

ment 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 sepa-

rate 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

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#### 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 inertia*, 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 Inertia* 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 electro-magnet, 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