(similar to the Inspectors under the Alkali Act) should be appointed, to whom should be committed the duty of detecting and proving offences against the law, and of procuring the conviction of offenders. They consider that the formation of River Conservancy Boards for authorising and carrying out river improvements will in course of time become imperative, but they are convinced that the thing of immediate importance in connection with river improvement throughout the country, is simply the prohibition, under adequate penalties, of the gross pollution which at present renders so much of the running water of this country useless to manufacturers, agriculturists, and the like.

The time has not yet arrived for the full discussion of these proposals. We shall doubtless hear much on this subject in the approaching or in the next session in parliament. It is, however, certain, from the opposition made to the bill of last year, that manufacturers do not as a rule agree with the Commissioners as to the feasibility of enforcing the proposed standards of purity, as regards the effluent water from works of various kinds. Nor is public opinion respecting the other and far more important source of pollution, the sewage of towns, in a sufficiently advanced or satisfactory condition to render legislation easy. It is not, for instance, clear how one and the same system, say of irrigation, can be applied to all districts possessing different soils, rainfalls and situations. Indeed, the more we consider the whole question of the prevention of the pollution of rivers, the more difficult does any general method of treatment appear to be. Each locality has its own peculiarities, and a system of prevention which is suited to one district may be inapplicable or inexpedient in another. But even supposing that when the subject comes before Parliament that difficulties are found to be of such a character as to render it impossible to legislate upon the exact basis laid down by the Commissioners, still the value of their conclusions, and of the mass of experimental evidence which they have collected, is extreme: and they have most fully earned the gratitude of all those interested in the satisfactory solution of one of the most important, though most difficult, questions of our social economy.

## THE CONSERVATION OF ENERGY

*An Elementary Treatise on Energy and its Laws.* By Balfour Stewart, M.A., LL.D., F.R.S., Professor of Natural Philosophy at the Owens College, Manchester. (Henry S. King & Co., 1873.)

IT is the proper function of Science to discover, among the ever-changing phenomena of the world, the permanent relations which are the conditions of reasonable thought. When we understand these relations well enough to express them in words we call them "Laws of Nature." When they rise to a higher stage of development and have become invariable habits of thought, we call them "Things."

Thus ice, under certain conditions, ceases to be ice. We observe that when the ice melts water appears in its place, and we find that there is always so much water in place of so much ice. We therefore obtain, in the first instance, a *law* of equivalence between a certain quantity of ice and a certain quantity of water, and finally, we arrive at the conclusion that water and ice are the same *thing* in different forms.

We are thus led to inquire what it is which remains permanent in the midst of all apparent changes, and the result of this inquiry has been the enunciation of a consistent definition of the quantity of matter in a body, and the establishment of the doctrine that the quantity of matter in a body is invariable, whatever transformations it may undergo.

This doctrine of the "Conservation of Matter" lies at the foundation of all reasoning, whether in physics or in chemistry. When the progress of Science rendered it possible to form exact ideas about the motion of bodies, men were again impelled to seek for something permanent, even in motion itself. They endeavoured to form some definition of the "Quantity of Motion" which should enable them to treat this quantity as a *thing* having a continuous existence. The long war between the followers of Newton and those of Leibniz as to whether, in estimating the quantity of motion, the mass must be multiplied into the velocity or into the square of the velocity, was not a mere debate about words and names, for it involved the question whether momentum or *vis viva* were the more fully possessed of that character of permanence which would justify its claim to the title of "The Quantity of Motion."

The doctrine of the Conservation of Energy is the most complete expression hitherto given to the belief that all the changes of phenomena are but different distributions of the same stock of energy, the total quantity of which remains invariable. The characteristic feature of scientific progress during the last thirty years has been the application of principles derived from this doctrine to the various branches of Science. The recent progress of the theory of heat is an instance of the direct and conscious application of the doctrine of the conservation of energy. In his electrical discoveries Faraday also was guided by the same doctrine, though less consciously, as he had no opportunity of becoming acquainted with it in the accurate form in which it may now be stated.

In the volume before us Dr. Balfour Stewart has explained, in a very clear and very elementary manner, what is meant by energy in its two forms, the energy of a moving system, and the energy due to the configuration of the system.

This exposition is so carefully drawn up that we think it ought to be intelligible even to students who approach the subject without any previous training in the technical dynamics of the ordinary text-books. This we consider a matter of great moment for the future progress of Science. It is no doubt easier, in dealing with the present generation of students, to gain their assent to doctrines about energy by deducing them from other principles which have been already taught them as the elementary principles of dynamics. But it is by no means always true in science that those principles which have been longest recognised are really the most elementary. The discovery of principles more fundamental and elementary than those which are already received, is not only of great importance in the philosophy of Science, but it tends to render Science less technical, and therefore more easily diffusible through the mass of society.

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Dr. Balfour Stewart, however, has not only endeavoured to give to the ideas of Work and Energy their proper position among the most elementary ideas which we can form, but he has displayed an equal amount of freedom in treating the still more modern ideas of the Dissipation of Energy, and of the difference between exact and statistical knowledge.

Thus his very first words relate to

"*Our Ignorance of Individuals*

"Very often we know little or nothing of individuals, while we yet possess a definite knowledge of the laws which regulate communities.

"The Registrar-General, for example, will tell us that the death-rate in London varies with the temperature in such a manner that a very low temperature is invariably accompanied by a very high death-rate. But if we ask him to select some one individual, and explain to us in what manner his death was caused by the low temperature, he will, most probably, be unable to do so. . . ."

"Nor is our knowledge of individuals greater in the domains of physical science. We know nothing, or next to nothing, of the ultimate structure and properties of matter, whether organic or inorganic.

"No doubt there are certain cases where a large number of particles are linked together so as to act as one individual, and then we can predict its action, as, for instance, in the solar system, where the physical astronomer is able to predict with great exactness the positions of the various planets, or of the moon."

We regret that we have not space enough to quote the whole of this introductory passage, which, in the unpretending language of clear thought, expresses ideas which have as yet been appreciated only by a very small number of scientific men, but which will, in due time, greatly modify the popular notions as to the nature of human knowledge.

The uniformities, therefore, which we observe in our experiments on quantities of matter containing many millions of molecules in continual motion, are uniformities of the same kind as those first explained by Laplace, and in more recent times wondered at by Buckle, and arise from the slumping together of innumerable cases, each of which is by no means uniform with the others.

This statement acquires still greater significance when it is combined with another consideration which Dr. Stewart, if we mistake not, has already insisted on in his opening lecture at the Owens College. This is the distinction between stable and unstable arrangements of matter and motion. A system, whether at rest or in motion, is said to be stable if a slight variation of its initial circumstances will, at the end of a finite time, produce only a slight variation in the configuration or motion at that time. If, on the contrary, a variation, however slight, in the initial circumstances, may produce, in a finite time, a large disturbance, the equilibrium or motion of the system is said to be unstable.

Dr. Stewart illustrates this by several examples, among which we may select a clock as an instance of a stable arrangement in which everything is contrived so that any slight disturbance shall produce as little effect as possible on the position of the hands at any future time. A rifle, on the other hand, is an unstable contrivance, for a very slight pressure on the trigger is sufficient to occasion the motion of the hammer and the explosion of the gunpowder—effects, the energy of which is out of all proportion to the work done on the trigger.

Thus we have stable arrangements which, when at work, are not easily put wrong, and unstable arrangements which are characterised by great delicacy of construction.

The rifle, however, as Dr. Stewart points out, is a machine which, though delicately constructed, is not incalculably so. Its instability is not like that of an egg balanced on its longer axis. But in an animal we find a structure composed of materials which are chemically unstable, so arranged that on account of the changes to which they are liable, the smallest disturbance may produce the most varied states of motion. If, then, an animal is to be compared to a machine, the delicacy of that machine must be incalculable.

It is a metaphysical doctrine, that from the same antecedents follow the same consequents. No one can gainsay this abstract statement. But it is not of much use in a world like ours, in which the same antecedents never again concur, and in which nothing ever happens twice. Indeed, for aught we know, one of the antecedents might be the precise time and place of the event, in which case experience would go for nothing.

The physical axiom which has a somewhat similar aspect is, "That from like antecedents follow like consequents." But here we have passed from sameness to likeness, from absolute accuracy to a more or less rough approximation. The axiom is now applicable only to systems of the kind which we have called stable, in which slight variations in the antecedents produce slight variations in the consequents. In unstable systems, like antecedents do not produce like consequents; and as our knowledge is never more than an approximation to the truth, the calculation of what will take place in such a system is impossible to us.

Dr. Balfour Stewart's discussion of the Dissipation of Energy is perhaps as satisfactory as it could be made in the space allotted to it, and without the use of mathematical methods. Energy is indestructible, but it may cease to be *available*. Here we have a word not familiar in pure science—a word connoting usefulness. We must therefore define what is meant by available, and state the conditions under which we are supposed to be placed

Energy is available when it can be made to do visible work. The conditions under which we attempt to transform energy into work are that we must make use of the interactions of a given system of bodies, moving within a given region of space, out of or into which neither matter nor heat can pass.

If these bodies are in visible motion, we first reduce them to rest by causing them to do a certain amount of work. We thus obtain their energy of visible motion.

If they are now at different temperatures, we convey heat from the hotter to the colder bodies by means of a heat-engine, till the whole system is at the same temperature. We thus obtain a second portion of the available energy.

Finally, if the pressures of different parts of the system are not alike, we allow the portions in which the pressure is great to expand, and so compress the portions in which the pressure is less, the volume of the whole system remaining constant. We thus obtain the third and last portion of the available energy.

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The parts of the system are now at rest relatively to each other, and are all at the same temperature and pressure. No more work can be done by the system if it is enclosed within a fixed boundary through which neither matter nor heat can pass. We have exhausted its available energy.

But there are two methods, both of them however unavailable to us, by which the energy of a system, even when rendered in this sense unavailable, may be recovered. One is by allowing the substances to expand into infinite space; the other is by conveying all the heat through a perfect heat-engine into a refrigerator at the temperature of absolute zero. Hence the importance of excluding these two methods, by limiting the statement to a system enclosed by a boundary through which neither matter nor heat can pass.

Now the doctrine of the dissipation of energy asserts that by the mutual action of the parts of such a system its available energy may be diminished, but can never be increased. If there is difference of temperature, conduction of heat takes place, and this is always accompanied by a diminution of the available energy. If there is visible motion, friction occurs, and this renders a certain amount of the energy unavailable.

Here, then, we have an irreversible process always going on, at a greater or less rate, in the universe. If, therefore, there was ever an instant at which the whole energy of the universe was available energy, that instant must have been the very first instant at which the universe began to exist. If there ever shall come a time at which the whole energy of the universe has become unavailable, the history of the universe will then have reached its close. During the whole intervening period the available energy has been diminishing and the unavailable increasing by a process as irresistible and as irreversible as Time itself. The duration of the universe according the present order of things is therefore essentially finite, both *à parte ante* and *à parte post*.

But, according to pure dynamics, every motion of a system may be performed in the reversed direction subject to the same system of forces. If then at a given instant, every particle of the universe were to have the direction of its motion reversed so as to start anew with an equal but opposite velocity, everything would run backwards from the end to the beginning. We might attempt a description of a world thus recoiling upon itself—the rivers running up into the hills, heat flowing from cold bodies to hot, and men passing over the stage of life from their graves to their cradles, ignorant of the past and remembering only the future, as Shelley sings, in his musical delirium :—

> "We have passed Age's icy caves,
> And Manhood's dark and tossing waves,
> And Youth's smooth ocean, smiling to betray;
> Along the glassy gulfs we flee
> Of shadow-haunted Infancy,
> Through Death and Birth, to a diviner day."

But then we must remember that every characteristic of the past is now transferred to the future, so that if this reversal of nature were actually to occur, we would be quite unconscious of it.

> "Thus
> Our weakness somehow shapes the shadow, Time."

Now why is this state of things, though dynamically possible, physically absurd? Simply because it requires the *exact* reversal of the motion of every atom in the universe. If but one atom were to receive a velocity differing infinitesimally from an exact reversal, that atom would leaven the whole universe with that tendency to dissipation of energy which actually exists, and things would go on as they now do.

We must now conclude, by thanking Dr. Balfour Stewart for bringing before the general public in so clear and intelligible a form some of the more intellectual results of physical science. We hope, however, that, in the next edition, the comparison between Euclid's *reductio ad absurdum* and the experimental verification of the results of a physical hypothesis, as given in Art. 118, will be re-written, as it is one of the very few passages which remind us of what is called the popular scientific style.

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## WEBERBAUER'S "FUNGI OF NORTH GERMANY"

*Die Pilze Nord-Deutschland mit besonderer Berücksichtigung Silesiens.* Beschrieben von Otto Weberbauer Heft I. mit sechs nach der Natur gezeichneten colorirten Tafeln. (Breslau: Kern; London: Williams and Norgate.)

THE mycologist has no reason to complain that he has not ample opportunities for identifying the various objects which fall into his hands, if he has but patience and book-learning enough to enable him to avail himself of all the various sources of information. There are not only abundant collections of dried specimens, like those of Rabenhorst, Fückel, and others, on the Continent, with others at home, but every day is bringing forward some new publication of greater or less excellence, with figures illustrative of obscure, or little known species, as well as those which are of more general occurrence. In that most difficult department, the Hymenomycetes, he has a host of excellent figures in Krombholz, more recent copies of which are, unfortunately, by no means equal to the original, while the analyses, for the most part, are unsatisfactory, and sometimes altogether deceptive. Eight numbers have already appeared of the Icones by Fries, which have all the advantage of coming from the author himself of nearly half of the species which are contained in the Epicrisis, a new edition of which is now in the press, including all the more recent additions, and which is proceeding with a rapidity which is somewhat wonderful, since the Prince of Mycologists is at least an octogenarian. It would be easy to mention other important works still in progress both in this country and abroad, but amongst them not the least so is the one whose title is given above, though from its nature the progress must, unfortunately, be somewhat slow. The first part now before us contains figures and analyses of twenty-six species in six plates, with descriptive letterpress, and two parts at least are promised every year.

Great care has evidently been taken in the identification, and it is, we think, a great merit that the author has been content to adopt the commonly received nomenclature, without carelessly sanctioning every new name which has been proposed by ambitious or shortsighted observers. We are glad, moreover, that the measurements are given

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