

Contributions

ON THE

PHYSIOLOGY AND THERAPEUTICS
OF FOOD.

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No. I.

INTRODUCTORY REMARKS ON THE DYNAMIC RELATIONS
OF FOOD.

THE discoveries and inductions of the present age have thrown new light on the physiology of food.

Around us we have to deal with Matter and Force: the one a substantive entity; the other recognisable only as a principle of action. It has long been known that, as cognisable in our own era, matter can be neither created nor destroyed. It may be variously combined and modified; but it remains the same in essence and unaltered in amount. Force also has, more recently, been recognised as similarly conditioned; and in order that the bearings of food in relation to this principle may be understood, some preliminary considerations explanatory of the views now entertained regarding it are necessary.

First, then, we may take it as accepted that, like matter under present circumstances, force can be neither created nor destroyed. "*Ex nihilo nihil fit*," and "*Nihil fit ad nihilum*," are axioms received by the mind as incontestable. If we except the inconsiderable accession derived from the occasional descent of a meteoric body, the earth's matter remains fixed in amount. It is otherwise, however, with respect to force. Under the form of heat and light, force is constantly being transmitted to us from the sun; and it is from the force thus derived that, in a manner to be explained further on, life on earth originates and is sustained.

Under the title of "*Correlation of Physical Forces*," Grove demonstrated that one kind of force was capable of producing another. His views were first made known at a lecture delivered at the London Institution in 1842. The word "*correlation*" he employed as meaning "*reciprocal production*—in other words, that any force capable of producing another may in its turn be produced by it." The position sought to be established was that heat, light, electricity, magnetism, chemical affinity, and motion, are all correlative, or are reciprocally interdependent. As a force, either might produce the others; from which it flows as an incontestable inference that a force cannot originate otherwise than by generation from some antecedent force or forces.

Just at this time the same field was being investigated by other workers. While Grove was asserting that the great problem awaiting solution in regard to the correlation of physical forces was the establishment of their equivalent of power, or their measurable relations to a given standard, Mayer, Joule, and Helmholtz were announcing the actual equivalents themselves.

Mayer, of Germany, had the priority in the publication of his researches. As a medical man he approached the subject through his interest in the solution of physiological questions. In 1842 he proclaimed, in its full comprehensiveness, the doctrine conveyed under the title "*Conservation of Force*."

Nearly at the same time Mr. Joule, of Manchester, discovered in mechanical motion the equivalent of heat. He had been led to prosecute researches in that direction with the view of ascertaining the relative value of heat and motion in relation to engineering science. He found that what sufficed to raise the temperature of a pound of water one degree Fahrenheit, would, under another mode of action, raise 772 pounds a foot high; or, putting it conversely, the fall of 772 pounds of water through one foot of height would give rise to an amount of heat sufficient to elevate the temperature of one pound to the extent of one degree Fahrenheit. Thus the mechanical work corresponding to the elevation of 772 pounds a foot high, or, what comes to the same thing, one pound 772 feet high, forms the dynamic equivalent of one degree of heat of Fahrenheit's scale.

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It is necessary to state here that the term "*force*," when used in a strict sense, is employed under a more limited acceptation now than formerly. Originally, it represented what is now distinguished as both "*force*" and "*energy*." By "*force*," in a rigid signification, is understood the power of producing energy; by "*energy*" the power of performing work. To give an illustration: powder has force, the cannon-ball energy; but to speak of the force of the cannon-ball is inexact. I may also remark that the words "*actual*" and "*potential*" are in frequent use to qualify the state in which energy is met with. By actual energy is meant energy in an active state, energy which is doing work. By potential energy, energy at rest—energy capable of doing work but not doing it. In a bent crossbow there is potential energy, energy in a state of rest but ready to become actual, or to manifest itself when the trigger is pulled. Again, actual energy is evolved from the sun. By vegetable life this is made potential in the organic compounds formed. In these organic compounds the energy is stored up in a latent condition; potential energy is reconverted into actual energy when they undergo oxidation during combustion or in their utilisation in the animal economy.

The doctrine of conservation of energy implies that energy is as indestructible as matter; that a fixed amount exists in the universe; and that, however variously it may be modified, transferred, or transformed,—in spite of all the changes of which it may be the subject throughout the realm of nature,—it cannot be created or annihilated, increased or diminished. The doctrine further implies that the different forms of energy have their definite reciprocal equivalents; that so much chemical energy, for instance, will produce so much heat, which is the representative of so much motive power, and so on. The ascertained equivalents of heat and motive power have been already given.

Accepted as applicable to the physical forces, the doctrine of conservation next began to be applied to living nature. Grove in his "*Correlation of Physical Forces*" suggested (second edition, p. 89) that the same principles and mode of reasoning adopted in his essay might answer equally for the organic as for the inorganic world; and that muscular force, animal and vegetable heat &c., might, and one day would, be shown to possess similar definite correlations. He proceeds no further, however; but only remarks that he purposely avoids a subject not pertaining to his own field of science.

At this time the general belief prevailed that the processes going on in the living body were determined by "*vitality*," or the "*vital principle*." The physical forces, it was supposed, were overruled in the living body by the vital principle. Without discussing whether we are to admit or deny this principle as a distinct operating force—a question which has been handled by some of the leading men of science of the day,—we must, I think, concede, as a matter of experience, that in the living organism there are influences in play which have no existence in the dead matter around. Matter which has been impressed with life can produce effects which dead matter cannot. This does not conflict with the extension of the law of conservation of energy to living nature. The effects produced may have their origin in the physical forces—the living matter forming the medium through which they operate. With artificial contrivances force may be made to produce various effects, according to the nature of the instrument employed. With the same force in operation different kinds of work are performed, according to the character of the machine set in motion. Between the two—living matter and a machine—there exists an analogy which admits of being followed still further. It is only when in a certain state that matter is capable of forming the medium for the exercise of force in the production of living operations. Modify this state, and though there may be the same matter to deal with, yet it is no longer capable of fulfilling the same office it before performed. So in the case of an ordinary machine: it must possess a particular construction before it can form the medium for the operation of force. Disarrange this construction, and, although the matter remains unchanged, the application of force is quite without its proper effect. Thus a disarranged machine may be compared with living matter devitalised. In both the capacity of being set in operation by force has existed, and in both that capacity has been lost. Further, it may be said that a machine in working order, but un-

operated on by force—that is, in a state of rest,—is like matter possessing vitality, but in a dormant state. Both are ready to move directly the proper force is supplied.

Applying the law of the conservation of energy to living nature, the forms of force which we observe in operation are in the first instance derived from the sun. When a weight is lifted by the hand, to go to the sun for the muscular force employed in the act seems a long journey. Yet the doctrine of the conservation of energy justifies, as I will proceed to show, the conclusion that its origin is there.

In the first place, the force evolved in muscular action has its source in the material which has been supplied to the body in the form of food. Now all food comes primarily from the vegetable kingdom, and vegetable products are built up through the agency of the sun's rays. It may be said that the energy contained in these rays, which has been employed in producing the compound, is fixed or rendered latent within it. When a crossbow is bent, the force derived from the muscular action employed in bending it is stored up, ready to be again liberated when the trigger is pulled—no matter whether this be at once or a hundred years hence; and the force given to the arrow when it is launched is neither more nor less than that which has sprung from the muscular action employed in bending the bow. The same with vegetable products. Their formation is coincident with the disengagement of oxygen from oxidised principles and the development of combustible compounds. To effect this disengagement the operation of force is required. Now the force so employed has its source in the heat and light evolved from the sun, and that which is used for the purpose may be said to become fixed and to exist in a latent condition—to exist stored up in the product, ready to be again liberated when exposed to conditions of oxidation. Thus may these vegetable products be compared to a bent crossbow, containing as they do a store of latent force which may for an indefinite period remain as such, or may be liberated soon after it has been fixed. Whenever liberated, it is no more nor less than the equivalent of the force which has been used in the formation of the product. Our coal-fields represent a vast magazine of force drawn, ages ago, from the sun's rays, and capable at any moment of being set free by the occurrence of oxidation.

Vegetable products, then, may be regarded as containing a store of force accumulated from the mighty supply continually emitted with the sun's rays; and, upon the principle of the indestructibility of force, that which has been employed in unlocking the elements in the combinations from which vegetable products are built up, and forming the new compound, is contained in the latter in a latent state. Now, as above stated, animals either directly or indirectly subsist upon these vegetable products and are supplied, in them, with accumulated force. By oxidation the force is set free in an active state under some form of manifestation or other. It matters not in what way, whether rapidly or slowly, or under what circumstances, whether inside the living system or outside the living system, the oxidation occurs. The result is the same, as far as the amount of the force liberated is concerned, it being implied in the doctrine of conservation of energy that it should constitute the equivalent of the solar force originally drawn upon. This is presuming complete oxidation to occur; but in the processes of animal life, although carbonic acid and water are formed, and these constitute fully oxidised products, yet urea is also a final product, and this, being an incompletely oxidised compound, contains a certain amount of latent or unutilised force.

Thus it is that the various forms of force manifested in the actions of animal life trace their origin to that emitted from the sun. Plants are media for fixing solar force—for converting actual into latent or potential energy. Animals reconvert latent into various forms of actual force. Thus, in the various forms of actual force liberated by the actions of animal life, we have the equivalent of the force which has been fixed by plants from the sun. As there is a revolution of matter, so is there a revolution of force in the universe within and around us.

In the liberation of actual force a complete analogy may be traced between the animal system and a steam engine. Both are media for the conversion of latent into actual force. In the animal system, combustible material is supplied under the form of the various kinds of food, and oxygen is taken in by the process of respiration. From the chemical energy due to the combination of these, force is

liberated in an active state; and, besides manifesting itself as heat, and in other ways peculiar to the animal system, is capable of accomplishing mechanical work. The steam-engine is fed with combustible material under the form of coal, which differs from our food only in representing the result of the vegetative activity of a former, instead of that of the vegetative activity of the present, epoch. Air is also supplied, and from the combination which occurs between its oxygen and the elements of the combustible material, heat is produced, which in part is dissipated as such, but in part is applied to the production of mechanical work. According to Helmholtz, the animal economy, in respect of its capacity to turn force to account in the accomplishment of mechanical work, is a more perfect instrument than the steam-engine. His calculations lead him to conclude that whilst in the best steam-engine only one-tenth of the force liberated by the combustion of its fuel is realisable as mechanical work, the rest escaping as heat, the human body is capable of turning one-fifth of the power of its food into the equivalent of work. On the other hand there is this to be remarked, that the fuel of a steam-engine is a far less expensive article than the food of an animal being.

The animal body, then, may be regarded as holding an analogous position to a machine, in which a transmutation of chemical into other forms of force is taking place. Food on the one hand, and air on the other, are the factors concerned in the chemical action that occurs. It is through the interplay of changes between food and air that the manifestations of animal life, consisting of heat-production, muscular contraction, nervous (including mental) action, and nutritive or formative, secretory and assimilative action, arise. The egesta, or substances dismissed from the system, are metamorphosed products of the ingesta, or substances entering the system. The elements are the same, and also their quantity, in the two cases; but their forms of combination, and, with them, their relations to force, are different. The force expended in the building up of the organic compounds belonging to food is again evolved as these compounds descend, through the action of oxygen, into simple combinations; and in the force evolved we have the simple representative of the active manifestations of animal life. If the products discharged from the system were fully oxidised principles, the force developed in the body would equal that contained in a latent condition in the food. Such, however, is not completely the case, and some latent force remains in the egesta. The changes may be formulated thus: the latent or potential force of ingesta = force developed in the body + the force escaping with the egesta. In other words, the unexpended force in the egesta and the force disengaged by the operations of life, and manifested under the various forms of vital activity = the force contained in the ingesta.

What is required in food, then, must consist of material susceptible of undergoing change in the system under the action of oxygen. Life implies change; and the manifestations of life are due to the interaction of food (as the primary material) and air. While in the organic kingdom a tendency to a state of rest prevails—while the closest affinities tend to become satisfied, and so establish equilibrium; in a manifestly living body rest is impossible. It is true, living organisms under certain conditions may exist in a state of rest; but then there is a suspension of vital manifestations. The state is known as one of dormant vitality, and the seed of a plant naturally remains for a while in this condition. There are also animal organisms which may exist in a similar state. Molecular rest and, with it, an absence of any show of vital activity prevail. Concurrent with the manifestation of vital action molecular change in a particular or prescribed direction occurs. The higher compounds become resolved by the agency of oxygen, the other factor of life, into simple combinations as carbonic acid, water, and urea, and with this the capacity for further service is exhausted. To maintain a continuance of vital action fresh material is required; and hence the demand for food. But food by itself, although in association with oxygen, does not suffice for the accomplishment of what is required. It is necessary that it come within the sphere of the influence of living matter, and this it is which determines the particular line of direction which the changes assume, and in which originate the phenomena of life.