

CHAPTER XIV.

'LAST ESSAYS AT CAMBRIDGE.

AFTER Maxwell's return to Cambridge in 1871, several of those who had been "Apostles" together in 1853-7, revived the habit of meeting together for the discussion of speculative questions. This club of elder men (*ἀνδρῶν πρεσβυτέρων ἐταιρία*), which included such men as Dr. Lightfoot, now Bishop of Durham, and Professors Hort and Westcott, was christened *Eränus* (see p. 366), and three of Maxwell's contributions, dated by himself, have been preserved. It seems advisable to print these entire,—although not even chips from his workshop, but rather sparks from the whetstone of his mind,—since what he thought worthy of detaining the attention of such listeners in those ripe years cannot fail to be of interest to many readers.

I.

Does the progress of Physical Science tend to give any advantage to the opinion of Necessity (or Determinism) over that of the Contingency of Events and the Freedom of the Will?

Æt. 41.

11th February 1873.

The general character and tendency of human thought is a topic the interest of which is not confined to professional philosophers. Though every one of us must, each for him-

self, accept some sort of a philosophy, good or bad, and though the whole virtue of this philosophy depends on it being our own, yet none of us thinks it out entirely for himself. It is essential to our comfort that we should know whether we are going with the general stream of human thought or against it, and if it should turn out that the general stream flows in a direction different from the current of our private thought, though we may endeavour to explain it as the result of a wide-spread aberration of intellect, we would be more satisfied if we could obtain some evidence that it is not ourselves who are going astray.

In such an enquiry we need some fiducial point or standard of reference, by which we may ascertain the direction in which we are drifting. The books written by men of former ages who thought about the same questions would be of great use, if it were not that we are apt to derive a wrong impression from them if we approach them by a course of reading unknown to those for whom they were written.

There are certain questions, however, which form the *pièces de résistance* of philosophy, on which men of all ages have exhausted their arguments, and which are perfectly certain to furnish matter of debate to generations to come, and which may therefore serve to show how we are drifting. At a certain epoch of our adolescence those of us who are good for anything begin to get anxious about these questions, and unless the cares of this world utterly choke our metaphysical anxieties, we become developed into advocates of necessity or of free-will. What it is which determines for us which side we shall take must for the purpose of this essay be regarded as contingent. According to Mr. F. Galton, it is derived from structureless elements in our parents, which were probably never developed in their earthly existence, and which may have been handed down to them, still in the latent state, through untold generations. Much might be said in favour of such a congenital bias towards a particular scheme of philosophy; at the same time we must acknowledge that much of a man's mental history depends upon events occurring after his birth in time, and that he is on the whole more

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likely to espouse doctrines which harmonise with the particular set of ideas to which he is induced, by the process of education, to confine his attention. What will be the probable effect if these ideas happen mainly to be those of modern physical science?

The intimate connexion between physical and metaphysical science is indicated even by their names. What are the chief requisites of a physical laboratory? Facilities for measuring space, time, and mass. What is the occupation of a metaphysician? Speculating on the modes of difference of co-existent things, on invariable sequences, and on the existence of matter.

He is nothing but a physicist disarmed of all his weapons,—a disembodied spirit trying to measure distances in terms of his own cubit, to form a chronology in which intervals of time are measured by the number of thoughts which they include, and to evolve a standard pound out of his own self-consciousness. Taking metaphysicians singly, we find again that as is their physics, so is their metaphysics. Descartes, with his perfect insight into geometrical truth, and his wonderful ingenuity in the imagination of mechanical contrivances, was far behind the other great men of his time with respect to the conception of matter as a receptacle of momentum and energy. His doctrine of the collision of bodies is ludicrously absurd. He admits, indeed, that the facts are against him, but explains them as the result either of the want of perfect hardness in the bodies, or of the action of the surrounding air. His inability to form that notion which we now call force is exemplified in his explanation of the hardness of bodies as the result of the quiescence of their parts.

“Neque profecto ullum glutinum possumus excogitare, quod particulas durorum corporum firmitus inter se conjungat, quàm ipsarum quies.” *Princip., Pars II. LV.*

Descartes, in fact, was a firm believer that matter has but one essential property, namely extension, and his influence in preserving this pernicious heresy in existence extends even to very recent times. Spinoza's idea of matter,

as he receives it from the authorities, is exactly that of Descartes; and if he has added to it another essential function, namely thought, the new ingredient does not interfere with the old, and certainly does not bring the matter of Descartes into closer resemblance with that of Newton.

The influence of the physical ideas of Newton on philosophical thought deserves a careful study. It may be traced in a very direct way through Maclaurin and the Stewarts to the Scotch School, the members of which had all listened to the popular expositions of the Newtonian Philosophy in their respective colleges. In England, Boyle and Locke reflect Newtonian ideas with tolerable distinctness, though both have ideas of their own. Berkeley, on the other hand, though he is a master of the language of his time, is quite impervious to its ideas. Samuel Clarke is perhaps one of the best examples of the influence of Newton; while Roger Cotes, in spite of his clever exposition of Newton's doctrines, must be condemned as one of the earliest heretics bred in the bosom of Newtonianism.

It is absolutely manifest from these and other instances that any development of physical science is likely to produce some modification of the methods and ideas of philosophers, provided that the physical ideas are expounded in such a way that the philosophers can understand them.

The principal developments of physical ideas in modern times have been—

1st. The idea of matter as the receptacle of momentum and energy. This we may attribute to Galileo and some of his contemporaries. This idea is fully expressed by Newton, under the form of Laws of Motion.

2d. The discussion of the relation between the fact of gravitation and the maxim that matter cannot act where it is not.

3d. The discoveries in Physical Optics, at the beginning of this century. These have produced much less effect outside the scientific world than might be expected. There are two reasons for this. In the first place it is difficult, especially in these days of the separation of technical from popular

knowledge, to expound physical optics to persons not professedly mathematicians. The second reason is, that it is extremely easy to show such persons the phenomena, which are very beautiful in themselves, and this is often accepted as instruction in physical optics.

4th. The development of the doctrine of the Conservation of Energy. This has produced a far greater effect on the thinking world outside that of technical thermodynamics.

As the doctrine of the conservation of matter gave a definiteness to statements regarding the immateriality of the soul, so the doctrine of the conservation of energy, when applied to living beings, leads to the conclusion that the soul of an animal is not, like the mainspring of a watch, the motive power of the body, but that its function is rather that of a steersman of a vessel,—not to produce, but to regulate and direct the animal powers.

5th. The discoveries in Electricity and Magnetism labour under the same disadvantages as those in Light. It is difficult to present the ideas in an adequate manner to laymen, and it is easy to show them wonderful experiments.

6th. On the other hand, recent developments of Molecular Science seem likely to have a powerful effect on the world of thought. The doctrine that visible bodies apparently at rest are made up of parts, each of which is moving with the velocity of a cannon ball, and yet never departing to a visible extent from its mean place, is sufficiently startling to attract the attention of an unprofessional man.

But I think the most important effect of molecular science on our way of thinking will be that it forces on our attention the distinction between two kinds of knowledge, which we may call for convenience the Dynamical and Statistical.

The statistical method of investigating social questions has Laplace for its most scientific and Buckle for its most popular expounder. Persons are grouped according to some characteristic, and the number of persons forming the group is set down under that characteristic. This is the raw material from which the statist endeavours to deduce general

theorems in sociology. Other students of human nature proceed on a different plan. They observe individual men, ascertain their history, analyse their motives, and compare their expectation of what they will do with their actual conduct. This may be called the dynamical method of study as applied to man. However imperfect the dynamical study of man may be in practice, it evidently is the only perfect method in principle, and its shortcomings arise from the limitation of our powers rather than from a faulty method of procedure. If we betake ourselves to the statistical method, we do so confessing that we are unable to follow the details of each individual case, and expecting that the effects of widespread causes, though very different in each individual, will produce an average result on the whole nation, from a study of which we may estimate the character and propensities of an imaginary being called the Mean Man.

Now, if the molecular theory of the constitution of bodies is true, all our knowledge of matter is of the statistical kind. A constituent molecule of a body has properties very different from those of the body to which it belongs. Besides its immutability and other recondite properties, it has a velocity which is different from that which we attribute to the body as a whole.

The smallest portion of a body which we can discern consists of a vast number of such molecules, and all that we can learn about this group of molecules is statistical information. We can determine the motion of the centre of gravity of the group, but not that of any one of its members for the time being, and these members themselves are continually passing from one group to another in a manner confessedly beyond our power of tracing them.

Hence those uniformities which we observe in our experiments with quantities of matter containing millions of millions of molecules are uniformities of the same kind as those explained by Laplace and wondered at by Buckle, arising from the slumping together of multitudes of cases, each of which is by no means uniform with the others.

The discussion of statistical matter is within the province

of human reason, and valid consequences may be deduced from it by legitimate methods; but there are certain peculiarities in the very form of the results which indicate that they belong to a different department of knowledge from the domain of exact science. They are not symmetrical functions of the time. It makes all the difference in the world whether we suppose the inquiry to be historical or prophetic—whether our object is to deduce the past state or the future state of things from the known present state. In astronomy, the two problems differ only in the sign of t , the time; in the theory of the diffusion of matter, heat, or motion, the prophetic problem is always capable of solution; but the historical one, except in singular cases, is insoluble. There may be other cases in which the past, but not the future, may be deducible from the present. Perhaps the process by which we remember past events, by submitting our memory to analysis, may be a case of this kind.

Much light may be thrown on some of these questions by the consideration of stability and instability. When the state of things is such that an infinitely small variation of the present state will alter only by an infinitely small quantity the state at some future time, the condition of the system, whether at rest or in motion, is said to be stable; but when an infinitely small variation in the present state may bring about a finite difference in the state of the system in a finite time, the condition of the system is said to be unstable.

It is manifest that the existence of unstable conditions renders impossible the prediction of future events, if our knowledge of the present state is only approximate, and not accurate.

It has been well pointed out by Professor Balfour Stewart that physical stability is the characteristic of those systems from the contemplation of which determinists draw their arguments, and physical stability that of those living bodies, and moral instability that of those developable souls, which furnish to consciousness the conviction of free will.

Having thus pointed out some of the relations of physical

science to the question, we are the better prepared to inquire what is meant by determination and what by free will.

No one, I suppose, would assign to free will a more than infinitesimal range. No leopard can change his spots, nor can any one by merely wishing it, or, as some say, *willing* it, introduce discontinuity into his course of existence. Our free will at the best is like that of Lucretius's atoms,—which at quite uncertain times and places deviate in an uncertain manner from their course. In the course of this our mortal life we more or less frequently find ourselves on a physical or moral watershed, where an imperceptible deviation is sufficient to determine into which of two valleys we shall descend. The doctrine of free will asserts that in some such cases the Ego alone is the determining cause. The doctrine of Determinism asserts that in every case, without exception, the result is determined by the previous conditions of the subject, whether bodily or mental, and that Ego is mistaken in supposing himself in any way the cause of the actual result, as both what he is pleased to call decisions and the resultant action are corresponding events due to the same fixed laws. Now, when we speak of causes and effects, we always imply some person who knows the causes and deduces the effects. Who is this person? Is he a man, or is he the Deity?

If he is man,—that is to say, a person who can make observations with a certain finite degree of accuracy,—we have seen that it is only in certain cases that he can predict results with even approximate correctness.

If he is the Deity, I object to any argument founded on a supposed acquaintance with the conditions of Divine foreknowledge.

The subject of the essay is the relation to determinism, not of theology, metaphysics, or mathematics, but of physical science,—the science which depends for its material on the observation and measurement of visible things, but which aims at the development of doctrines whose consistency with each other shall be apparent to our reason.

It is a metaphysical doctrine that from the same antecedents follow the same consequents. No one can gainsay this. But it is not of much use in a world like this, in which the same antecedents never again concur, and nothing ever happens twice. Indeed, for aught we know, one of the antecedents might be the precise date and place of the event, in which case experience would go for nothing. The metaphysical axiom would be of use only to a being possessed of the knowledge of contingent events, *scientia simplicis intelligentiæ*,—a degree of knowledge to which mere omniscience of all facts, *scientia visionis*, is but ignorance.

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. There are certain classes of phenomena, as I have said, in which a small error in the data only introduces a small error in the result. Such are, among others, the larger phenomena of the Solar System, and those in which the more elementary laws in Dynamics contribute the greater part of the result. The course of events in these cases is stable.

There are other classes of phenomena which are more complicated, and in which cases of instability may occur, the number of such cases increasing, in an exceedingly rapid manner, as the number of variables increases. Thus, to take a case from a branch of science which comes next to astronomy itself as a manifestation of order: In the refraction of light, the direction of the refracted ray depends on that of the incident ray, so that in general, if the one direction be slightly altered, the other also will be slightly altered. In doubly refracting media there are two refracting rays, but it is true of each of them that like causes produce like effects. But if the direction of the ray within a biaxial crystal is nearly but not exactly coincident with that of the ray-axis of the crystal, a small change in direction will produce a great change in the direction of the emergent ray. Of course, this arises from a singularity in the properties of the ray-axis, and there are only two ray-axes among the infinite number of

possible directions of lines in the crystal; but it is to be expected that in phenomena of higher complexity there will be a far greater number of singularities, near which the axiom about like causes producing like effects ceases to be true. Thus the conditions under which gun-cotton explodes are far from being well known; but the aim of chemists is not so much to predict the time at which gun-cotton will go off of itself, as to find a kind of gun-cotton which, when placed in certain circumstances, has never yet exploded, and this even when slight irregularities both in the manufacture and in the storage are taken account of by trying numerous and long continued experiments.

In all such cases there is one common circumstance,—the system has a quantity of potential energy, which is capable of being transformed into motion, but which cannot begin to be so transformed till the system has reached a certain configuration, to attain which requires an expenditure of work, which in certain cases may be infinitesimally small, and in general bears no definite proportion to the energy developed in consequence thereof. For example, the rock loosed by frost and balanced on a singular point of the mountain-side, the little spark which kindles the great forest, the little word which sets the world a fighting, the little scruple which prevents a man from doing his will, the little spore which blights all the potatoes, the little gemmule which makes us philosophers or idiots. Every existence above a certain rank has its singular points: the higher the rank, the more of them. At these points, influences whose physical magnitude is too small to be taken account of by a finite being, may produce results of the greatest importance. All great results produced by human endeavour depend on taking advantage of these singular states when they occur.

There is a tide in the affairs of men
Which, taken at the flood, leads on to fortune.

The man of tact says "the right word at the right time," and, "a word spoken in due season how good is it!"
The man of no tact is like vinegar upon nitre when

he sings his songs to a heavy heart. The ill-timed admonition hardens the heart, and the good resolution, taken when it is sure to be broken, becomes macadamised into pavement for the abyss.

It appears then that in our own nature there are more singular points,—where prediction, except from absolutely perfect data, and guided by the omniscience of contingency, becomes impossible,—than there are in any lower organisation. But singular points are by their very nature isolated, and form no appreciable fraction of the continuous course of our existence. Hence predictions of human conduct may be made in many cases. First, with respect to those who have no character at all, especially when considered in crowds, after the statistical method. Second, with respect to individuals of confirmed character, with respect to actions of the kind for which their character is confirmed.

If, therefore, those cultivators of physical science from whom the intelligent public deduce their conception of the physicist, and whose style is recognised as marking with a scientific stamp the doctrines they promulgate, are led in pursuit of the arcana of science to the study of the singularities and instabilities, rather than the continuities and stabilities of things, the promotion of natural knowledge may tend to remove that prejudice in favour of determinism which seems to arise from assuming that the physical science of the future is a mere magnified image of that of the past.

II.

ON MODIFIED ASPECTS OF PAIN.

31st October 1876.

- Æt.* 45. We often make sensation in general the subject of discussion, but it does not appear that we think much about particular sensations. If we did, we should have had more names for them. Most of the words which seem at first sight to be names of sensations are really used as names of objects which we suppose to be associated with the sensation, and to be indicated by it. All such words as hot and