Chapter VII.

On Observation And Experiment.

§ 1. It results from the preceding exposition, that the process of ascertaining what consequents, in nature, are invariably connected with what antecedents, or in other words what phenomena are related to each other as causes and effects, is in some sort a process of analysis. That every fact which begins to exist has a cause, and that this cause must be found in some fact or concourse of facts which immediately preceded the occurrence, may be taken for certain. The whole of the present facts are the infallible result of all past facts, and more immediately of all the facts which existed at the moment previous. Here, then, is a great sequence, which we know to be uniform. If the whole prior state of the entire universe could again recur, it would again be followed by the present state. The question is, how to resolve this complex uniformity into the simpler uniformities which compose it, and assign to each portion of the vast antecedent the portion of the consequent which is attendant on it.

This operation, which we have called analytical, inasmuch as it is the resolution of a complex whole into the component elements, is more than a merely mental analysis. No mere contemplation of the phenomena, and partition of them by the intellect alone, will of itself accomplish the end we have now in view. Nevertheless, such a mental partition is an indispensable first step. The order of nature, as perceived at a first glance, presents at every instant a chaos followed by another chaos. We must decompose each chaos into single facts. We must learn to see in the chaotic antecedent a multitude of distinct antecedents, in the chaotic consequent a multitude of distinct consequents. This, supposing it done, will not of itself tell us on which of the antecedents each consequent is invariably attendant. To determine that point, we must endeavor to effect a separation of the facts from one another, not in our minds only, but in nature. The mental analysis, however, must take place first. And every one knows that in the mode of performing it, one intellect differs immensely from another. It is the essence of the act of observing; for the observer is not he who merely sees the thing which is before his eyes, but he who sees what parts that thing is composed of. To do this well is a rare talent. One person, from inattention, or attending only in the wrong place, overlooks half of what he sees; another sets down much more than he sees, confounding it with what he imagines, or with what he infers; another takes note of the *kind* of all the circumstances, but being inexpert in estimating their degree, leaves the quantity of each vague and uncertain; another sees indeed the whole, but makes such an awkward division of it into parts, throwing things into one mass which require to be separated, and separating others which might more conveniently be considered as one, that the result is much the same, sometimes even worse, than if no analysis had been attempted at all. It would be possible to point out what qualities of mind, and modes of mental culture, fit a person for being a good observer: that, however, is a question not of Logic, but of the Theory of Education, in the most enlarged sense of the term. There is not properly an Art of Observing. There may be rules for observing. But these, like rules for inventing, are properly instructions for the preparation of one's own mind; for putting it into the state in which it will be most fitted to observe, or most likely to invent. They are, therefore, essentially rules of self-education, which is a different thing from Logic. They do not teach how to do the thing, but how to make ourselves capable of doing it. They are an art of strengthening the limbs, not an art of using them.

The extent and minuteness of observation which may be requisite, and the degree of decomposition to which it may be necessary to carry the mental analysis, depend on the particular purpose in view. To ascertain the state of the whole universe at any particular moment is impossible, but would also be useless. In making chemical experiments, we do not think it necessary to note the position of the planets; because experience has shown, as a very superficial experience is sufficient to show, that in such cases that circumstance is not material to the result: and accordingly, in the ages when men believed in the occult influences of the heavenly bodies, it might have been unphilosophical to omit ascertaining the precise condition of those bodies at the moment of the experiment. As to the degree of minuteness of the mental subdivision, if we were obliged to break down what we observe into its very simplest elements, that is, literally into single facts, it would be difficult to say where we should find them; we can hardly ever affirm that our divisions of any kind have

reached the ultimate unit. But this, too, is fortunately unnecessary. The only object of the mental separation is to suggest the requisite physical separation, so that we may either accomplish it ourselves, or seek for it in nature; and we have done enough when we have carried the subdivision as far as the point at which we are able to see what observations or experiments we require. It is only essential, at whatever point our mental decomposition of facts may for the present have stopped, that we should hold ourselves ready and able to carry it further as occasion requires, and should not allow the freedom of our discriminating faculty to be imprisoned by the swathes and bands of ordinary classification; as was the case with all early speculative inquirers, not excepting the Greeks, to whom it seldom occurred that what was called by one abstract name might, in reality, be several phenomena, or that there was a possibility of decomposing the facts of the universe into any elements but those which ordinary language already recognized.

§ 2. The different antecedents and consequents being, then, supposed to be, so far as the case requires, ascertained and discriminated from one another, we are to inquire which is connected with which. In every instance which comes under our observation, there are many antecedents and many consequents. If those antecedents could not be severed from one another except in thought, or if those consequents never were found apart, it would be impossible for us to distinguish (*a posteriori* at least) the real laws, or to assign to any cause its effect, or to any effect its cause. To do so, we must be able to meet with some of the antecedents apart from the rest, and observe what follows from them; or some of the consequents, and observe by what they are preceded. We must, in short, follow the Baconian rule of *varying the circumstances*. This is, indeed, only the first rule of physical inquiry, and not, as some have thought, the sole rule; but it is the foundation of all the rest.

For the purpose of varying the circumstances, we may have recourse (according to a distinction commonly made) either to observation or to experiment; we may either *find* an instance in nature suited to our purposes, or, by an artificial arrangement of circumstances, *make* one. The value of the instance depends on what it is in itself, not on the mode in which it is obtained: its employment for the purposes of induction depends on the same principles in the one case and in the other; as the uses of money are the same whether it is inherited or acquired. There is, in short, no difference in kind, no real logical distinction, between the two processes of investigation. There are, however, practical distinctions to which it is of considerable importance to advert.

§ 3. The first and most obvious distinction between Observation and Experiment is, that the latter is an immense extension of the former. It not only enables us to produce a much greater number of variations in the circumstances than nature spontaneously offers, but also, in thousands of cases, to produce the precise *sort* of variation which we are in want of for discovering the law of the phenomenon; a service which nature, being constructed on a quite different scheme from that of facilitating our studies, is seldom so friendly as to bestow upon us. For example, in order to ascertain what principle in the atmosphere enables it to sustain life, the variation we require is that a living animal should be immersed in each component element of the atmosphere separately. But nature does not supply either oxygen or azote in a separate state. We are indebted to artificial experiment for our knowledge that it is the former, and not the latter, which supports respiration; and for our knowledge of the very existence of the two ingredients.

Thus far the advantage of experimentation over simple observation is universally recognized: all are aware that it enables us to obtain innumerable combinations of circumstances which are not to be found in nature, and so add to nature's experiments a multitude of experiments of our own. But there is another superiority (or, as Bacon would have expressed it, another prerogative) of instances artificially obtained over spontaneous instances--of our own experiments over even the same experiments when made by nature--which is not of less importance, and which is far from being felt and acknowledged in the same degree.

When we can produce a phenomenon artificially, we can take it, as it were, home with us, and observe it in the midst of circumstances with which in all other respects we are accurately acquainted. If we desire to know what are the effects of the cause A, and are able to produce A by means at our disposal, we can generally determine at our own discretion, so far as is compatible with the nature of the phenomenon A, the whole of

the circumstances which shall be present along with it: and thus, knowing exactly the simultaneous state of every thing else which is within the reach of A's influence, we have only to observe what alteration is made in that state by the presence of A.

For example, by the electric machine we can produce, in the midst of known circumstances, the phenomena which nature exhibits on a grander scale in the form of lightning and thunder. Now let any one consider what amount of knowledge of the effects and laws of electric agency mankind could have obtained from the mere observation of thunder-storms, and compare it with that which they have gained, and may expect to gain, from electrical and galvanic experiments. This example is the more striking, now that we have reason to believe that electric action is of all natural phenomena (except heat) the most pervading and universal, which, therefore, it might antecedently have been supposed could stand least in need of artificial means of production to enable it to be studied; while the fact is so much the contrary, that without the electric machine, the Leyden jar, and the voltaic battery, we probably should never have suspected the existence of electricity as one of the great agents in nature; the few electric phenomena we should have known of would have continued to be regarded either as supernatural, or as a sort of anomalies and eccentricities in the order of the universe.

When we have succeeded in insulating the phenomenon which is the subject of inquiry, by placing it among known circumstances, we may produce further variations of circumstances to any extent, and of such kinds as we think best calculated to bring the laws of the phenomenon into a clear light. By introducing one well-defined circumstance after another into the experiment, we obtain assurance of the manner in which the phenomenon behaves under an indefinite variety of possible circumstances. Thus, chemists, after having obtained some newly-discovered substance in a pure state (that is, having made sure that there is nothing present which can interfere with and modify its agency), introduce various other substances, one by one, to ascertain whether it will combine with them, or decompose them, and with what result; and also apply heat, or electricity, or pressure, to discover what will happen to the substance under each of these circumstances.

But if, on the other hand, it is out of our power to produce the phenomenon, and we have to seek for instances in which nature produces it, the task before us is very different.

Instead of being able to choose what the concomitant circumstances shall be, we now have to discover what they are; which, when we go beyond the simplest and most accessible cases, it is next to impossible to do with any precision and completeness. Let us take, as an exemplification of a phenomenon which we have no means of fabricating artificially, a human mind. Nature produces many; but the consequence of our not being able to produce them by art is, that in every instance in which we see a human mind developing itself, or acting upon other things, we see it surrounded and obscured by an indefinite multitude of unascertainable circumstances, rendering the use of the common experimental methods almost delusive. We may conceive to what extent this is true, if we consider, among other things, that whenever Nature produces a human mind, she produces, in close connection with it, a body; that is, a vast complication of physical facts, in no two cases perhaps exactly similar, and most of which (except the mere structure, which we can examine in a sort of coarse way after it has ceased to act), are radically out of the reach of our means of exploration. If, instead of a human mind, we suppose the subject of investigation to be a human society or State, all the same difficulties recur in a greatly augmented degree.

We have thus already come within sight of a conclusion, which the progress of the inquiry will, I think, bring before us with the clearest evidence: namely, that in the sciences which deal with phenomena in which artificial experiments are impossible (as in the case of astronomy), or in which they have a very limited range (as in mental philosophy, social science, and even physiology), induction from direct experience is practiced at a disadvantage in most cases equivalent to impracticability; from which it follows that the methods of those sciences, in order to accomplish any thing worthy of attainment, must be to a great extent, if not principally, deductive. This is already known to be the case with the first of the sciences we have mentioned, astronomy; that it is not generally recognized as true of the others, is probably one of the reasons why they are not in a more advanced state.

§ 4. If what is called pure observation is at so great a disadvantage, compared with artificial experimentation, in one department of the direct exploration of phenomena, there is another branch in which the advantage is all on the side of the former.

Inductive inquiry having for its object to ascertain what causes are connected with what effects, we may begin this search at either end of the road which leads from the one point to the other: we may either inquire into the effects of a given cause or into the causes of a given effect. The fact that light blackens chloride of silver might have been discovered either by experiments on light, trying what effect it would produce on various substances, or by observing that portions of the chloride had repeatedly become black, and inquiring into the circumstances. The effect of the urali poison might have become known either by administering it to animals, or by examining how it happened that the wounds which the Indians of Guiana inflict with their arrows prove so uniformly mortal. Now it is manifest from the mere statement of the examples, without any theoretical discussion, that artificial experimentation is applicable only to the former of these modes of investigation. We can take a cause, and try what it will produce; but we can not take an effect, and try what it will be produced by. We can only watch till we see it produced, or are enabled to produce it by accident.

This would be of little importance, if it always depended on our choice from which of the two ends of the sequence we would undertake our inquiries. But we have seldom any option. As we can only travel from the known to the unknown, we are obliged to commence at whichever end we are best acquainted with. If the agent is more familiar to us than its effects, we watch for, or contrive, instances of the agent, under such varieties of circumstances as are open to us, and observe the result. If, on the contrary, the conditions on which a phenomenon depends are obscure, but the phenomenon itself familiar, we must commence our inquiry from the effect. If we are struck with the fact that chloride of silver has been blackened, and have no suspicion of the cause, we have no resource but to compare instances in which the fact has chanced to occur, until by that comparison we discover that in all those instances the substances had been exposed to light. If we knew nothing of the Indian arrows but their fatal effect, accident alone could turn our attention to experiments on the urali; in the regular course of investigation, we could only inquire, or try to observe, what had been done to the arrows in particular instances.

Wherever, having nothing to guide us to the cause, we are obliged to set out from the effect, and to apply the rule of varying the circumstances to the consequents, not the antecedents, we are necessarily destitute of the resource of artificial experimentation. We can not, at our choice, obtain consequents, as we can antecedents, under any set of circumstances compatible with their nature. There are no means of producing effects but through their causes, and by the supposition the causes of the effect in question are not known to us. We have, therefore, no expedient but to study it where it offers itself spontaneously. If nature happens to present us with instances sufficiently varied in their circumstances, and if we are able to discover, either among the proximate antecedents or among some other order of antecedents, something which is always found when the effect is found, however various the circumstances, and never found when it is not, we may discover, by mere observation without experiment, a real uniformity in nature.

But though this is certainly the most favorable case for sciences of pure observation, as contrasted with those in which artificial experiments are possible, there is in reality no case which more strikingly illustrates the inherent imperfection of direct induction when not founded on experimentation. Suppose that, by a comparison of cases of the effect, we have found an antecedent which appears to be, and perhaps is, invariably connected with it: we have not yet proved that antecedent to be the cause until we have reversed the process, and produced the effect by means of that antecedent. If we can produce the antecedent artificially, and if, when we do so, the effect follows, the induction is complete; that antecedent is the cause of that consequent.(135) But we have then added the evidence of experiment to that of simple observation. Until we had done so, we had only proved *invariable* antecedence within the limits of experience, but not *unconditional* antecedence, or causation. Until it had been shown by the actual production of the antecedent under known circumstances, and the occurrence thereupon of the consequent, that the antecedent was really the condition on which it depended; the uniformity of succession which was proved to exist between them might, for aught

we knew, be (like the succession of day and night) not a case of causation at all; both antecedent and consequent might be successive stages of the effect of an ulterior cause. Observation, in short, without experiment (supposing no aid from deduction) can ascertain sequences and co-existences, but can not prove causation.

In order to see these remarks verified by the actual state of the sciences, we have only to think of the condition of natural history. In zoology, for example, there is an immense number of uniformities ascertained, some of co-existence, others of succession, to many of which, notwithstanding considerable variations of the attendant circumstances, we know not any exception: but the antecedents, for the most part, are such as we can not artificially produce; or if we can, it is only by setting in motion the exact process by which nature produces them; and this being to us a mysterious process, of which the main circumstances are not only unknown but unobservable, we do not succeed in obtaining the antecedents under known circumstances. What is the result? That on this vast subject, which affords so much and such varied scope for observation, we have made most scanty progress in ascertaining any laws of causation. We know not with certainty, in the case of most of the phenomena that we find conjoined, which is the condition of the other; which is cause, and which effect, or whether either of them is so, or they are not rather conjunct effects of causes yet to be discovered, complex results of laws hitherto unknown.

Although some of the foregoing observations may be, in technical strictness of arrangement, premature in this place, it seemed that a few general remarks on the difference between sciences of mere observation and sciences of experimentation, and the extreme disadvantage under which directly inductive inquiry is necessarily carried on in the former, were the best preparation for discussing the methods of direct induction; a preparation rendering superfluous much that must otherwise have been introduced, with some inconvenience, into the heart of that discussion. To the consideration of these methods we now proceed.