Chapter XIII.

Miscellaneous Examples Of The Explanation Of Laws Of Nature.

§ 1. The most striking example which the history of science presents, of the explanation of laws of causation and other uniformities of sequence among special phenomena, by resolving them into laws of greater simplicity and generality, is the great Newtonian generalization; respecting which typical instance, so much having already been said, it is sufficient to call attention to the great number and variety of the special observed uniformities, which are in this case accounted for, either as particular cases, or as consequences, of one very simple law of universal nature. The simple fact of a tendency of every particle of matter toward every other particle, varying inversely as the square of the distance, explains the fall of bodies to the earth, the revolutions of the planets and satellites, the motions (so far as known) of comets, and all the various regularities which have been observed in these special phenomena; such as the elliptical orbits, and the variations from exact ellipses; the relation between the solar distances of the planets and the duration of their revolutions; the precession of the equinoxes; the tides, and a vast number of minor astronomical truths.

Mention has also been made in the preceding chapter of the explanation of the phenomena of magnetism from laws of electricity; the special laws of magnetic agency having been affiliated by deduction to observed laws of electric action, in which they have ever since been considered to be included as special cases. An example not so complete in itself, but even more fertile in consequences, having been the starting-point of the really scientific study of physiology, is the affiliation, commenced by Bichat, and carried on by subsequent biologists, of the properties of the bodily organs, to the elementary properties of the tissues into which they are anatomically decomposed.

Another striking instance is afforded by Dalton's generalization, commonly known as the atomic theory. It had been known from the very commencement of accurate chemical observation, that any two bodies combine chemically with one another in only a certain number of proportions; but those proportions were in each case expressed by a percentage--so many parts (by weight) of each ingredient, in 100 of the compound (say 35 and a fraction of one element, 64 and a fraction of the other); in which mode of statement no relation was perceived between the proportion in which a given element combines with one substance, and that in which it combines with others. The great step made by Dalton consisted in perceiving that a unit of weight might be established for each substance, such that by supposing the substance to enter into all its combinations in the ratio either of that unit, or of some low multiple of that unit, all the different proportions, previously expressed by percentages, were found to result. Thus 1 being assumed as the unit of hydrogen, if 8 were then taken as that of oxygen, the combination of one unit of hydrogen with one unit of oxygen would produce the exact proportion of weight between the two substances which is known to exist in water; the combination of one unit of hydrogen with two units of oxygen would produce the proportion which exists in the other compound of the same two elements, called peroxide of hydrogen; and the combinations of hydrogen and of oxygen with all other substances, would correspond with the supposition that those elements enter into combination by single units, or twos, or threes, of the numbers assigned to them, 1 and 8, and the other substances by ones or twos or threes of other determinate numbers proper to each. The result is that a table of the equivalent numbers, or, as they are called, atomic weights, of all the elementary substances, comprises in itself, and scientifically explains, all the proportions in which any substance, elementary or compound, is found capable of entering into chemical combination with any other substance whatever.

§ 2. Some interesting cases of the explanation of old uniformities by newly ascertained laws are afforded by the researches of Professor Graham. That eminent chemist was the first who drew attention to the distinction which may be made of all substances into two classes, termed by him crystalloids and colloids; or rather, of all states of matter into the crystalloid and the colloidal states, for many substances are capable of existing in either. When in the colloidal state, their sensible properties are very different from those of the same substance when crystallized, or when in a state easily susceptible of crystallization. Colloid substances pass with extreme difficulty and slowness into the crystalline state, and are extremely inert in all the ordinary chemical relations. Substances in the colloid state are almost always, when combined with water, more or less viscous or gelatinous. The most prominent examples of the state are certain animal and vegetable substances, particularly gelatine, albumen, starch, the gums, caramel, tannin, and some others. Among substances not of organic origin, the most notable instances are hydrated silicic acid, and hydrated alumina, with other metallic peroxides of the aluminous class.

Now it is found, that while colloidal substances are easily penetrated by water, and by the solutions of crystalloid substances, they are very little penetrable by one another: which enabled Professor Graham to introduce a highly effective process (termed dialysis) for separating the crystalloid substances contained in any liquid mixture, by passing them through a thin septum of colloidal matter, which does not suffer any thing colloidal to pass, or suffers it only in very minute quantity. This property of colloids enabled Mr. Graham to account for a number of special results of observation, not previously explained.

For instance, "while soluble crystalloids are always highly sapid, soluble colloids are singularly insipid," as might be expected; for, as the sentient extremities of the nerves of the palate "are probably protected by a colloidal membrane," impermeable to other colloids, a colloid, when tasted, probably never reaches those nerves. Again, "it has been observed that vegetable gum is not digested in the stomach; the coats of that organ dialyse the soluble food, absorbing crystalloids, and rejecting all colloids." One of the mysterious processes accompanying digestion, the secretion of free muriatic acid by the coats of the stomach, obtains a probable hypothetical explanation through the same law. Finally, much light is thrown upon the observed phenomena of osmose (the passage of fluids outward and inward through animal membranes) by the fact that the membranes are colloidal. In consequence, the water and saline solutions contained in the animal body pass easily and rapidly through the membranes, while the substances directly applicable to nutrition, which are mostly colloidal, are detained by them.(154)

The property which salt possesses of preserving animal substances from putrefaction is resolved by Liebig into two more general laws, the strong attraction of salt for water, and the necessity of the presence of water as a condition of putrefaction. The intermediate phenomenon which is interpolated between the remote cause and the effect, can here be not merely inferred but seen; for it is a familiar fact, that flesh upon which salt has been thrown is speedily found swimming in brine.

The second of the two factors (as they may be termed) into which the preceding law has been resolved, the necessity of water to putrefaction, itself affords an additional example of the Resolution of Laws. The law itself is proved by the Method of Difference, since flesh completely dried and kept in a dry atmosphere does not putrefy; as we see in the case of dried provisions and human bodies in very dry climates. A deductive explanation of this same law results from Liebig's speculations. The putrefaction of animal and other azotized bodies is a chemical process, by which they are gradually dissipated in a gaseous form, chiefly in that of carbonic acid and ammonia; now to convert the carbon of the animal substance into carbonic acid requires oxygen, and to convert the azote into ammonia requires hydrogen, which are the elements of water. The extreme rapidity of the putrefaction of azotized substances, compared with the gradual decay of non-azotized bodies (such as wood and the like) by the action of oxygen alone, he explains from the general law that substances are much more easily decomposed by the action of two different affinities upon two of their elements than by the action of only one.

§ 3. Among the many important properties of the nervous system which have either been first discovered or strikingly illustrated by Dr. Brown-Séquard, I select the reflex influence of the nervous system on nutrition and secretion. By reflex nervous action is meant, action which one part of the nervous system exerts over another part, without any intermediate action on the brain, and consequently without consciousness; or which, if it does pass through the brain, at least produces its effects independently of the will. There are many experiments which prove that irritation of a nerve in one part of the body may in this manner excite powerful action in another part; for example, food injected into the stomach through a divided oesophagus, nevertheless produces secretion of saliva; warm water injected into the bowels, and various other irritations of the lower intestines, have been found to excite secretion of the gastric juice, and so forth. The reality of the power being thus proved, its agency explains a great variety of apparently anomalous phenomena; of which I select the following from Dr. Brown-Séquard's *Lectures on the Nervous System*:

The production of tears by irritation of the eye, or of the mucous membrane of the nose;

The secretions of the eye and nose increased by exposure of other parts of the body to cold;

Inflammation of the eye, especially when of traumatic origin, very frequently excites a similar affection in the other eye, which may be cured by section of the intervening nerve;

Loss of sight sometimes produced by neuralgia, and has been known to be at once cured by the extirpation (for instance) of a carious tooth;

Even cataract has been produced in a healthy eye by cataract in the other eye, or by neuralgia, or by a wound of the frontal nerve;

The well-known phenomenon of a sudden stoppage of the heart's action, and consequent death, produced by irritation of some of the nervous extremities; *e.g.*, by drinking very cold water, or by a blow on the abdomen, or other sudden excitation of the abdominal sympathetic nerve, though this nerve may be irritated to any extent without stopping the heart's action, if a section be made of the communicating nerves;

The extraordinary effects produced on the internal organs by an extensive burn on the surface of the body, consisting in violent inflammation of the tissues of the abdomen, chest, or head, which, when death ensues from this kind of injury, is one of the most frequent causes of it;

Paralysis and anæsthesia of one part of the body from neuralgia in another part; and muscular atrophy from neuralgia, even when there is no paralysis;

Tetanus produced by the lesion of a nerve. Dr. Brown-Séquard thinks it highly probable that hydrophobia is a phenomenon of a similar nature;

Morbid changes in the nutrition of the brain and spinal cord, manifesting themselves by epilepsy, chorea, hysteria, and other diseases, occasioned by lesion of some of the nervous extremities in remote places, as by worms, calculi, tumors, carious bones, and in some cases even by very slight irritations of the skin.

§ 4. From the foregoing and similar instances, we may see the importance, when a law of nature previously unknown has been brought to light, or when new light has been thrown upon a known law by experiment, of examining all cases which present the conditions necessary for bringing that law into action; a process fertile in demonstrations of special laws previously unsuspected, and explanations of others already empirically known.

For instance, Faraday discovered by experiment, that voltaic electricity could be evolved from a natural magnet, provided a conducting body were set in motion at right angles to the direction of the magnet; and this he found to hold not only of small magnets, but of that great magnet, the earth. The law being thus established experimentally, that electricity is evolved, by a magnet, and a conductor moving at right angles to the direction of its poles, we may now look out for fresh instances in which these conditions meet. Wherever a conductor moves or revolves at right angles to the direction of the earth's magnetic poles, there we may expect an evolution of electricity. In the northern regions, where the polar direction is nearly perpendicular to the horizon, all horizontal motions of conductors will produce electricity; horizontal wheels, for example, made of metal; likewise all running streams will evolve a current of electricity, which will circulate round them; and the air thus charged with electricity may be one of the causes of the Aurora Borealis. In the equatorial regions, on the contrary, upright wheels placed parallel to the equator will originate a voltaic circuit, and water-falls will naturally become electric.

For a second example, it has been proved, chiefly by the researches of Professor Graham, that gases have a strong tendency to permeate animal membranes, and diffuse themselves through the spaces which such membranes inclose, notwithstanding the presence of other gases in those spaces. Proceeding from this general law, and reviewing a variety of cases in which gases lie contiguous to membranes, we are enabled to demonstrate or to explain the following more special laws: 1st. The human or animal body, when surrounded with any gas not already contained within the body, absorbs it rapidly; such, for instance, as the gases of putrefying matters: which helps to explain malaria. 2d. The carbonic acid gas of effervescing drinks, evolved in the stomach, permeates its membranes, and rapidly spreads through the system. 3d. Alcohol taken into the stomach passes into vapor, and spreads through the system with great rapidity (which, combined with the high combustibility of alcohol, or in other words its ready combination with oxygen, may perhaps help to explain the bodily warmth immediately consequent on drinking spirituous liquors). 4th. In any state of the body in which peculiar gases are formed within it, these will rapidly exhale through all parts of the body; and hence the rapidity with which, in certain states of disease, the surrounding atmosphere becomes tainted. 5th. The putrefaction of the interior parts of a carcass will proceed as rapidly as that of the exterior, from the ready passage outward of the gaseous products. 6th. The exchange of oxygen and carbonic acid in the lungs is not prevented, but rather promoted, by the intervention of the membrane of the lungs and the coats of the blood-vessels between the blood and the air. It is necessary, however, that there should be a substance in the blood with which the oxygen of the air may immediately combine; otherwise, instead of passing into the blood, it would permeate the whole organism: and it is necessary that the carbonic acid, as it is formed in the capillaries, should also find a substance in the blood with which it can combine; otherwise it would leave the body at all points, instead of being discharged through the lungs.

§ 5. The following is a deduction which confirms, by explaining, the empirical generalization, that soda powders weaken the human system. These powders, consisting of a mixture of tartaric acid with bicarbonate of soda, from which the carbonic acid is set free, must pass into the stomach as tartrate of soda. Now, neutral tartrates, citrates, and acetates of the alkalis are found, in their passage through the system, to be changed into carbonates; and to convert a tartrate into a carbonate requires an additional quantity of oxygen, the abstraction of which must lessen the oxygen destined for assimilation with the blood, on the quantity of which the vigorous action of the human system partly depends.

The instances of new theories agreeing with and explaining old empiricisms, are innumerable. All the just remarks made by experienced persons on human character and conduct, are so many special laws, which the general laws of the human mind explain and resolve. The empirical generalizations on which the operations of the arts have usually been founded, are continually justified and confirmed on the one hand, or corrected and improved on the other, by the discovery of the simpler scientific laws on which the efficacy of those operations depends. The effects of the rotation of crops, of the various manures, and other processes of improved agriculture, have been for the first time resolved in our own day into known laws of chemical and organic action, by Davy, Liebig, and others. The processes of the medical art are even now mostly empirical: their efficacy is concluded, in each instance, from a special and most precarious experimental generalization: but as science advances in discovering the simple laws of chemistry and physiology, progress is made in ascertaining the intermediate links in the series of phenomena, and the more general laws on which they depend; and thus, while the old processes are either exploded, or their efficacy, in so far as real, explained, better processes, founded on the knowledge of proximate causes, are continually suggested and brought into use.(155) Many even of the truths of geometry were generalizations from experience before they were deduced from first principles. The quadrature of the cycloid is said to have been first effected by measurement, or rather by weighing a cycloidal card, and comparing its weight with that of a piece of similar card of known dimensions.

§ 6. To the foregoing examples from physical science, let us add another from mental. The following is one of the simple laws of mind: Ideas of a pleasurable or painful character form associations more easily and strongly than other ideas, that is, they become associated after fewer repetitions, and the association is more durable. This is an experimental law, grounded on the Method of Difference. By deduction from this law, many of the more special laws which experience shows to exist among particular mental phenomena may be demonstrated and explained: the ease and rapidity, for instance, with which thoughts connected with our passions or our more cherished interests are excited, and the firm hold which the facts relating to them have on our memory; the vivid recollection we retain of minute circumstances which accompanied any object or event that deeply interested us, and of the times and places in which we have been very happy or very miserable; the horror with which we view the accidental instrument of any occurrence which shocked us, or the locality where it took place and the pleasure we derive from any memorial of past enjoyment; all these effects being proportional to the sensibility of the individual mind, and to the consequent intensity of the pain or pleasure from which the association originated. It has been suggested by the able writer of a biographical sketch of Dr. Priestley in a monthly periodical,(156) that the same elementary law of our mental constitution, suitably followed out, would explain a variety of mental phenomena previously inexplicable, and in particular some of the fundamental diversities of human character and genius. Associations being of two sorts, either between synchronous, or between successive impressions; and the influence of the law which renders associations stronger in proportion to the pleasurable or painful character of the impressions, being felt with peculiar force in the synchronous class of associations; it is remarked by the writer referred to, that in minds of strong organic sensibility synchronous associations will be likely to predominate, producing a tendency to conceive things in pictures and in the concrete, richly clothed in attributes and circumstances, a mental habit which is commonly called Imagination, and is one of the peculiarities of the painter and the poet; while persons of more moderate susceptibility to pleasure and pain will have a tendency to associate facts chiefly in the order of their succession, and such persons, if they possess mental superiority, will addict themselves to history or science rather than to creative art. This interesting speculation the author of the present work has endeavored, on another occasion, to pursue further, and to examine how far it will avail toward explaining the peculiarities of the poetical temperament.(157) It is at least an example which may serve, instead of many others, to show the extensive scope which exists for deductive investigation in the important and hitherto so imperfect Science of Mind.

§ 7. The copiousness with which the discovery and explanation of special laws of phenomena by deduction from simpler and more general ones has here been exemplified, was prompted by a desire to characterize clearly, and place in its due position of importance, the Deductive Method; which, in the present state of knowledge, is destined henceforth irrevocably to predominate in the course of scientific investigation. A revolution is peaceably and progressively effecting itself in philosophy, the reverse of that to which Bacon has attached his name. That great man changed the method of the sciences from deductive to experimental, and it is now rapidly reverting from experimental to deductive. But the deductions which Bacon abolished were from premises hastily snatched up, or arbitrarily assumed. The principles were neither established by legitimate canons of experimental inquiry, nor the results tested by that indispensable element of a rational Deductive Method, verification by specific experience. Between the primitive method of Deduction and that which I have attempted to characterize, there is all the difference which exists between the Aristotelian physics and the Newtonian theory of the heavens.

It would, however, be a mistake to expect that those great generalizations, from which the subordinate truths of the more backward sciences will probably at some future period be deduced by reasoning (as the truths of astronomy are deduced from the generalities of the Newtonian theory), will be found in all, or even in most cases, among truths now known and admitted. We may rest assured, that many of the most general laws of nature are as yet entirely unthought of; and that many others, destined hereafter to assume the same character, are known, if at all, only as laws or properties of some limited class of phenomena; just as electricity, now recognized as one of the most universal of natural agencies, was once known only as a curious property which certain substances acquired by friction, of first attracting and then repelling light bodies. If the theories of heat, cohesion, crystallization, and chemical action are destined, as there can be little doubt that they are, to become deductive, the truths which will then be regarded as the *principia* of those sciences would probably, if now announced, appear quite as novel(158) as the law of gravitation appeared to the contemporaries of Newton; possibly even more so, since Newton's law, after all, was but an extension of the law of weight--that is, of a generalization familiar from of old, and which already comprehended a not inconsiderable body of natural phenomena. The general laws of a similarly commanding character, which we still look forward to the discovery of, may not always find so much of their foundations already laid.

These general truths will doubtless make their first appearance in the character of hypotheses; not proved, nor even admitting of proof, in the first instance, but assumed as premises for the purpose of deducing from them the known laws of concrete phenomena. But this, though their initial, can not be their final state. To entitle an hypothesis to be received as one of the truths of nature, and not as a mere technical help to the human faculties, it must be capable of being tested by the canons of legitimate induction, and must actually have been submitted to that test. When this shall have been done, and done successfully, premises will have been obtained from which all the other propositions of the science will thenceforth be presented as conclusions, and the science will, by means of a new and unexpected Induction, be rendered Deductive.