CHAPTER XVI.

OF EMPIRICAL LAWS.

Sec. 1. Scientific inquirers give the name of Empirical Laws to those uniformities which observation or experiment has shown to exist, but on which they hesitate to rely in cases varying much from those which have been actually observed, for want of seeing any reason *why* such a law should exist. It is implied, therefore, in the notion of an empirical law, that it is not an ultimate law; that if true at all, its truth is capable of being, and requires to be, accounted for. It is a derivative law, the derivation of which is not yet known. To state the explanation, the *why*, of the empirical law, would be to state the laws from which it is derived; the ultimate causes on which it is contingent. And if we knew these, we should also know what are its limits; under what conditions it would cease to be fulfilled.

The periodical return of eclipses, as originally ascertained by the persevering observation of the early eastern astronomers, was an empirical law, until the general laws of the celestial motions had accounted for it. The following are empirical laws still waiting to be resolved into the simpler laws from which they are derived. The local laws of the flux and reflux of the tides in different places: the succession of certain kinds of weather to certain appearances of sky: the apparent exceptions to the almost universal truth that bodies expand by increase of temperature: the law that breeds, both animal and vegetable, are improved by crossing: that gases have a strong tendency to permeate animal membranes: that substances containing a very high proportion of nitrogen (such as hydrocyanic acid and morphia) are powerful poisons: that when different metals are fused together, the alloy is harder than the various elements: that the number of atoms of acid required to neutralize one atom of any base, is equal to the number of atoms of oxygen in the base: that the solubility of substances in one another, depends[12] (at least in some degree) on the similarity of their elements.

An empirical law, then, is an observed uniformity, presumed to be resolvable into simpler laws, but not yet resolved into them. The ascertainment of the empirical laws of phenomena often precedes by a long interval the explanation of those laws by the Deductive Method; and the verification of a deduction usually consists in the comparison of its results with empirical laws previously ascertained.

Sec. 2. From a limited number of ultimate laws of causation, there are necessarily generated a vast number of derivative uniformities, both of succession and of coexistence. Some are laws of succession or of coexistence between different effects of the same cause: of these we had examples in the last chapter. Some are laws of succession between effects and their remote causes; resolvable into the laws which connect each with the intermediate link. Thirdly, when causes act together and compound their effects, the laws of those causes generate the fundamental law of the effect, namely, that it depends on the coexistence of those causes. And, finally, the order of succession or of coexistence which obtains among effects, necessarily depends on their causes. If they are effects of the same cause, it depends on the laws of that cause; if on different causes, it depends on the laws of those causes severally, and on the circumstances which determine their coexistence. If we inquire further when and how the causes will coexist, that, again, depends on *their* causes: and we may thus trace back the phenomena higher and higher, until the different series of effects meet in a point, and the whole is shown to have depended ultimately on some common cause; or until, instead of converging to one point, they terminate in different points, and the order of the effects is proved to have arisen from the collocation of some of the primeval causes, or natural agents. For example, the order of succession and of coexistence among the heavenly motions, which is expressed by Kepler's laws, is derived from the coexistence of two primeval causes, the sun, and the original impulse or projectile force belonging to each planet.[13] Kepler's laws are resolved into the laws of these causes and the fact of their coexistence.

Derivative laws, therefore, do not depend solely on the ultimate laws into which they are resolvable: they mostly depend on those ultimate laws, and an ultimate fact; namely, the mode of coexistence of some of the component elements of the universe. The ultimate laws of causation might be the same as at present, and yet the derivative laws completely different, if the causes coexisted in different proportions, or with any

difference in those of their relations by which the effects are influenced. If, for example, the sun's attraction, and the original projectile force, had existed in some other ratio to one another than they did (and we know of no reason why this should not have been the case), the derivative laws of the heavenly motions might have been quite different from what they are. The proportions which exist happen to be such as to produce regular elliptical motions; any other proportions would have produced different ellipses, or circular, or parabolic, or hyperbolic motions, but still regular ones; because the effects of each of the agents accumulate according to an uniform law; and two regular series of quantities, when their corresponding terms are added, must produce a regular series of some sort, whatever the quantities themselves are.

Sec. 3. Now this last-mentioned element in the resolution of a derivative law, the element which is not a law of causation, but a collocation of causes, cannot itself be reduced to any law. There is (as formerly remarked[14]) no uniformity, no *norma*, principle, or rule, perceivable in the distribution of the primeval natural agents through the universe. The different substances composing the earth, the powers that pervade the universe, stand in no constant relation to one another. One substance is more abundant than others, one power acts through a larger extent of space than others, without any pervading analogy that we can discover. We not only do not know of any reason why the sun's attraction and the force in the direction of the tangent coexist in the exact proportion they do, but we can trace no coincidence between it and the proportions in which any other elementary powers in the universe are intermingled. The utmost disorder is apparent in the combination of the causes; which is consistent with the most regular order in their effects; for when each agent carries on its own operations according to an uniform law, even the most capricious combination of agencies will generate a regularity of some sort; as we see in the kaleidoscope, where any casual arrangement of coloured bits of glass produces by the laws of reflection a beautiful regularity in the effect.

Sec. 4. In the above considerations lies the justification of the limited degree of reliance which scientific inquirers are accustomed to place in empirical laws.

A derivative law which results wholly from the operation of some one cause, will be as universally true as the laws of the cause itself; that is, it will always be true except where some one of those effects of the cause, on which the derivative law depends, is defeated by a counteracting cause. But when the derivative law results not from different effects of one cause, but from effects of several causes, we cannot be certain that it will be true under any variation in the mode of coexistence of those causes, or of the primitive natural agents on which the causes ultimately depend. The proposition that coal beds rest on certain descriptions of strata exclusively, though true on the earth so far as our observation has reached, cannot be extended to the moon or the other planets, supposing coal to exist there; because we cannot be assured that the original constitution of any other planet was such as to produce the different depositions in the same order as in our globe. The derivative law in this case depends not solely on laws, but on a collocation; and collocations cannot be reduced to any law.

Now it is the very nature of a derivative law which has not yet been resolved into its elements, in other words, an empirical law, that we do not know whether it results from the different effects of one cause, or from effects of different causes. We cannot tell whether it depends wholly on laws, or partly on laws and partly on a collocation. If it depends on a collocation, it will be true in all the cases in which that particular collocation exists. But, since we are entirely ignorant, in case of its depending on a collocation, what the collocation is, we are not safe in extending the law beyond the limits of time and place in which we have actual experience of its truth. Since within those limits the law has always been found true, we have evidence that the collocations, whatever they are, on which it depends, do really exist within those limits. But, knowing of no rule or principle to which the collocations themselves conform, we cannot conclude that because a collocation is proved to exist within certain limits of place or time, it will exist beyond those limits. Empirical laws, therefore, can only be received as true within the limits of time and place in which they have been found true by observation: and not merely the limits of time and place, but of time, place, and circumstance: for since it is the very meaning of an empirical law that we do not know the ultimate laws of causation on which it is dependent, we cannot foresee, without actual trial, in what manner or to what extent the introduction of any

new circumstance may affect it.

Sec. 5. But how are we to know that an uniformity, ascertained by experience, is only an empirical law? Since, by the supposition, we have not been able to resolve it into any other laws, how do we know that it is not an ultimate law of causation?

I answer, that no generalization amounts to more than an empirical law when the only proof on which it rests is that of the Method of Agreement. For it has been seen that by that method alone we never can arrive at causes. The utmost that the Method of Agreement can do is, to ascertain the whole of the circumstances common to all cases in which a phenomenon is produced: and this aggregate includes not only the cause of the phenomenon, but all phenomena with which it is connected by any derivative uniformity, whether as being collateral effects of the same cause, or effects of any other cause which, in all the instances we have been able to observe, coexisted with it. The method affords no means of determining which of these uniformities are laws of causation, and which are merely derivative laws, resulting from those laws of causation and from the collocation of the causes. None of them, therefore, can be received in any other character than that of derivative laws, the derivation of which has not been traced; in other words, empirical laws: in which light, all results obtained by the Method of Agreement (and therefore almost all truths obtained by simple observation without experiment) must be considered, until either confirmed by the Method of Difference, or explained deductively, in other words accounted for *a priori*.

These empirical laws may be of greater or less authority, according as there is reason to presume that they are resolvable into laws only, or into laws and collocations together. The sequences which we observe in the production and subsequent life of an animal or a vegetable, resting on the Method of Agreement only, are mere empirical laws; but though the antecedents in those sequences may not be the causes of the consequents, both the one and the other are doubtless, in the main, successive stages of a progressive effect originating in a common cause, and therefore independent of collocations. The uniformities, on the other hand, in the order of superposition of strata on the earth, are empirical laws of a much weaker kind, since they not only are not laws of causation, but there is no reason to believe that they depend on any common cause: all appearances are in favour of their depending on the particular collocation of natural agents which at some time or other existed on our globe, and from which no inference can be drawn as to the collocation which exists or has existed in any other portion of the universe.

Sec. 6. Our definition of an empirical law including not only those uniformities which are not known to be laws of causation, but also those which are, provided there be reason to presume that they are not ultimate laws; this is the proper place to consider by what signs we may judge that even if an observed uniformity be a law of causation, it is not an ultimate but a derivative law.

The first sign is, if between the antecedent *a* and the consequent *b* there be evidence of some intermediate link; some phenomenon of which we can surmise the existence, though from the imperfection of our senses or of our instruments we are unable to ascertain its precise nature and laws. If there be such a phenomenon (which may be denoted by the letter *x*), it follows that even if *a* be the cause of *b*, it is but the remote cause, and that the law, *a* causes *b*, is resolvable into at least two laws, *a* causes *x*, and *x* causes *b*. This is a very frequent case, since the operations of nature mostly take place on so minute a scale, that many of the successive steps are either imperceptible, or very indistinctly perceived.

Take, for example, the laws of the chemical composition of substances; as that hydrogen and oxygen being combined, water is produced. All we see of the process is, that the two gases being mixed in certain proportions, and heat or electricity being applied, an explosion takes place, the gases disappear, and water remains. There is no doubt about the law, or about its being a law of causation. But between the antecedent (the gases in a state of mechanical mixture, heated or electrified), and the consequent (the production of water), there must be an intermediate process which we do not see. For if we take any portion whatever of the water, and subject it to analysis, we find that it always contains hydrogen and oxygen; nay, the very same

proportions of them, namely, two thirds, in volume, of hydrogen, and one third oxygen. This is true of a single drop; it is true of the minutest portion which our instruments are capable of appreciating. Since, then, the smallest perceptible portion of the water contains both those substances, portions of hydrogen and oxygen smaller than the smallest perceptible must have come together in every such minute portion of space; must have come closer together than when the gases were in a state of mechanical mixture, since (to mention no other reasons) the water occupies far less space than the gases. Now, as we cannot see this contact or close approach of the minute particles, we cannot observe with what circumstances it is attended, or according to what laws it produces its effects. The production of water, that is, of the sensible phenomena which characterize the compound, may be a very remote effect of those laws. There may be innumerable intervening links; and we are sure that there must be some. Having full proof that corpuscular action of some kind takes place previous to any of the great transformations in the sensible properties of substances, we can have no doubt that the laws of chemical action, as at present known, are not ultimate but derivative laws; however ignorant we may be, and even though we should for ever remain ignorant, of the nature of the laws of corpuscular action from which they are derived.

In like manner, all the processes of vegetative life, whether in the vegetable properly so called or in the animal body, are corpuscular processes. Nutrition is the addition of particles to one another, sometimes merely replacing other particles separated and excreted, sometimes occasioning an increase of bulk or weight, so gradual, that only after a long continuance does it become perceptible. Various organs, by means of peculiar vessels, secrete from the blood, fluids, the component particles of which must have been in the blood, but which differ from it most widely both in mechanical properties and in chemical composition. Here, then, are abundance of unknown links to be filled up; and there can be no doubt that the laws of the phenomena of vegetative or organic life are derivative laws, dependent on properties of the corpuscles, and of those elementary tissues which are comparatively simple combinations of corpuscles.

The first sign, then, from which a law of causation, though hitherto unresolved, may be inferred to be a derivative law, is any indication of the existence of an intermediate link or links between the antecedent and the consequent. The second is, when the antecedent is an extremely complex phenomenon, and its effects therefore, probably, in part at least, compounded of the effects of its different elements; since we know that the case in which the effect of the whole is not made up of the effects of its parts, is exceptional, the Composition of Causes being by far the more ordinary case.

We will illustrate this by two examples, in one of which the antecedent is the sum of many homogeneous, in the other of heterogeneous, parts. The weight of a body is made up of the weights of its minute particles: a truth which astronomers express in its most general terms, when they say that bodies, at equal distances, gravitate to one another in proportion to their quantity of matter. All true propositions, therefore, which can be made concerning gravity, are derivative laws; the ultimate law into which they are all resolvable being, that every particle of matter attracts every other. As our second example, we may take any of the sequences observed in meteorology: for instance, a diminution of the pressure of the atmosphere (indicated by a fall of the barometer) is followed by rain. The antecedent is here a complex phenomenon, made up of heterogeneous elements; the column of the atmosphere over any particular place consisting of two parts, a column of air, and a column of aqueous vapour mixed with it; and the change in the two together manifested by a fall of the barometer, and followed by rain, must be either a change in one of these, or in the other, or in both. We might, then, even in the absence of any other evidence, form a reasonable presumption, from the invariable presence of both these elements in the antecedent, that the sequence is probably not an ultimate law, but a result of the laws of the two different agents; a presumption only to be destroyed when we had made ourselves so well acquainted with the laws of both, as to be able to affirm that those laws could not by themselves produce the observed result.

There are but few known cases of succession from very complex antecedents, which have not either been actually accounted for from simpler laws, or inferred with great probability (from the ascertained existence of intermediate links of causation not yet understood) to be capable of being so accounted for. It is, therefore,

highly probable that all sequences from complex antecedents are thus resolvable, and that ultimate laws are in all cases comparatively simple. If there were not the other reasons already mentioned for believing that the laws of organized nature are resolvable into simpler laws, it would be almost a sufficient reason that the antecedents in most of the sequences are so very complex.

Sec. 7. In the preceding discussion we have recognised two kinds of empirical laws: those known to be laws of causation, but presumed to be resolvable into simpler laws; and those not known to be laws of causation at all. Both these kinds of laws agree in the demand which they make for being explained by deduction, and agree in being the appropriate means of verifying such deduction, since they represent the experience with which the result of the deduction must be compared. They agree, further, in this, that until explained, and connected with the ultimate laws from which they result, they have not attained the highest degree of certainty of which laws are susceptible. It has been shown on a former occasion that laws of causation which are derivative, and compounded of simpler laws, are not only, as the nature of the case implies, less general, but even less certain, than the simpler laws from which they result; not in the same degree to be relied on as universally true. The inferiority of evidence, however, which attaches to this class of laws, is trifling, compared with that which is inherent in uniformities not known to be laws of causation at all. So long as these are unresolved, we cannot tell on how many collocations, as well as laws, their truth may be dependent; we can never, therefore, extend them with any confidence to cases in which we have not assured ourselves, by trial, that the necessary collocation of causes, whatever it may be, exists. It is to this class of laws alone that the property, which philosophers usually consider as characteristic of empirical laws, belongs in all its strictness; the property of being unfit to be relied on beyond the limits of time, place, and circumstance, in which the observations have been made. These are empirical laws in a more emphatic sense; and when I employ that term (except where the context manifestly indicates the reverse) I shall generally mean to designate those uniformities only, whether of succession or of coexistence, which are not known to be laws of causation.