

THE ANIMAL
AS A
MACHINE AND A PRIME MOTOR.

I.

INTRODUCTION.

ENERGY AND ITS TRANSFORMATIONS.

ENERGETICS AND ITS LAWS.

1. Energy and its Transformations are the source and the method of all useful work, as of all natural phenomena involving motions of masses or of molecules of whatever kind. All "prime movers" are machines by means of which man diverts energy from natural channels and compels it to do his own work. The water-wheels and windmills simply transfer the energy of the moving fluid to the machinery of the transmission through which it performs useful work; the heat-engines and electric machinery transfer energy, and at the same time convert it from the thermal or the electrical to the dynamic form for application, and thermodynamic or electro-dynamic apparatus thus have two distinct functions.

In some instances we may observe a succession of

transformations of energy, as where a steam boiler transforms, and stores for transmission to the engine, energy of chemical affinity; the engine, in turn, transforming it into mechanical energy and transmitting it to a dynamo-electric machine, where it is again transformed, changing into the electrical current, to be sent perhaps miles away to an electro-dynamic machine or motor, where its retransformation into mechanical power occurs, and it is set at the work of driving a mill or other collection of mechanisms. A telephone system illustrates in another way similar transformations and retransformations of mechanical and electric energy, and Mr. Hammer has thus produced a system involving many transformations and including a circuit of a hundred miles.

Nature herself has in these cases usually already performed some such transformations of energy in the reduction of that so collected and applied to the form in which the mechanic and the engineer finds it ready to his hand. The water has been raised from the lakes and the sea, and distributed by the clouds to the elevated sources from which it flows downward in the streams; the winds are the result of differences of temperature and the action of heat energy; the heat of combustion is the representative of an earlier form of energy in which the heat of the sun and of the still cooling earth, and the formation of the coal deposits in early geological periods, played a part. In a general way it has come to be seen that every display of energy, like every new form of matter, is the result of change in some antecedent form, and that neither matter nor energy can be destroyed. This has been admitted from the time of Lavoisier, so far as it affects matter; it has

been admitted as applicable to physical energy since the doctrines of the correlation of forces and the persistence of energy became accepted by men of science; and we are gradually progressing towards the establishment of a law of persistence of all existence, whether of matter, of force and energy, or of organic vitality, and perhaps even to its extension until it includes intellectual and soul life.

We see that in the beginning there entered upon an existence of indefinite duration a great universe of matter endowed with its characterizing attributes—the forces. These forces, acting upon a definite quantity of matter with definite intensity, give origin to a fixed amount of actual energy, and become capable of producing another fixed quantity of what is now potential energy. Energy thus brought into existence remains constant in total amount as the quantity of created matter remains constant.

The action of these forces upon this matter has given rise to every phenomenon which has come, or which can come, within the range of scientific inquiry.

2. Forces are Classified, according to their methods of affecting matter, into three great classes:

(1) Those forces with which we are able to make ourselves so readily and thoroughly familiar that we find no difficulty in assigning to each of them its proper place in the scheme of scientific systematization, and which we have found it comparatively easy to distinguish by their peculiar and readily observed effects. These include the familiar physical forces, as gravitation, electrical, chemical, and mechanical forces.

(2) The vital forces—those which are preservative of all life, which produce and promote the growth of or-

ganisms having life, and which are less easily understood, more difficult to study, and far less subject to the modifying power of human action, than are those of the first described class.

(3) The forces of the soul and of the intellect—those most wonderful and most mysterious of all known forms of force—forces of the nature of which we know nothing, and of the effects of which, actual and possible, we have the least comprehension.

By the study of the universe as it now exists, philosophers are led to perceive that its present state is such as would have resulted had the various forms of matter with which we are surrounded, and of which we ourselves are corporeally formed, and had other existences which we suppose to form a part of our universe been, at the beginning, so distributed and so placed in reference to the several kinds of forces that the former, acted freely upon by the latter, should, by a continuity of never-ceasing, ever-progressing change, take those infinite variations of growth, and all that inconceivable variety of shapes, that have supposed to have been, by the process called “evolution,” brought into the visible universe.*

Studying the accessible universe, as far as we are permitted, in greater detail, we find that each of the various kinds of forces set at work to modify the position and character of matter has a special part to play, a peculiar work to do; we find that the first class has a

* As early as 1854 Helmholtz showed that the condensation of an infinitely diffused nebulous mass of matter, to form the stellar systems of the universe, by gravitation, was sufficient to furnish all existing heat-energy, and a source of all that mechanical and other transformed energy known now to exist.

sphere of operation which is fully within the reach of our senses; that the second class of forces is also, to a certain extent, familiar to us through a knowledge of their effects: but the last of these several classes of forces existing in nature is, as yet, quite beyond our ken.

Studying these forms of manifestation of force which are divided between the first two classes, we perceive a distinction which is as well defined as is the line separating the two classes of phenomena to which they give rise.

(1) The *physical forces*—and it is intended here to include the mechanical and chemical, as well as the forces which are usually alone treated of in works on physics—are capable of being observed, of being distinguished by certain readily defined qualities, and of being accurately measured quantitatively. The conditions which lead to their active display are capable of being exactly ascertained, and the precise results of their operations under any given set of conditions may usually be accurately predicted. These conditions are subject to certain definite modifications by the power of man, and the changes of effect which will result from such changes of condition may be predicted. The effects which nature produces in certain cases by the action of these forces may be modified by man without entirely defeating the original tendency to bring about a certain change of mode of action of existing energy. These forces, acting alone, never give rise to the more intricate forms seen in nature. Their highest product in the whole morphological range is a crystal of more or less perfect shape, but of a form which is always of some simple geometrical class. These forces do not

exhibit the play of definitely directed energy tending to effect a perfectly well defined, though remote, result. Their effects are the accidental and the incidental, so far as the more wonderful and most intricate of the operations of nature are concerned.

(2) The *vital forces*, on the other hand, effect operations which human power can only touch to impede or to destroy. They have for their mission the creation of strangely complicated and curiously organized structures, in which are stored certain definite amounts of energy, and which are given a power of acquiring and of applying extraneous energy, in probably also definite amount, to the accomplishment of certain tasks. Man may modify their operation and may produce some change in the phenomena which they are appointed to bring about; but it is only by deranging their action. He can mar their work, but cannot directly aid them. That store of vital energy which was created in the infinite past, and which is now passing through one after another of the forms of life, new and old, which are constantly coming into the field of our cognizance, and as constantly disappearing from view, is continually developing organisms of every grade from the simple life-seed, if such exist—from the basic protoplasm—to the human ruler of them all.

Of these two sets of forces, the one is blind and aimless, unintelligent as to the direction of its efforts, indifferent as to its results, and is governed by laws which, under all known conditions, are as simple as they are invariable. The other set appears to act at all times upon a definite, far-reaching plan, and these forces set themselves intelligently about the production of the most elegant and intricate of designs, and the

