GRANT ALLEN

FORCE AND ENERGY; A THEORY OF DYNAMICS

Grant Allen

Force and Energy; A Theory of Dynamics

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Contact: DigiCat@okpublishing.info

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CHAPTER I.

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POWER.

A POWER is that which initiates or terminates, accelerates or retards, motion in one or more particles of ponderable matter or of the ethereal medium.

Power, as here understood, is thus the widest of all possible dynamical conceptions. It cannot be defined by genus and differentia, because it is itself the *summum genus* of dynamical science. Accordingly, it will be observed that no attempt is made above to assign it to any higher class, such as *things*, *entities*, or *concepts*. Nothing would be gained, for example, by saying that a power is the *tendency* to initiate or terminate motion: it is best described by the indefinite statement given at the head of this chapter. It is simply *that which produces or destroys, increases or lessens*, motion in any particle or particles of any substance whatsoever cognisable by man.

Powers are of two sorts, Forces and Energies, the differences between which will be fully set forth in subsequent chapters. Meanwhile, as a help to the provisional comprehension of the nature of Power, which can scarcely be grasped at first in the abstract terms of our formal definition, it may be mentioned that amongst the varieties of Power are such Forces as Gravitation, Cohesion, and Chemical Affinity, besides such Energies as Heat, Electricity, and Light. These expressions are here employed in their popular sense, merely as guides to the sort of

concept provisionally set forward for the term Power, until the subsequent investigation has rendered possible a more rational and comprehensive notion in the mind of the reader.

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FORCE.

A FORCE is a Power which initiates or accelerates aggregative motion, while it resists or retards separative motion, in two or more particles of ponderable matter (and possibly also of the ethereal medium).

All particles possess the Power of attracting one another —in other words, of setting up mutually aggregative motion —unless prevented by some other Power of an opposite nature. Thus a body suspended freely in the air is attracted towards the earth by the Force (or aggregative Power) known as Gravitation. A piece of sugar, held close over a cup of tea, attracts into itself the water of the tea-cup, by the Force (or aggregative Power) known as Capillarity. A spoon left in tea grounds or a foot planted on the moist sand similarly attracts the neighbouring drops. A piece of iron or coal exposed to free oxygen (each at a certain fixed temperature) attracts the particles of oxygen by the Force known as Chemical Affinity. In every case there must be an absence of counteracting Energies (or separative Powers) sufficient to prevent the union of the particles, as will be shown hereafter: but for the present it will be enough to notice that every particle attracts every other particle in some one of various ways, unless prevented by other Powers.[1]

Not only, however, do all particles thus attract one another, but they also resist all attempts to separate them

from one another. A weight suspended in the air falls to the ground: but it also resists any attempt to remove it from the ground, which can only be done by the employment of a proportionate Energy (or separative Power). The water which the sugar has absorbed can only be drawn from it by the Energy of suction. The oxygen with which the iron has united can only be driven off by the Energy of heat: while the carbonic anhydride and water which resulted from the burning of the coal yield only as a rule to the separative Energy of light or electricity. In every case the Force which brought two or more particles together in the first instance keeps them united ever after, and must be neutralised by an equal Power of an opposite description before they can be disjoined.

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ENERGY.

An Energy is a power which resists or retards aggregative motion, while it initiates or accelerates separative motion, in two or more particles of ponderable matter or of the ethereal medium.

All particles, or aggregates of particles, not actually in contact with one another in stable equilibrium at the absolute zero of temperature, are kept apart by an Energy or separative Power of some sort, which prevents them from aggregating as they would otherwise do under the influence of the Forces inherent in them. Thus the moon is prevented from falling upon the earth, and the earth from falling into the sun, by the Energy of their respective orbital motions. A ball shot from a cannon into the air is prevented from falling by the Energy of its upward flight. A red-hot poker has its particles kept apart by the Energy of heat. In every case, so soon as the Energy is dissipated (as hereafter explained) the ball yields to the aggregative Power of Gravitation, and the poker contracts to its ordinary dimensions; while there is no reason to doubt that under similar circumstances the moon and the earth will aggregate with the sun. The particles of water are kept in the liquid state by the Energy known as *latent heat*,[2] and so are those of steam: when the 'latent heat' is dissipated, the steam condenses and the water freezes. There are many apparent exceptions; but they will be considered at later stages of the argument. For the

present, the reader must be content to understand the word *Energy* (when used in this treatise) only in the sense here given to it of a Power which resists or retards aggregation.

Energies also initiate separative motions. Thus, a cannon ball is raised by Energy to a distance from the main mass of the earth which usually holds it bound by Gravitation on its surface. A poker placed in the fire has its particles separated from one another by the Energy of Heat. When ice melts or water is converted into steam, the same Energy similarly severs their particles from one another and places them in positions of relative freedom. In the electrolysis of water the Energy of the galvanic current tears asunder the atoms of hydrogen and oxygen from their close union in the compound molecule. In short, wherever we see masses or particles in the act of separating from one another, we know that the separation is due to some Energy.

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THE SPECIES OF FORCE.

Forces may be most conveniently divided according to the nature of the particles or bodies in which they initiate and accelerate aggregative motion or resist and retard separative motion. Of these, there are four principal kinds known to us or conjectured by us. The first kind is the Mass or visible aggregation of particles, which admits of mechanical separation into minor masses. The second kind is the Molecule, or ultimate mechanical unit, which does not admit of subdivision, except by resolution into its chemical components. The third kind is the Atom, or ultimate chemical unit, which does not admit of subdivision by any known means, though it may perhaps be resoluble hereafter into some simpler and more primitive units. The fourth is the Electrical Unit,[3] whose nature is very inadequately known to us, but which must be considered for our present purpose as in some way the analogue of the others, though we have no sufficient warrant for giving it any material properties.

The Force which aggregates Masses and resists the separation of Masses is known as Gravitation. When any two Masses are left free to act upon one another without the counteracting influence of an Energy, they aggregate in obedience to this Power. When the cannon ball falls upon the earth, it is Gravitation which draws them together. When an aërolite comes within the circle of the earth’s attraction,

it is Gravitation which makes them leap towards one another. If the moon were to lose its orbital Energy, Gravitation would pull it to the earth; and if our planet in her turn were suddenly checked in her course, Gravitation would cause her to plunge into the sun, while the sun in return would make a slight bound to meet her. Again, when any two Masses are in a state of aggregation, the Force of Gravitation resists any attempt to sever them. If the cannon ball lies upon the ground, it cannot be raised without an expenditure of Energy, and the amount of the Energy required to lift it to a given height (or distance from the surface of the earth) is the measure of the resistance offered by Gravitation. Similarly, when the Masses are not in actual contact owing to the existence of an Energy which keeps them apart, as in the case of the earth and her satellite, or the sun and the planets, Gravitation resists any attempt to sever them beyond their actual distances. It would be impossible to remove the moon a hundred miles from the earth, or the earth a hundred miles from the sun, except by the employment of an adequate Energy; and, as in the simpler case, the amount of Energy required would be the measure of resistance offered by Gravitation.

The Force which aggregates Molecules and resists the separation of Molecules is known as Cohesion. When any two Molecules are left free to act upon one another without the counteracting influence of an Energy, they aggregate in obedience to this Power. But the cases are much more difficult to illustrate than those of gravitation, because while masses attract one another powerfully at very conspicuous distances, Molecules (practically speaking) only attract one