CHAPTER XI.

OF THE DEDUCTIVE METHOD.

§ 1. The mode of investigation which, from the proved inapplicability of direct methods of observation and experiment, remains to us as the main source of the knowledge we possess or can acquire respecting the conditions, and laws of recurrence, of the more complex phenomena, is called, in its most general expression, the Deductive Method; and consists of three operations: the first, one of direct induction; the second, of ratiocination; and the third, of verification.

I call the first step in the process an inductive operation, because there must be a direct induction as the basis of the whole; although in many particular investigations the place of the induction may be supplied by a prior deduction; but the premisses of this prior deduction must have been derived from induction.

The problem of the Deductive Method is, to find the law of an effect, from the laws of the different tendencies of which it is the joint result. The first requisite, therefore, is to know the laws of those tendencies; the law of each of the concurrent causes: and this supposes a previous process of observation or experiment upon each cause separately; or else a previous deduction, which also must depend for its ultimate premisses on observation or experiment. Thus, if the subject be social or historical phenomena, the premisses of the Deductive Method must be the laws of the causes which determine that class of phenomena; and those causes are human actions, together with the general outward circumstances under the influence of which mankind are placed, and which constitute man's position on the earth. The Deductive Method, applied to social phenomena, must begin, therefore, by investigating, or must suppose to have been already investigated, the laws of human action, and those properties of outward things by which the actions of human beings in society are determined. Some of these general truths will naturally be obtained by observation and experiment, others by deduction: the more complex laws of human action, for example, may be deduced from the simpler ones; but the simple or elementary laws will always, and necessarily, have been obtained by a directly inductive process.

To ascertain, then, the laws of each separate cause which takes a share in producing the effect, is the first desideratum of the Deductive Method. To know what the causes are, which must be subjected to this process of study, may or may not be difficult. In the case last mentioned, this first condition is of easy fulfilment. That social phenomena depend on the acts and mental impressions of human beings, never could have been a matter of any doubt, however imperfectly it may have been known either by what laws those impressions and actions are governed, or to what social consequences their laws naturally lead. Neither, again, after physical science had attained a certain development, could there be any real doubt where to look for the laws on which the phenomena of life depend, since they must be the mechanical and chemical laws of the solid and fluid substances composing the organised body and the medium in which it subsists, together with the peculiar vital laws of the different tissues constituting the organic structure. In other cases, really far more simple than these, it was much less obvious in what quarter the causes were to be looked for: as in the case of the celestial phenomena. Until, by combining the laws of certain causes, it was found that those laws explained all the facts which experience had proved concerning the heavenly motions, and led to predictions which it always verified, mankind never knew that those *were* the causes. But whether we are able to put the question before, or not until after, we have become capable of answering it, in either case it must be answered; the laws of the different causes must be ascertained, before we can proceed to deduce from them the conditions of the effect.

The mode of ascertaining those laws neither is, nor can be, any other than the fourfold method of experimental inquiry, already discussed. A few remarks on the application of that method to cases of the Composition of Causes, are all that is requisite.

It is obvious that we cannot expect to find the law of a tendency, by an induction from cases in which the tendency is counteracted. The laws of motion could never have been brought to light from the observation of bodies kept at rest by the equilibrium of opposing forces. Even where the tendency is not, in the ordinary sense of the word, counteracted, but only modified, by having its effects compounded with the effects arising from some other tendency or tendencies, we are still in an unfavourable position for tracing, by means of such cases, the law of the tendency itself. It would have been difficult to discover the law that every body in motion tends to continue moving in a straight line, by an induction from instances in which the motion is deflected into a curve, by being compounded with the effect of an accelerating force. Notwithstanding the resources afforded in this description of cases by the Method of Concomitant Variations, the principles of a judicious experimentation prescribe that the law of each of the tendencies should be studied, if possible, in cases in which that tendency operates alone, or in combination with no agencies but those of which the effect can, from previous knowledge, be calculated and allowed for.

Accordingly, in the cases, unfortunately very numerous and important, in which the causes do not suffer themselves to be separated and observed apart, there is much difficulty in laying down with due certainty the inductive foundation necessary to support the deductive method. This difficulty is most of all conspicuous in the case of physiological phenomena; it being impossible to separate the different agencies which collectively compose an organised body, without destroying the very phenomena which it is our object to investigate:

following life, in creatures we dissect, We lose it, in the moment we detect.

And for this reason I am inclined to the opinion, that physiology is embarrassed by greater natural difficulties, and is probably susceptible of a less degree of ultimate perfection, than even the social science; inasmuch as it is possible to study the laws and operations of one human mind apart from other minds, much less imperfectly than we can study the laws of one organ or tissue of the human body apart from the other organs or tissues.

It has been judiciously remarked that pathological facts, or, to speak in common language, diseases in their different forms and degrees, afford in the case of physiological investigation the most available equivalent to experimentation properly so called; inasmuch as they often exhibit to us a definite disturbance in some one organ or organic function, the remaining organs and functions being, in the first instance at least, unaffected. It is true that from the perpetual actions and reactions which are going on among all parts of the organic economy, there can be no prolonged disturbance in any one function without ultimately involving many of the others; and when once it has done so, the experiment for the most part loses its scientific value. All depends on observing the early stages of the derangement; which, unfortunately, are of necessity the least marked. If, however, the organs and functions not disturbed in the first instance, become affected in a fixed order of succession, some light is thereby thrown upon the action which one organ exercises over another; and we occasionally obtain a series of effects which we can refer with some confidence to the original local derangement; but for this it is necessary that we should know that the original derangement *was* local. If it was what is termed constitutional, that is, if we do not know in what part of the animal economy it took its rise, or the precise nature of the disturbance which took place in that part, we are unable to determine which of the various derangements was cause and which effect; which of them were produced by one another, and which by the direct, though perhaps tardy, action of the original cause.

Besides natural pathological facts, we can produce pathological facts artificially; we can try experiments, even in the popular sense of the term, by subjecting the living being to some external agent, such as the mercury of our former example. As this experimentation is not intended to obtain a direct solution of any practical question, but to discover general laws, from which afterwards the conditions of any particular effect may be obtained by deduction; the best cases to select are those of which the circumstances can be best ascertained: and such are generally not those in which there is any practical object in view. The experiments are best tried, not in a state of disease, which is essentially a changeable state, but in the condition of health, comparatively a fixed state. In the one, unusual agencies are at work, the results of which we have no means of predicting; in the other, the course of the accustomed physiological phenomena would, it may generally be presumed, remain undisturbed, were it not for the disturbing cause which we introduce.

Such, with the occasional aid of the method of Concomitant Variations, (the latter not less encumbered than the more elementary methods by the peculiar difficulties of the subject,) are our inductive resources for ascertaining the laws of the causes considered separately, when we have it not in our power to make trial of them in a state of actual separation. The insufficiency of these resources is so glaring, that no one can be surprised at the backward state of the science of physiology; in which indeed our knowledge of causes is so imperfect, that we can neither explain, nor could without specific experience have predicted, many of the facts which are certified to us by the most ordinary observation. Fortunately, we are much better informed as to the empirical laws of the phenomena, that is, the uniformities respecting which we cannot yet decide whether they are cases of causation or mere results of it. Not only has the order in which the facts of organization and life successively manifest themselves, from the first germ of existence to death, been found to be uniform, and very accurately ascertainable; but, by a great application of the Method of Concomitant Variations to the entire facts of comparative anatomy and physiology, the conditions of organic structure corresponding to each class of functions have been determined with considerable precision. Whether these organic conditions are the whole of the conditions, and indeed whether they are conditions at all, or mere collateral effects of some common cause, we are quite ignorant: nor are we ever likely to know, unless we could construct an organized body, and try whether it would live.

Under such disadvantages do we, in cases of this description, attempt the initial, or inductive step, in the application of the Deductive Method to complex phenomena. But such, fortunately, is not the common case. In general, the laws of the causes on which the effect depends may be obtained by an induction from comparatively simple instances, or, at the worst, by deduction from the laws of simpler causes so obtained. By simple instances are meant, of course, those in which the action of each cause was not intermixed or interfered with, or not to any great extent, by other causes whose laws were unknown. And only when the induction which furnished the premisses to the Deductive Method rested on such instances, has the application of such a method to the ascertainment of the laws of a complex effect, been attended with brilliant results.

§ 2. When the laws of the causes have been ascertained, and the first stage of the great logical operation now under discussion satisfactorily accomplished, the second part follows; that of determining, from the laws of the causes, what effect any given combination of those causes will produce. This is a process of calculation, in the wider sense of the term; and very often involves processes of calculation in the narrowest sense. It is a ratiocination; and when our knowledge of the causes is so perfect, as to extend to the exact numerical laws which they observe in producing their effects, the ratiocination may reckon among its premisses the theorems of the science of number, in the whole immense extent of that science. Not only are the highest truths of mathematics often required to enable us to compute an effect, the numerical law of which we already know; but, even by the aid of those highest truths, we can go but a little way. In so simple a case as the common problem of three bodies gravitating towards one another, with a force directly as their mass and inversely as the square of the distance, all the resources of the calculus have not hitherto sufficed to obtain any general solution but an approximate one. In a case a little more complex, but still one of the simplest which arise in practice, that of the motion of a projectile, the causes which affect the velocity and range (for example) of a cannon-ball may be all known and estimated; the force of the gunpowder, the angle of elevation, the density of the air, the strength and direction of the wind; but it is one of the most difficult of mathematical problems to combine all these, so as to determine the effect resulting from their collective action.

Besides the theorems of number, those of geometry also come in as premisses, where the effects take place in space, and involve motion and extension, as in mechanics, optics, acoustics, astronomy. But when the complication increases, and the effects are under the influence of so many and such shifting causes as to give no room either for fixed numbers, or for straight lines and regular curves, (as in the case of physiological, to say nothing of mental and social phenomena,) the laws of number and extension are applicable, if at all, only on that large scale on which precision of details becomes unimportant; and although these laws play a conspicuous part in the most striking examples of the investigation of nature by the Deductive Method, as for example in the Newtonian theory of the celestial motions, they are by no means an indispensable part of every such process. All that is essential in it is, reasoning from a general law to a particular case, that is, determining by means of the particular circumstances of that case, what result is required in that instance to fulfil the law. Thus in the Torricellian experiment, if the fact that air has weight had been previously known, it would have been easy, without any numerical data, to deduce from the general law of equilibrium, that the mercury would stand in the tube at such a height that the column of mercury would exactly balance a column of the atmosphere of equal diameter; because, otherwise, equilibrium would not exist.

By such ratiocinations from the separate laws of the causes, we may, to a certain extent, succeed in answering either of the following questions: Given a certain combination of causes, what effect will follow? and, What combination of causes, if it existed, would produce a given effect? In the one case, we determine the effect to be expected in any complex circumstances of which the different elements are known: in the other case we learn, according to what law--under what antecedent conditions--a given complex effect will occur.

§ 3. But (it may here be asked) are not the same arguments by which the methods of direct observation and experiment were set aside as illusory when applied to the laws of complex phenomena, applicable with equal force against the Method of Deduction? When in every single instance a multitude, often an unknown multitude of agencies, are clashing and combining, what security have we that in our computation *à priori* have taken all these into our reckoning? How many must we not generally be ignorant of? Among those which we know, how probable that some have been overlooked; and even were all included, how vain the pretence of summing up the effects of many causes, unless we know accurately the numerical law of each,--a condition in most cases not to be fulfilled; and even when fulfilled, to make the calculation transcends, in any but very simple cases, the utmost power of mathematical science with its most modern improvements.

These objections have real weight, and would be altogether unanswerable, if there were no test by which, when we employ the Deductive Method, we might judge whether an error of any of the above descriptions had been committed or not. Such a test however there is: and its application forms, under the name of Verification, the third essential component part of the Deductive Method; without which all the results it can give have little other value than that of guess-work. To warrant reliance on the general conclusions arrived at by deduction, these conclusions must be found, on careful comparison, to accord with the results of direct observation wherever it can be had. If, when we have experience to compare with them, this experience confirms them, we may safely trust to them in other cases of which our specific experience is yet to come. But if our deductions have led to the conclusion that from a particular combination of causes a given effect would result, then in all known cases where that combination can be shown to have existed, and where the effect has not followed, we must be able to show (or at least to make a probable surmise) what frustrated it: if we cannot, the theory is imperfect, and not yet to be relied upon. Nor is the verification complete, unless some of the cases in which the theory is borne out by the observed result, are of at least equal complexity with any other cases in which its application could be called for.

It needs scarcely be observed, that,--if direct observation and collation of instances have furnished us with any empirical laws of the effect, whether true in all observed cases or only true for the most part,--the most effectual verification of which the theory could be susceptible would be, that it led deductively to those empirical laws; that the uniformities, whether complete or incomplete, which were observed to exist among the phenomena, were *accounted for* by the laws of the causes--were such as could not *but* exist if those be really the causes by which the phenomena are produced. Thus it was very reasonably deemed an essential requisite of any true theory of the causes of the celestial motions, that it should lead by deduction to Kepler's laws: which, accordingly, the Newtonian theory did.

In order, therefore, to facilitate the verification of theories obtained by deduction, it is important that as many as possible of the empirical laws of the phenomena should be ascertained, by a comparison of instances, conformably to the Method of Agreement: as well as (it must be added) that the phenomena themselves should be described, in the most comprehensive as well as accurate manner possible; by collecting from the observation of parts, the simplest possible correct expressions for the corresponding wholes: as when the series of the observed places of a planet was first expressed by a circle, then by a system of epicycles, and subsequently by an ellipse.

It is worth remarking, that complex instances which would have been of no use for the discovery of the simple laws into which we ultimately analyse their phenomena, nevertheless, when they have served to verify the analysis, become additional evidence of the laws themselves. Although we could not have got at the law from complex cases, still when the law, got at otherwise, is found to be in accordance with the result of a complex case, that case becomes a new experiment on the law, and helps to confirm what it did not assist to discover. It is a new trial of the principle in a different set of circumstances; and occasionally serves to eliminate some circumstance not previously excluded, and the exclusion of which might require an experiment impossible to be executed. This was strikingly conspicuous in the example formerly quoted, in which the difference between the observed and the calculated velocity of sound was ascertained to result from the heat extricated by the condensation which takes place in each sonorous vibration. This was a trial, in new circumstances, of the law of the development of heat by compression; and it added materially to the proof of the universality of that law. Accordingly any law of nature is deemed to have gained in point of certainty, by being found to explain some complex case which had not previously been thought of in connexion with it; and this indeed is a consideration to which it is the habit of scientific inquirers to attach rather too much value than too little.

To the Deductive Method, thus characterised in its three constituent parts, Induction, Ratiocination, and Verification, the human mind is indebted for its most conspicuous triumphs in the investigation of nature. To it we owe all the theories by which vast and complicated phenomena are embraced under a few simple laws, which, considered as the laws of those great phenomena, could never have been detected by their direct study. We may form some conception of what the method has done for us, from the case of the celestial motions; one of the simplest among the greater instances of the Composition of Causes, since (except in a few cases not of primary importance) each of the heavenly bodies may be considered, without material inaccuracy, to be never at one time influenced by the attraction of more than two bodies, the sun and one other planet or satellite, making with the reaction of the body itself, and the tangential force (as I see no objection to calling the force generated by the body's own motion, and acting in the direction of the tangent(89)) only four different agents on the concurrence of which the motions of that body depend; a much smaller number, no doubt, than that by which any other of the great phenomena of nature is determined or modified. Yet how could we ever have ascertained the combination of forces on which the motions of the earth and planets are dependent, by merely comparing the orbits, or velocities, of different planets, or the different velocities or positions of the same planet? Notwithstanding the regularity which manifests itself in those motions, in a degree so rare among the effects of a concurrence of causes; although the periodical recurrence of exactly the same effect, affords positive proof that all the combinations of causes which occur at all, recur periodically; we should not have known what the causes were, if the existence of agencies precisely similar on our own earth had not, fortunately, brought the causes themselves within the reach of experimentation under simple circumstances. As we shall have occasion to analyse, further on, this great example of the Method of Deduction, we shall not occupy any time with it here, but shall proceed to that secondary application of the Deductive Method, the result of which is not to prove laws of phenomena, but to explain them.