliva has been made to flow by irritation of the gland, Pflüger concludes that they are important secretory organs. Such ducts frequently form loops, or bend suddenly, or possess diverticula. The epithelium of the ducts, which carry the secretion out of the gland, is of a different and apparently less important kind.

Pflüger directs special attention to the great number of nerves connected with the alveoli. He has identified them in fresh specimens by their investment here and there by an ordinary double-contoured medulla, by their being blackened by perosmic acid, by their varicosities, and by tracing them to large and more easily recognisable nerves. He finds them branching in great numbers amongst the cells of the alveoli, and traces their fibrils to the nuclei of the cells, sometimes after they have been connected with multipolar ganglion-cells. Or nerves covered by medulla and sheath, and containing numerous varicose axis cylinders, branch, enlarge, and become covered with protoplasm set with nuclei, forming what Pflüger calls a protoplasmic foot, and supposes to be a structure intermediate in character between nervous and glandular tissue. And on the surface of the ducts lined by columnar epithelium a nerve divides into a pencil-like tuft of varicose fibrils, each of which Pflüger says is directly continuous with one of the processes of a columnar epithelial cell. I have frequently seen the pencil-like tuft of varicose fibrils on the surface of the ducts lined by columnar epithelium; but it is not so easy to be sure that the fibrils are connected with the processes of the cells. However, the statement is made in the most positive way by Pflüger, who has made these glands the subjects of very special and lengthened investigation; and his drawings afford very strong corroborative testimony of the value of his statements. Moreover, in independent observations on the pancreas, he has also traced the nerves to endings in the secreting cells.

But Pflüger has gone greatly further than this. He has figured the hair-like processes at the attached end of the columnar cells in all stages of transition into salivary cells of new alveoli; and having previously found the nerves connected by varicose fibrils with protoplasmic masses set with nuclei, he concludes that it is possible that the salivary cells are developed on the ends of the nerves without interference of their own nuclei, and that, as a continual new formation of alveoli and salivary cells implies the atrophy and disintegration of corresponding older parts, the alveoli with pale offshoots of various forms which he has seen in moles are evidences of such atrophy.

With these numerous instances in which nerves are alleged to pass through membranes to be connected with the cells on their surfaces, as if these were their special modes of termination, we might well be content until there has been time for further investigation by independent observers. But there are yet other instances. Langerhans described, in 1868, a fine network of fibres in the skin, from the superficial part of which fine non-medullated fibres pass out of the cutis and end in the Malpighian layer of the epidermis. He saw in the epidermis also well-marked cells which gave off several processes towards the horny layer, and one long slender process which passed through the Malpighian layer into the cutis. He considers these cells to be nervous, and their peripheral processes to be the terminal parts of the nerves of the skin. C. J. Eberth agrees in the main with Langerhans, and recognises fine nerve-fibres passing from the nerves of the cutis into the deeper layer of cuticular cells, and also star-and-spindle-shaped cells in the cuticle, which he suggests may be nervous structures, though he has not traced them in connection with nerve-fibres.

On the surface of young fishes and Amphibia F. E. Schutze has described nerve-hairs arranged in the form of tufts or brushes very much as in the case in the organ of hearing; in this instance the brush-like endings of the nerves are probably connected with touch.

Cohnheim has described the corneal nerves as forming a superficial plexus under the anterior elastic lamina; from this perforating branches pass perpendicularly through the lamina, and then under the epithelium, break up into brush-like or star-shaped finer branches, which form a plexus giving off fine nerves at tolerably regular intervals between the deep columnar cells and the more superficial spheroidal ones, and dividing at length into their finest branches, which end by somewhat swollen extremities in the most superficial epithelial layers. Thus the exquisite sensibility of the front of the eye, like that of the olfactory or gustatory mucous membranes, may be accounted for.

When I look upon the vast amount of research which has been applied to this department of biology for some years past, and think that the instrument which has afforded the great means for it was only perfected so as to be capable of use for such purposes about 1820, I cannot but congratulate the Section on the abundant fruits we are reaping.

And when, in addition, I contemplate the amount of certainty which physical science has imparted to physiology by furnishing the means of examining and accurately measuring the rates of transmission of nerve-currents, of obtaining tracings of the respiratory movements and of the arterial pulsations, of examining the retina in the living eye and the larynx of a living man almost as readily as if these parts were exposed in a dissection, I cannot but conclude that this nineteenth century has already been distinguished as a very notable one for biology, and especially for physiology.

Considering that so much time is required for making a single careful observation, it is very fortunate that so large an array of inquirers and so much talent are employed upon the subjects in which we are interested, and that once a year we have this admirable opportunity of listening to the results of inquiries instituted by the most eminent men in all parts of the world, and of hearing different views advocated with the greatest earnestness and yet with perfect good humour, and a rigorous determination to rest satisfied with nothing but the truth.

SCIENTIFIC SERIALS

Proceedings of the Berwickshire Naturalists' Club.—This is the first part of a new volume of the always welcome proceedings of this almost venerable club, which, although nominally a "Naturalists' Club," concerns itself not only with all departments of natural history, but also with subjects of antiquarian, archæological, and general historical nature. This part of the Proceedings especially contains a very large proportion of papers on the antiquities and history of the district worked by the club. As usual, the annual address of the president, Dr. Charles Stuart, consists of a summary of the proceedings of the club during the previous year, and as the proceedings take place mostly in the open air, in spring and summer, the president's address is almost always bracing and interesting, and full of information; it is so in the present case. One of the longest papers is by Dr. George Johnston, having a description of a visit to Holy Island in May 1854, and contains a great deal of interest on the history, natural history, and curiosities of that historical islet; appended is a list of the plants and animals which were seen during the visit. Mr. James Hardy has a large number of papers in this part; of his more strictly scientific contributions are the "History of some Bass Plants," "Arrival, Departure, and Local Migration of Birds near Old Cambus, 1873," "On Insects of East Berwickshire," "Contributions to the Entomology of Cheviot Hills, No. IV." Under the head of "Hawick and its Neighbourhood" we have the geology of the Hawick district by Prof. James Elliott, and its prehistoric antiquities by Dr. Bryden. Mr. John Anderson gives a list of Lepidoptera taken at various places in the south-east of Scotland in 1873, and Mr. A. Kelly the Habitats of some Berwickshire Birds. There are three contributions on *Poa Sudetica* by Mr. A. Brotherton, Mr. A. Kelly, and Mr. J. Hardy. Mr. Brotherton also contributes "Zoological Notes, 1873," and a "List of Tweedside Plants, mostly of recent introduction." Sir Walter Elliot has an interesting obituary of the late Dr. T. C. Jerdon, who wrote so largely on Indian natural history. We have not space to refer to the interesting historical and antiquarian papers.

SOCIETIES AND ACADEMIES

GÖTTINGEN

Royal Society of Sciences, March 7.—M. Wieseler read a paper On the Surname "Asphaleios" as applied to Poseidon. —Dr. Drude presented a note On the Systematic Position of Schizocodon, a genus created by Siebold, to which some plants found in the highlands of Japan are referred. The author regards Schizocodon as an anomalous Primulacea, allied to Soldanella, and clearing up the relationship between the Primulaceæ and the Polemionaceæ.—Dr. Carl Fromme made a communication On the magnetisation-function of a ball of soft iron, *i.e.* the magnetic moment obtained in a ball of unit volume by unit magnetising force.—M. Nöldeke communicated a note On the Greek Names of Susiana.—M. Bjerkesm gave a generalisation of the problem of motions produced in a still inelastic fluid by the motion of an ellipsoid.

PARIS

Academy of Sciences, Aug. 10.—M. Bertrand in the chair. The following papers were read:—On a new memoir by M. Helmholtz, by M. Bertrand.—Studies on the fossil grain found in a silicified state in the coal formation of Saint Etienne, by M. Ad. Brongniart.—Note on the isthmus of Gabès and the eastern extremity of the Saharan depression, by M. Edm. Fuchs. The author speaks in unfavourable terms of the scheme for establishing a central sea in Algeria.—Fifth note on the conductivity of ligneous bodies, by M. Th. du Moncel.—Researches on explosive bodies; explosion of powder; by MM. Noble and F. A. Abel. Second memoir.—Actual state of the invasion of *Phylloxera* in the Charente provinces: extract from a letter from M. J. Girard to the perpetual secretary.—On the employment of flax waste against *Phylloxera*: a letter from M. La Perre de Roo to M. Dumas.—Vines attacked by *Phylloxera* treated by sand: extract from a letter from M. L. Faucon to M. Dumas.—Note on Coggia's comet, by MM. Wolf and Rayet. The authors made two determinations of the wave-length of the central and most brilliant band in the spectrum. The results are—July 1st, 5161; July 6th, 5165.—Observations of Coggia's comet (III. 1874) made with the Secrétan-Eichens equatoreal, by M. Baillaud.—Observations of Borrelly's comet (IV. 1874) made with the Secrétan-Eichens equatoreal, by M. Wolf.—On the application of gilding on glass to the construction of the camera lucida, by M. G. Govi.—Stratification of the electric light, by M. Bidaud.—On decolorising charcoals and their artificial production, by M. Melsens.—On the constitution of clays (second note), by M. Th. Schlœsing.—Estimation of tannin, by MM. A. Muntz and Ramspacher. The authors allow the tanning solution to pass through a piece of hide, and estimate the amount of matter removed by loss.—Note relating to the action of muscarine (toxic principle of *Agaricus muscarius*) on the pancreatic, biliary, and urinary secretions, by M. J. L. Prevost.—On an arrangement of apparatus permitting the recovery of the iodine which is disengaged during the manufacture of "superphosphate of lime," by M. P. Thibault.—On the etherification of glycol, by M. Lorin.—On a solid polymeride of the essence of terebenthene, tetraterebenthene, by M. J. Ribau. This substance is obtained by the action of antimonious chloride upon terebenthene.—On the albumens of the white of egg, *à propos* of a reclamation of M. Arm. Gautier, by M. A. Béchamp.—Analysis of different pieces of beef sold in the Paris market in 1873, by M. Ch. Mène.—On the Annelids of the Gulf of Marseilles, by M. A. F. Marion.—On the Echini from the environs of Marseilles, by M. V. Gauthier.—On the dressing of wounds with phenic acid (according to Dr. Leister's process), and on the development of vibrios in the wounds, by M. Demarquay.—On the scales of the lateral line in different percoid fish, by M. L. Vaillant.—On the influence of forests on the quantity of rain which a country receives, by MM. L. Fautrat and A. Sartiaux.—On the age and position of the white statuary marbles of the Pyrenees and Alps, by M. H. Coquand.

BOOKS RECEIVED

BRITISH.—British Wild Flowers, Part I.: Sowerby and Johnson (Van Voorst).—Reclamation and Protection of Agricultural Land: David Stevenson (Black).—Proceedings of the Manchester Literary and Philosophical Society, vols. viii. ix. x.—Memoirs of the Manchester Literary and Philosophical Society, vol. iv., 3rd series.—How I found Livingstone in Central Africa: H. M. Stanley. Cheap Edition (Low).—Twelfth Annual Report of the Birmingham Free Libraries Committees.—On the Modern Hypothesis of Atomic Matter and Luminiferous Ether: H. Deacon.—Proceedings of the Bristol Naturalists' Society, 1873.—Divine Revelation; or, Pseudo-Science: R. G. Suckling Browne (Longmans).—Tyer's Block Telegraph and Electric Locking Signals. 5th edit. (Tyer & Co.).—The Human Eye: W. Whalley (J. and A. Churchill).—Physiology of the Circulation: Dr. Bell Pettigrew (Macmillan & Co.).—Researches in the Life History of the Monads: W. H. Dallinger and J. Drysdale, M.D.—Journal of the Iron and Steel Institute, vol. i. (Newcastle).—Treasury of Natural History. New Edition (Longmans.)

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