CROONIAN LECTURES

ON

MATTER AND FORCE.

Delivered at the Royal College of Physicians.

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LECTURE I. (Concluded.)

On the Three Stages of our Ideas regarding the Union of Matter and Force in the Abiological Sciences.

"But though the natural works of God can never by any possibility come in contradiction with the higher things which belong to our future existence, and must with everything concerning him ever glorify him, still I do not think it at all necessary to tie the study of the natural sciences and religion together."

FARADAY, M.S.

WE come, then, now to the third, or modern stage, in which there is complete union, and no possibility of any separation between the ideas of matter and force. The absolute union—the complete inseparability—of our ideas of matter and force, is most apparent in our ideas of matter and chemical force. A molecule has been endowed with a force which gives rise to its various chemical qualities, and these never change either in their nature or in their amount. Mr. Faraday says, "a particle of oxygen is ever a particle of oxygen—nothing can in the least wear it. If it enter into combination, and disappear as oxygen—if it pass through a thousand combinations, animal, vegetable, and mineral—if it lie hid for a thousand years, and then be evolved, it is oxygen with its first qualities. Neither more nor less. It has all its original force, and only that; the amount of force which it disengaged when hiding itself has again to be employed in a reverse direction when it is set at liberty." (Faraday, *Researches in Chemistry*, p. 454.) If it were possible to take the ultimate atom of any one of the elements, we should find that the chemical force which constitutes and determines its nature, would be absolutely inseparable from the matter of which the element consists. For example, the ultimate atom of carbon would have the same kind of force as any mass of carbon, and it would differ in kind, and always from the ultimate atom of any other element, because of the peculiarity of its force. If the chemical force could be separated from the atom of carbon, the matter might cease to be carbon, and might become some other element, and the transmutation of metals might then be possible. The union, also, between matter and gravity is just as inseparable as the union between matter and chemical force. Matter without weight is not matter at all; the weight belongs to the matter, and cannot be taken from it. The gravity can no more be destroyed than the matter itself can be destroyed. However small the matter may be divided, yet each part will have a part of the force, and there can be no more of the force lost than of the matter. We cannot think that the matter can exist without the force of gravity being always acting or ready to act in each atom of it. Nor can we think that any portion of the force of gravity can be separated from the matter. If we mentally attempt to divide any amount of the force into its constituent portions, then every portion, however minute, of the force, must have a corresponding portion of matter to which it is inherent, and without which the force cannot be thought to exist.

Newton's great discovery consisted in determining the existence of force in each particle of the matter of the earth and the planets; and Adams and Leverrier, recognising the action of a force not accounted for in the matter that was known, predicted the existence of unknown matter in an undiscovered planet which was looked for and found. The great advance, however, towards the modern stage of ideas regarding the inseparability of matter and force, is owing to Young and Fresnel, who overthrew the second stage by their discoveries regarding light. Dr. Whewell says, "By their ideas on the interference of undulations, of double refraction (or the passage of undulations through substances in which the resistance to the undulations is different in different directions. By their ideas of transverse vibration or polarisation and dipolarisation, they did away with the most material part of Newton's ideas on the nature of light, and now the only vestige that remains is the luminiferous ether; the imponderable material substance which is still assumed to carry the motions which constitute light."

As the question of the existence of this luminiferous ether is of great interest in connection with our ideas of matter and force, I must bring

before you as shortly as possible the opposite views that now exist regarding it, whether it be regarded simply as the carrier, or as essential to the origination of that form of motion called light. The Rev. T. R. Birks, in his work on matter and aether, published in 1862, most powerfully defends its existence and defends its properties. He assumes that it exercises a strong repulsive power among its own particles, and a strong attraction and power of combining with all other elements. Every monad of ordinary matter, he considers, is combined with a monad of aether, forming a double conjugate compound atom or unit. Compounds of several monads may combine in several ways, forming different chemical elements. Every chemical element is not a solid sphere, either in motion or at rest, but consists of a definite number of units, duads, centres of force, or monads of matter and aether inseparably joined together, arranged in some definite order, revolving usually round some axis of rotation, and parted from the nearest elements by a certain amount of attached aether. Every such element must in its very structure have four or five different sources of contrast, from which a kind of polarity may arise. Contrasts of matter, aether, and rotation, and these contrasts may be included under the general term of polarity. For example, positive or vitreous electricity may be an excess of attached aether; negative or resinous a deficiency.

Professor Clark Maxwell, in the *Philosophical Transactions*, 1865, part 3, p. 460, says: "We have, therefore, some reason to believe, from the phenomena of light and heat, that there is an ethereal medium filling space and permeating bodies, capable of being set in motion and of transmitting that motion from one part to another, and of communicating that motion to gross matter, so as to heat it and affect it in various ways."

Mr. Grove, on the other side, says (p. 163): "In a lecture delivered in January 1842, I stated that it appeared to me more consistent with known facts to regard light as resulting from a vibration or motion of the molecules of matter itself rather than from a specific aether pervading it, just as sound is propagated by the vibration of wood, or as waves are by water. I am not here speaking of the character of the vibrations of light, sound, or water, which are doubtless very different from each other, but am only comparing them so far as they illustrate the propagation of force by motion in the matter itself. To the main objection of Dr. Young, that all bodies would have the properties of solar phosphorus if light consisted in the undulations of ordinary matter, it may be answered that so many bodies have this property, and with so great variety in its duration that *non constat* all may not have it, though for a time so short that the eye cannot detect its duration. If it be said that there is not sufficient elasticity in ordinary matter for the transmission of undulations with such velocity as light is known to travel with, this may be so if the vibrations be supposed exactly analogous to those of sound; but that molecular motion can travel with equal and even greater velocity than light, is shown by the rapidity with which electricity traverses a metal wire when each particle of metal is undoubtedly affected."

Mr. Brooke, in the *Proceed. of the Royal Soc.*, 1867 (p. 412), says: "The known enormous velocity (of probably not less than 250,000 miles in a second) at which electricity travels through a copper conductor is complete evidence that ordinary matter is capable of transmitting something at a considerable greater velocity than the waves of light and heat. Why should not appropriate kinds of matter be assumed capable of transmitting these also? and if so, the need of the interstitial presence of aether ceases altogether." Mr. Grove sums up the arguments in favour of and against the luminiferous ether thus (p. 186, ed., 1867): "At the utmost our assumption, on the one hand, is that whenever light, heat, etc., exist, ordinary matter exists, though it may be so attenuated that we cannot recognise it by the test of other forces such as gravitation; and that to the expansibility of matter no limit can be assigned. On the other hand, a specific matter without weight must be assumed, of the existence of which there is no evidence but in the phenomena, for the explanation of which its existence is supposed. To account for the phenomena the aether is assumed, and to prove the existence of the aether the phenomena are cited. For these reasons and others above given, I think the assumption of the universality of ordinary matter is the least gratuitous."

Mr. W. K. Clifford, in a lecture at the Royal Institution, says: "It has been supposed for a long time that light consists of waves transmitted through an extremely thin ethereal jelly that pervades all space; it is easy to see the very rapid tremor which spreads through a jelly when you shake it at one point. From this hypothesis we can deduce the laws of the propagation of light, and of the way in which different rays interfere with one another, and the laws so deduced are abundantly confirmed by experiment. But here also science kicks down the ladder by which she has risen. In order to explain the phenomena of light, it is not necessary to assume anything more than a periodical oscillation between two states at any given point of space. What the two states are nobody

knows, and the only thing we can assert with any degree of probability is that they are not states of merely mechanical displacement, like the tremor of a jelly, for the phenomena of fluorescence appear to negative this supposition."

Of the existence of this æther, spectrum analysis has given us no evidence, yet this most sensitive test has proved that some of the substances that are on our earth exist also in the stars, nebulae, and comets. As yet no great opportunity for analysing the matter of comets has occurred. It is probable that nitrogen and the aerolitic metals exist in them. When we are told that the tail of the comet of 1811 extended 112 million miles through space, and that the nature of the matter composing it may be determined, it is evident that ultimately we shall know much more regarding the interplanetary medium than we do at present. However much our knowledge may extend, even if it should be proved that an æther exists for the conveyance of light through interplanetary space, probably it will be found to be as unessential for the production of light itself, as it is unessential for the production of heat.

The ideas of the union of matter and force followed the same course with regard to heat as they did with regard to light. "The discovery of polarisation of heat by Professor Forbes, and its confirmation and extension to dipolarisation by Melloni, almost at a single blow ruined the emission theory" (Whewell). It made the doctrine of emission as untenable regarding heat as it had before been found regarding light.

As early as 1798, Count Rumford read a paper before the Royal Society concerning the heat which is excited by friction. "It appears to me," he says, "to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in these experiments, except motion." In 1799, Davy published a paper on heat and light, in which he said: "I conclude that heat or the power of repulsion is not matter." "Again," he says, "heat then, or that power which prevents the actual contact of the corpuscles of bodies, and which is the cause of our peculiar sensations of heat and cold, may be defined as a peculiar motion, probably as a vibration of the corpuscles of bodies tending to separate them. It may, with propriety, be called the repulsive motion."

"I am obliged," says Mr. Grove, "in order to be intelligible, to talk of heat as an entity, and of its conduction, radiation, etc.; yet these expressions are, in fact, inconsistent with the dynamic theory, which regards heat as motion, and as nothing else. Thus conduction would be simply a progressive dilatation or motion of the particles of the conducting substance." The phenomena depend upon the molecular structure of the matter affected; and, although these facts are not absolutely inconsistent with the theory which supposes them to be fluids or entities, it will, I think, be found to be far more consistent with that which views them as motion. Heat, which we are at present considering, cannot be insulated. We cannot remove the heat from a substance, and retain it as heat. We can only transmit it to another substance, either as heat, or as some other mode of force. We only know certain changes of matter, for which changes heat is a generic name. The thing heat is unknown.

In 1863, Professor Tyndall says: "The dynamical theory, or, as it is sometimes called, the mechanical theory of heat, discards the idea of materiality as applied to heat. The supporters of this theory do not believe heat to be matter, but to be an accident or condition of matter—namely, a motion of its ultimate particles. From the direct contemplation of some of the phenomena of heat, a profound mind is led almost instinctively to conclude that heat is a kind of motion."

The theory, then, which Rumford so powerfully advocated, and Davy so ably supported, was, that heat is a kind of motion; and that by friction, percussion, and compression, this motion may be generated, as well as by combustion. Mr. Clifford, in his lecture at the Royal Institution, says: "Fourier, in trying to find the laws of the spread of heat from one part of a body to another, took the hypothesis that heat was a fluid which flowed from the hot end into the cold as water flows through a pipe. From this hypothesis the laws of conduction were deduced; but, in the process, it was found that the very same laws would flow from other hypotheses. In fact, whatever can be explained by the notion of a fluid, can be equally well explained either by the attraction of particles or by the strains of a solid substance. The very same mathematical calculations result from three distinct hypotheses."

With regard to the third stage of ideas regarding the union of matter and electric and magnetic force, Dr. Whewell says, the discovery of the polarisation of heat shook the idea of the electric fluids as physical realities. Material caloric and material electricity fell together.

Mr. Grove says: "Electricity is that affection of matter or mode of force which most distinctly and beautifully brings into relation other modes of force, and exhibits to a great extent, in a qualitative form, its own relation with them, and their reciprocal relations with it and with

each other. From the manner in which the particular force called electricity is seemingly transmitted through certain bodies, such as metallic wires, the term current is commonly used to denote its apparent progress. It is very difficult to present to the mind any theory which will give a definite conception of its *modus agendi*. The early theories regard its phenomena as produced either by a single fluid, idio-repulsive, but attractive of all other matter; or else as produced by two fluids, each idio-repulsive, but attractive of the other. No substantive theory has been proposed other than these two. But, although this is the case, I think I shall not be unsupported by many who have attentively studied electrical phenomena, in viewing them as resulting, not from the action of a fluid or fluids, but as a molecular polarisation of ordinary matter, or as matter acting by attraction and repulsion in a definite direction."

Electricity and magnetism, like light and heat, in the third stage, will be regarded as peculiar vibratory motions of ponderable matter, having quantitative relations to all other forms of motion. The difficulty of realising the nature of a complex transverse double polar motion of a particle of gaseous, liquid, or solid matter, is, however, far beyond our comprehension now.

Such, then, is a sketch of the history of the three stages of ideas regarding the separability of matter and force. It must, however, be remembered, that these three stages pass insensibly into one another; and that, in the history of these ideas in individual minds, some ideas regarding the separability of matter and force may be found in the third stage, while other ideas may still halt at the second, or never get beyond even the first stage which I have described. Thus every one may admit the inseparability of matter from the forces that cause gravitation and chemical action; whilst some may hardly be prepared even now to allow that heat is equally inseparable from matter. Still less readily may the cause of light be admitted to be inherent in ponderable matter; and few at present are able to believe that electricity and magnetism are peculiar motions, excited only in the molecules of ponderable matter. In other words, the third stage of ideas regarding the union of matter and force may to some extent be received by every one; but, in its full extent, it is only gradually becoming recognised as undoubted truth. As soon as it is admitted that force is absolutely inseparable from matter, whether gas, liquid, or solid, it will become as impossible to think that matter can consist only of centres of force, as to think that matter can be inert or void of all force. Matter must always be in a state of motion, or of tendency to, or of resistance to, motion; it can never be in a state of perfect rest.

Immediately connected with the idea of the inseparability of matter and force is another modern idea regarding force, the history of which in England must be given here. This idea was first represented by the term conversion of force, then by correlation of forces, then by conservation of force, and now by conservation of energy. In 1839, Mr. Faraday, in a paper on the Improbability of Contact exciting Voltaic Electricity, wrote (*Exp. Researches*, vol. ii, p. 103): "We have many processes by which the form of the power may be so changed that an apparent conversion of one into another takes place." "But in no case is there a pure creation—a production of power, without a corresponding exhaustion of something to supply it."

Mr. Grove, in a lecture on the Progress of Physical Science in 1842, says: "The present tendency of theory seems to lead to the opinion that all these affections (of matter) are resolvable into one—namely, motion;" and: "Light, heat, electricity, magnetism, motion, and chemical affinity, are all convertible material affections. Assuming either as the cause, one of the others will be the effect. Thus heat may be said to produce electricity, electricity to produce heat, magnetism to produce electricity, electricity magnetism, and so of the rest. . . . We must humbly refer their causation to one omnipresent influence, and content ourselves with studying their effect, and developing by experiment their mutual relations." In 1843, in a course of lectures on the Correlation of Forces, he says: "The view which I venture to submit to you in these lectures is, that force cannot be annihilated, but is merely subdivided, and altered in direction and character." "I will venture as an opinion, founded after much consideration, that science is rapidly progressing towards the establishment of immediate or direct relations between all these forces."

In 1843, Mr. Joule (*Phil. Mag.*, vol. xxiii, p. 442), on the Mechanical Value of Heat, says that he shall repeat and extend his experiments, being satisfied that the grand agents of Nature are, by the Creator's fiat, indestructible, and that wherever mechanical force is expended, an exact equivalent of heat is always obtained; and he mentions the practical conclusions which may be drawn from the convertibility of heat and mechanical powers into one another.

Mr. Faraday, in a lecture on the Conservation of Force in 1857 (*Researches*, p. 454), says the idea we have of the indestructibility of indi-

vidual matter is one case, and a most important one, of the conservation of force; and, in a manuscript, he says, "Force cannot be annihilated or created at pleasure. It cannot act, then cease to act, then act, then cease to act, without being otherwise disposed of." In another manuscript, he says: "What I mean by the word force is the source or sources of all possible actions of the particles or materials of the universe; being often called the powers of Nature, when spoken of in respect of the different manners in which these effects are shown."

In order to avoid the indistinctness and confusion which come from using the word force at one time as the cause of an effect, and at another time as the effect itself; and, in order to confine ideas to the effect which alone can be the object of experimental research, the term conservation of energy is now adopted, instead of the term conservation of force. Thus, the word force, of the nature of which we know only that it is indestructible and inseparable from matter, is the cause of energy, and energy is the effect of force.

This diagram may perhaps render the use of these terms more clear.

The idea of the conservation of energy is, that the sum of the actual and potential energy in the world is constant. The force, or, as it is better called, the actual energy, that can be put into the cannon ball, is exactly equal to the latent or potential energy in the gunpowder, and this depends on the chemical force in the oxygen, hydrogen, and carbon. The ball gains only what the powder loses. As the potential energy, or tension, decreases, the actual energy, or motion, increases, and no loss or gain in the total amount of motion and tension can occur. Whatever the form of motion may be, it can only come either from some other form of motion: or from some form of tension.

It has been Dr. Joule's great work to exhibit experimentally the measurable relation between heat and gravity. He has determined that a certain amount of one kind of motion does produce an equivalent quantity of another kind. He proved that 772 pounds weight of matter falling one foot gives rise to enough heat to raise a pound of water one deg. Fahr. in temperature. He called the unit of mechanical motion one pound weight falling one foot = one foot-pound, and the unit of heat that quantity which raises one pound of water one deg. Fahr.; then the mechanical equivalent of heat is 772 foot-pounds.

The equivalence of other forms of energy has yet to be determined by experiment. Meanwhile, according to modern ideas, the different forms are so related to one another, that none can be lost, and none can be produced except by passing into or out of some other form of energy.

"But," says Mr. Faraday (*Researches in Chemistry and Physics*, p. 459), "after all, the principle of the conservation of force may by some be denied. Well, then, if it be unfounded, even in its application to the smallest part of the science of force, the proof must be within our reach, for all physical science is so. In that case, discoveries as large, or even larger, than any yet made, may be anticipated. I do not resist the search for them; for no one can do harm, but only good, who works with an earnest and truthful spirit in such a direction. But let us not admit the destruction or creation of force without clear and constant proof. Just as the chemist owes all the perfection of his science to his dependence on the certainty of gravitation applied by the balance, so may the physical philosopher expect to find the greatest security and the utmost aid in the principle of the conservation of force. All that we have that is good and safe, as the steam-engine, the electric telegraph, etc., witness to that principle. It would require a perpetual motion, a fire without heat, heat without a source, action without reaction, cause without effect, or effect without a cause, to displace it from its rank as a law of Nature." Finally, he says, "by admitting no hypothesis, and believing in no assertion of any fact opposed to the principle of the conservation of force, the natural philosopher is prepared to look for effects and conditions as yet unknown, and the way for him is open to any degree of development of the consequences and relations of power. By denying this principle, he opposes a dogmatic barrier to improvement; whilst, by admitting it, he has a fresh stimulus to investigation and a pilot to human science." (P. 450.)

In my next lectures, I shall show you how far the three stages of ideas on the separability of matter and force can be recognised in the history of sciences into which the idea of life enters; and I shall try to make some application of the doctrine of the conservation of energy to physiology, pathology, and therapeutics.

A CASE OF ANEURISM OF THE ASCENDING AORTA COMMUNICATING WITH THE PULMONARY ARTERY.

BY WILLIAM ROBERTS, M.D., F.R.C.P.,
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CASES of aortic aneurism communicating with the pulmonary artery, and studied with some accuracy during life, are still of sufficient rarity to deserve separate record.

On October 9th, 1867, I was requested by Mr. Stocks, of Salford, to see with him a gentleman labouring under some obscure disease of the heart. The patient (Mr. J.) was engaged in business; and, in addition, acted as organist of a church in the suburbs of Manchester. He was a spare weakly-looking man, aged 28, of somewhat intemperate habits. It appeared that, about a month before, Mr. J. began to suffer from cough and difficulty of breathing. He thought he had taken cold, and for this he consulted Mr. Stocks about a week before my visit. On examining him, Mr. Stocks discovered in the præcordial region a loud harsh murmur, which was evidently different from the murmurs produced by ordinary valvular disease.

When Mr. J. was first seen by me, he did not keep his bed; he even went out a little occasionally. His face was pale and thin; the lips were somewhat livid. There was no dropsy nor oedema of any part. He complained of an irritating cough, with oppression in the chest, and occasional paroxysmal attacks of difficulty of breathing, which were relieved by ether draughts. There were no antecedents in his history bearing specially on the production of heart-disease; unless the fact that, owing to his irregular habits, he sometimes had to hurry and run on Sunday mornings, to keep his appointment at church, can be so regarded. He was subjected to a careful examination, and evidence was found of extensive disease of the heart and great vessels; but, as the physical signs differed in no appreciable manner from those found on November 1st and 4th, the detail of these, to avoid repetition, will be described from the notes taken on the latter of these dates. In the meantime dropsy had set in, and advanced rapidly; the strength declined, and the patient became confined to his room, and, finally, to his bed.

On November 4th, he was in the following condition. He was lying in bed, with the head much raised to facilitate his breathing. The face was calm and pale; the lips livid. There was considerable oedema of the legs and thighs, with some ascites. There was short frequent cough and somewhat abundant expectoration of a liquid albuminous matter, mostly airless, mixed with a little froth and a few specks of blood. Pulse 112, markedly jerking, and strongly visible in all the superficial arteries; respiration 32. The tongue was red and clean, and freely mapped with furrows. There were almost perpetual insomnia, considerable thirst, and failing appetite. On examining the chest, there was found some præcordial bulging; the heart's apex beat in the fifth interspace, half an inch outside the vertical line of the nipple. The superficial cardiac dulness was very extensive, reaching from an inch and a half to the right of the middle line to one inch outside the left nipple; it reached upwards as high as the third rib in the sternal region, and formed a parallelogram five inches across and four inches deep. The cardiac dulness was thus situated rather high up; the liver also reached as high as the fifth rib in the nipple-line. Both organs were evidently pushed up by the intestines, floated upwards by the peritoneal effusion. The visible cardiac impulse was not very great. A loud harsh double murmur was heard at the mid-sternal base; or rather, it was a single murmur consisting of two parts and covering completely both sounds. This murmur diminished rapidly in intensity towards the apex; where, however, both parts of it were distinctly audible. It was not heard beyond the apex. It was heard in moderate intensity at the ensiform cartilage. It was well conducted up the aorta, and into the great vessels at the root of the neck. But the murmur was heard far most loudly at the upper margin of the cardiac dulness, midway between the middle line and the left nipple. At this spot it was excessively loud, harsh, and rasping; it gave the impression of being produced very near the ear. It could even be heard by the naked ear at a distance of an inch from the surface of the chest. It diminished in intensity in all directions from this centre. Over the body of the ventricle it seemed so superficial, that it deceitfully resembled a pericardial friction-sound. The murmur was accompanied with an intense vibratile thrill. There was abundant fluttering pulsation at the root of the neck; but the parts hereabouts presented no unusual fullness. Both sides of the chest expanded indifferently; especially the left. Over both lungs there was a somewhat abundant liquid subcrepitant rhonchus. The voice was weak; the cough-voice a little metallic; and, both in its ineffectiveness and in this slight metallic quality, suggestive of mediastinal