CHAPTER XII.

OF THE EXPLANATION OF LAWS OF NATURE.

Sec. 1. The deductive operation by which we derive the law of an effect from the laws of the causes, the concurrence of which gives rise to it, may be undertaken either for the purpose of discovering the law, or of explaining a law already discovered. The word *explanation* occurs so continually and holds so important a place in philosophy, that a little time spent in fixing the meaning of it will be profitably employed.

An individual fact is said to be explained, by pointing out its cause, that is, by stating the law or laws of causation, of which its production is an instance. Thus, a conflagration is explained, when it is proved to have arisen from a spark falling into the midst of a heap of combustibles. And in a similar manner, a law or uniformity in nature is said to be explained, when another law or laws are pointed out, of which that law itself is but a case, and from which it could be deduced.

Sec. 2. There are three distinguishable sets of circumstances in which a law of causation may be explained from, or, as it also is often expressed, resolved into, other laws.

The first is the case already so fully considered; an intermixture of laws, producing a joint effect equal to the sum of the effects of the causes taken separately. The law of the complex effect is explained, by being resolved into the separate laws of the causes which contribute to it. Thus, the law of the motion of a planet is resolved into the law of the acquired force, which tends to produce an uniform motion in the tangent, and the law of the centripetal force which tends to produce an accelerating motion towards the sun; the real motion being a compound of the two.

It is necessary here to remark, that in this resolution of the law of a complex effect, the laws of which it is compounded are not the only elements. It is resolved into the laws of the separate causes, together with the fact of their coexistence. The one is as essential an ingredient as the other; whether the object be to discover the law of the effect, or only to explain it. To deduce the laws of the heavenly motions, we require not only to know the law of a rectilineal and that of a gravitative force, but the existence of both these forces in the celestial regions, and even their relative amount. The complex laws of causation are thus resolved into two distinct kinds of elements: the one, simpler laws of causation, the other (in the aptly selected expression of Dr. Chalmers) collocations; the collocations consisting in the existence of certain agents or powers, in certain circumstances of place and time. We shall hereafter have occasion to return to this distinction, and to dwell on it at such length as dispenses with the necessity of further insisting on it here. The first mode, then, of the explanation of Laws of Causation, is when the law of an effect is resolved into the various tendencies of which it is the result, together with the laws of those tendencies.

Sec. 3. A second case is when, between what seemed the cause and what was supposed to be its effect, further observation detects an intermediate link; a fact caused by the antecedent, and in its turn causing the consequent; so that the cause at first assigned is but the remote cause, operating through the intermediate phenomenon. A seemed the cause of C, but it subsequently appeared that A was only the cause of B, and that it is B which was the cause of C. For example: mankind were aware that the act of touching an outward object caused a sensation. It was subsequently discovered, that after we have touched the object, and before we experience the sensation, some change takes place in a kind of thread called a nerve, which extends from our outward organs to the brain. Touching the object, therefore, is only the remote cause of our sensation; that is, not the cause, properly speaking, but the cause of the cause;--the real cause of the sensation is the change in the state of the nerve. Future experience may not only give us more knowledge than we now have of the particular nature of this change, but may also interpolate another link: between the contact (for example) of the object with our outward organs, and the production of the change of state in the nerve, there may take place some electric phenomenon; or some phenomenon of a nature not resembling the effects of any known agency. Hitherto, however, no such intermediate link has been discovered; and the touch of the object must be

considered, provisionally, as the proximate cause of the affection of the nerve. The sequence, therefore, of a sensation of touch on contact with an object, is ascertained not to be an ultimate law; it is resolved, as the phrase is, into two other laws,--the law, that contact with an object produces an affection of the nerve; and the law, that an affection of the nerve produces sensation.

To take another example: the more powerful acids corrode or blacken organic compounds. This is a case of causation, but of remote causation; and is said to be explained when it is shown that there is an intermediate link, namely, the separation of some of the chemical elements of the organic structure from the rest, and their entering into combination with the acid. The acid causes this separation of the elements, and the separation of the elements causes the disorganization, and often the charring of the structure. So, again, chlorine extracts colouring matters, (whence its efficacy in bleaching,) and purifies the air from infection. This law is resolved into the two following laws. Chlorine has a powerful affinity for bases of all kinds, particularly metallic bases and hydrogen. Such bases are essential elements of colouring matters and contagious compounds: which substances, therefore, are decomposed and destroyed by chlorine.

Sec. 4. It is of importance to remark, that when a sequence of phenomena is thus resolved into other laws, they are always laws more general than itself. The law that A is followed by C, is less general than either of the laws which connect B with C and A with B. This will appear from very simple considerations.

All laws of causation are liable to be counteracted or frustrated, by the non-fulfilment of some negative condition: the tendency, therefore, of B to produce C may be defeated. Now the law that A produces B, is equally fulfilled whether B is followed by C or not; but the law that A produces C by means of B, is of course only fulfilled when B is really followed by C, and is therefore less general than the law that A produces B. It is also less general than the law that B produces C. For B may have other causes besides A; and as A produces C only by means of B, while B produces C whether it has itself been produced by A or by anything else, the second law embraces a greater number of instances, covers as it were a greater space of ground, than the first.

Thus, in our former example, the law that the contact of an object causes a change in the state of the nerve, is more general than the law that contact with an object causes sensation, since, for aught we know, the change in the nerve may equally take place when, from a counteracting cause, as for instance, strong mental excitement, the sensation does not follow; as in a battle, where wounds are sometimes received without any consciousness of receiving them. And again, the law that change in the state of a nerve produces sensation, is more general than the law that contact with an object produces sensation; since the sensation equally follows the change in the nerve when not produced by contact with an object, but by some other cause; as in the well-known case, when a person who has lost a limb, feels the same sensation which he has been accustomed to call a pain in the limb.

Not only are the laws of more immediate sequence into which the law of a remote sequence is resolved, laws of greater generality than that law is, but (as a consequence of, or rather as implied in, their greater generality) they are more to be relied on; there are fewer chances of their being ultimately found not to be universally true. From the moment when the sequence of A and C is shown not to be immediate, but to depend on an intervening phenomenon, then, however constant and invariable the sequence of A and C has hitherto been found, possibilities arise of its failure, exceeding those which can affect either of the more immediate sequences, A, B, and B, C. The tendency of A to produce C may be defeated by whatever is capable of defeating either the tendency of A to produce B, or the tendency of B to produce C; it is therefore twice as liable to failure as either of those more elementary tendencies; and the generalization that A is always followed by C, is twice as likely to be found erroneous. And so of the converse generalization, that C is always preceded and caused by A; which will be erroneous not only if there should happen to be a second immediate mode of production of C itself, but moreover if there be a second mode of production of B, the immediate antecedent of C in the sequence.

The resolution of the one generalization into the other two, not only shows that there are possible limitations

of the former, from which its two elements are exempt, but shows also where these are to be looked for. As soon as we know that B intervenes between A and C, we also know that if there be cases in which the sequence of A and C does not hold, these are most likely to be found by studying the effects or the conditions of the phenomenon B.

It appears, then, that in the second of the three modes in which a law may be resolved into other laws, the latter are more general, that is, extend to more cases, and are also less likely to require limitation from subsequent experience, than the law which they serve to explain. They are more nearly unconditional; they are defeated by fewer contingencies; they are a nearer approach to the universal truth of nature. The same observations are still more evidently true with regard to the first of the three modes of resolution. When the law of an effect of combined causes is resolved into the separate laws of the causes, the nature of the case implies that the law of the effect is less general than the law of any of the causes, since it only holds when they are combined; while the law of any one of the causes holds good both then, and also when that cause acts apart from the rest. It is also manifest that the complex law is liable to be oftener unfulfilled than any one of the simpler laws of which it is the result, since every contingency which defeats any of the laws prevents so much of the effect as depends on it, and thereby defeats the complex law. The mere rusting, for example, of some small part of a great machine, often suffices entirely to prevent the effect which ought to result from the joint action of all the parts. The law of the effect of a combination of causes is always subject to the whole of the negative conditions which attach to the action of all the causes severally.

There is another and an equally strong reason why the law of a complex effect must be less general than the laws of the causes which conspire to produce it. The same causes, acting according to the same laws, and differing only in the proportions in which they are combined, often produce effects which differ not merely in quantity, but in kind. The combination of a centripetal with a projectile force, in the proportions which obtain in all the planets and satellites of our solar system, gives rise to an elliptical motion; but if the ratio of the two forces to each other were slightly altered, it is demonstrated that the motion produced would be in a circle, or a parabola, or an hyperbola: and it is thought that in the case of some comets one of these is probably the fact. Yet the law of the parabolic motion would be resolvable into the very same simple laws into which that of the elliptical motion is resolved, namely, the law of the permanence of rectilineal motion, and the law of gravitation. If, therefore, in the course of ages, some circumstance were to manifest itself which, without defeating the law of either of those forces, should merely alter their proportion to one another, (such as the shock of some solid body, or even the accumulating effect of the resistance of the medium in which astronomers have been led to surmise that the motions of the heavenly bodies take place,) the elliptical motion might be changed into a motion in some other conic section; and the complex law, that the planetary motions take place in ellipses, would be deprived of its universality, though the discovery would not at all detract from the universality of the simpler laws into which that complex law is resolved. The law, in short, of each of the concurrent causes remains the same, however their collocations may vary; but the law of their joint effect varies with every difference in the collocations. There needs no more to show how much more general the elementary laws must be, than any of the complex laws which are derived from them.

Sec. 5. Besides the two modes which have been treated of, there is a third mode in which laws are resolved into one another; and in this it is self-evident that they are resolved into laws more general than themselves. This third mode is the *subsumption* (as it has been called) of one law under another: or (what comes to the same thing) the gathering up of several laws into one more general law which includes them all. The most splendid example of this operation was when terrestrial gravity and the central force of the solar system were brought together under the general law of gravitation. It had been proved antecedently that the earth and the other planets tend to the sun; and it had been known from the earliest times that terrestrial bodies tend towards the earth. These were similar phenomena; and to enable them both to be subsumed under one law, it was only necessary to prove that, as the effects were similar in quality, so also they, as to quantity, conform to the same rules. This was first shown to be true of the moon, which agreed with terrestrial objects not only in tending to a centre, but in the fact that this centre was the earth. The tendency of the moon towards the earth being ascertained to vary as the inverse square of the distance, it was deduced from this, by direct calculation, that if

the moon were as near to the earth as terrestrial objects are, and the acquired force in the direction of the tangent were suspended, the moon would fall towards the earth through exactly as many feet in a second as those objects do by virtue of their weight. Hence the inference was irresistible, that the moon also tends to the earth by virtue of its weight: and that the two phenomena, the tendency of the moon to the earth and the tendency of terrestrial objects to the earth, being not only similar in quality, but, when in the same circumstances, identical in quantity, are cases of one and the same law of causation. But the tendency of the moon to the earth, and the tendency of the earth and planets to the sun, were already known to be cases of the same law of causation: and thus the law of all these tendencies, and the law of terrestrial gravity, were recognised as identical, and were subsumed under one general law, that of gravitation.

In a similar manner, the laws of magnetic phenomena have more recently been subsumed under known laws of electricity. It is thus that the most general laws of nature are usually arrived at: we mount to them by successive steps. For, to arrive by correct induction at laws which hold under such an immense variety of circumstances, laws so general as to be independent of any varieties of space or time which we are able to observe, requires for the most part many distinct sets of experiments or observations, conducted at different times and by different people. One part of the law is first ascertained, afterwards another part: one set of observations teaches us that the law holds good under some conditions, another that it holds good under other conditions, by combining which observations we find that it holds good under conditions much more general, or even universally. The general law, in this case, is literally the sum of all the partial ones; it is the recognition of the same sequence in different sets of instances; and may, in fact, be regarded as merely one step in the process of elimination. That tendency of bodies towards one another, which we now call gravity, had at first been observed only on the earth's surface, where it manifested itself only as a tendency of all bodies towards the earth, and might, therefore, be ascribed to a peculiar property of the earth itself: one of the circumstances, namely, the proximity of the earth, had not been eliminated. To eliminate this circumstance required a fresh set of instances in other parts of the universe: these we could not ourselves create; and though nature had created them for us, we were placed in very unfavourable circumstances for observing them. To make these observations, fell naturally to the lot of a different set of persons from those who studied terrestrial phenomena; and had, indeed, been a matter of great interest at a time when the idea of explaining celestial facts by terrestrial laws was looked upon as the confounding of an indefeasible distinction. When, however, the celestial motions were accurately ascertained, and the deductive processes performed, from which it appeared that their laws and those of terrestrial gravity corresponded, those celestial observations became a set of instances which exactly eliminated the circumstance of proximity to the earth; and proved that in the original case, that of terrestrial objects, it was not the earth, as such, that caused the motion or the pressure, but the circumstance common to that case with the celestial instances, namely, the presence of some great body within certain limits of distance.

Sec. 6. There are, then, three modes of explaining laws of causation, or, which is the same thing, resolving them into other laws. First, when the law of an effect of combined causes is resolved into the separate laws of the causes, together with the fact of their combination. Secondly, when the law which connects any two links, not proximate, in a chain of causation, is resolved into the laws which connect each with the intermediate links. Both of these are cases of resolving one law into two or more; in the third, two or more are resolved into one: when, after the law has been shown to hold good in several different classes of cases, we decide that what is true in each of these classes of cases, is true under some more general supposition, consisting of what all those classes of cases have in common. We may here remark that this last operation involves none of the uncertainties attendant on induction by the Method of Agreement, since we need not suppose the result to be extended by way of inference to any new class of cases, different from those by the comparison of which it was engendered.

In all these three processes, laws are, as we have seen, resolved into laws more general than themselves; laws extending to all the cases which the former extended to, and others besides. In the first two modes they are also resolved into laws more certain, in other words, more universally true than themselves; they are, in fact, proved not to be themselves laws of nature, the character of which is to be universally true, but *results* of laws

of nature, which may be only true conditionally, and for the most part. No difference of this sort exists in the third case; since here the partial laws are, in fact, the very same law as the general one, and any exception to them would be an exception to it too.

By all the three processes, the range of deductive science is extended; since the laws, thus resolved, may be thenceforth deduced demonstratively from the laws into which they are resolved. As already remarked, the same deductive process which proves a law or fact of causation if unknown, serves to explain it when known.

The word explanation is here used in its philosophical sense. What is called explaining one law of nature by another, is but substituting one mystery for another; and does nothing to render the general course of nature other than mysterious: we can no more assign a *why* for the more extensive laws than for the partial ones. The explanation may substitute a mystery which has become familiar, and has grown to *seem* not mysterious, for one which is still strange. And this is the meaning of explanation, in common parlance. But the process with which we are here concerned often does the very contrary: it resolves a phenomenon with which we are familiar, into one of which we previously knew little or nothing; as when the common fact of the fall of heavy bodies was resolved into the tendency of all particles of matter towards one another. It must be kept constantly in view, therefore, that in science, those who speak of explaining any phenomenon mean (or should mean) pointing out not some more familiar, but merely some more general, phenomenon, of which it is a partial exemplification; or some laws of causation which produce it by their joint or successive action, and from which, therefore, its conditions may be determined deductively. Every such operation brings us a step nearer towards answering the question which was stated in a previous chapter as comprehending the whole problem of the investigation of nature, viz. What are the fewest assumptions, which being granted, the order of nature as it exists would be the result? What are the fewest general propositions from which all the uniformities existing in nature could be deduced?

The laws, thus explained or resolved, are sometimes said to be *accounted for*; but the expression is incorrect, if taken to mean anything more than what has been already stated. In minds not habituated to accurate thinking, there is often a confused notion that the general laws are the *causes* of the partial ones; that the law of general gravitation, for example, causes the phenomenon of the fall of bodies to the earth. But to assert this, would be a misuse of the word cause: terrestrial gravity is not an effect of general gravitation, but a *case* of it; that is, one kind of the particular instances in which that general law obtains. To account for a law of nature means, and can mean, nothing more than to assign other laws more general, together with collocations, which laws and collocations being supposed, the partial law follows without any additional supposition.