Scientific Induction.

SCIENTIFIC induction is a subject so broad and indeed so varied in respect to its treatment by different philosophers, that neither space nor ability would permit us to do justice to it here. Nevertheless, it is a question of such importance in this great age of science, that all should know at least something of the method and means used by discoverers in their search for the laws that govern the movements of the universe. We shall endeavour to describe as briefly as possible the method as laid down by the Scholastics and later philosophers of that school.

What is Induction? It is a science which proceeds to the discovery of unknown truths, and as such it should give us clear and *certain* knowledge. It is a reasoning process by which present unknown truths are inferred from ones we already know. As all sound reasoning depends upon true propositions the truth of our conclusions follows from correct judgments of which these propositions are the expression. These judgments, in turn, are made by the comparison of concepts formed in the mind by simple apprehension. It is on the proper arrangement of these three mental acts : simple apprehension, judgment and reason, that the discovery and proof of truth depends. This process of regulating and co-ordinating our mental acts for the discovery of the natural truths of the universe is called applied logic, or the science of logical method.

The art of applying logic in seeking knowledge is carried on in two different ways. If we start out with a few self-evident, first principles and proceed by comparing and combining these elementary truths to deduce new, more complex relations, we call our method synthetic. As the word implies it signifies a "*building up*," an "*arranging together*," of a few simple, general truths from which we extract the more complex, the less general. This is the method employed in *deductive science*. Euclid, for example, starts out with a few axioms and postulates : necessary, universal principles ; and by combining deducing, and repeating these operations indefinitely, he builds up the vast structure

of Geometry. So, also, of the other pure mathematical sciences. It will be seen that in such a method the aid of sense experience, of observation or experiment, are altogether unnecessary. If, however, we start out with concrete facts obtained by the observation of natural phenomena and, by further observation and prolonged experiment, aim at the discovery of the laws which govern these phenomena, we are proceeding from the complex to the simple, from the particular to the general. This is called the *analytic method*, or the process of *Induction* and is the chief stay in all experimental, physical sciences.

We usually distingnish the rational, deductive science from the experimental, inductive, by saying that the former is synthetic and the latter, analytic ; not that deduction excludes analysis and that induction rejects altogether the synthetic method ; but only because analysis is the predominant feature of induction, and synthesis that of deduction. There can be no absolute separation of the two methods ; for the axioms which are the basis of all rational sciences rest on the mental analysis of elementary observation, while the results obtained by the long and varied experiments of the inductive sciences furnish us with principles for the deductive process.

Induction is commonly divided into two divisions : complete and incomplete. The terms, however, are somewhat misleading, for, as "complete' induction attains to the universal by *complete* enumeration of singulars, it would appear that the "incomplete" process is only a partial application of this method : that the result is obtained by incomplete enumeration and is therefore imperfect and uncertain. This is not the case, as incomplete, "*scientific*" induction does not, as a matter of fact, come to the universal by enumeration at all.

Induction by complete enumeration has been defined as "the process by which we predicate about a whole class or collection of things what we have already predicated of each thing separately." It is evident that this process cannot lead us to certain conclusions unless the enumeration is full and complete. Now in

dealing with natural phenomena we can never be sure that we have enumerated all the instances, and even if we were, we could not call our process scientific; for all science is of the universal and the universal is not reached by collecting the instances which make up an actual whole. On the contrary, it is obtaiued by abstracting the nature of a thing, considering it apart from its individuating principles, and forming a concept which can be predicated not of a limited collection but of an indefinite number of instances. In our own experience we, perhaps, have often observed recurring phenomena; or in doing some little experiment we may have noticed the same thing happening at different times; and immediately we began to wonder if it would always do so We tried a few instances and found it worked all right; but usually we never thought of going on experimenting till we had tried *all* the instances. We supposed it was true and turned to examine the nature of the happening to see if it did not possess *something* which would give us some reason for its so happening. In this way we were, though perhaps unconsciously, proceeding by means of scientific induction.

This method, as can be readily seen, comes natural to us; so it is not to be wondered at, that the earliest philosophers made mention of it in their writings. Of course, they did not bring it to any degree of perfection, for reasons which we shall see later, but, that they believed in the possibility of arriving at a universal conclusion by this so-called incomplete induction cannot be denied. Aristotle speaks of sensations engendering experience which suggests abstraction; this separates from the particular the universal. "And," he says, "The abstract put in relation to an indefinite number of individuals is a principle of science." The Scholastics, also, wrote on this method. St. Thomas elaborated on the above extract from Aristotle, and Duns Scotus pointed out that "what regularly results from the action of non-free cause cannot be the result of mere chance but must have a necessary connexion with the nature of those causes." These examples show clearly that the primitive philosophers and Scholastics knew the principle of the method; and it matters little

whether they called it "*empeiria*," "*experientia*," or "*scientific induction.*"

It is true that they made little progress in the application of this method for the advancement of science, and the reasons are obvious. The inductive method requires keen observation and accurate means of measuring and weighing ; but neither Aristotle nor St. Thomas had telescopes, microscopes, delicate balances, barometers, or thermometers ; in a word, they had none of the fine special instruments which the scientists of today possess. The thirteenth century produced one exception in the person of Roger Bacon, who, perhaps, left a greater legacy to science than his better known namesake, Francis, of the sixteenth century. He was a Franciscan monk aud during his spare moments devated all his time to experiment, even inventing instruments of his own to aid him in scientific research.

English philosophers usually look upon Francis Lord Bacon as the father of the inductive method, though the great scientists, Copernicus, Galileo, and Kepler, preceded him, and succeeding discoverers such as Newton and Harvey altogether ignored his methods. Many critics appose his claim but it is generally admitted that he was the herald of a new era and that it was "his trumpet call which animated the troops and led them on to victory."

As we have said before, the object of induction is to gain a scientific knowledge of the laws which govern the existence or occurrence of natural phenomena, i.e. a knowledge of them through their causes. By nothing particular occurences and by seeking their causes, nature, and laws, we extract what is universal, necessary and abiding in them. This observation, known as experience, "*experientia*," is the work of the senses, while the cause is determined by the intellect, and reason explains and applies the law. Thus, we can enumerate the essential steps in the process : Ist, Sense experience, which is both *observation* of facts by us a passive agents ; and *experiment* in which we ourselves actively assist in the production of phenomena ; 2nd, Supposition as to the cause, which we express in a *hypothesis* ; 3rd, Verification of our hypothesis by con-

tinued observation and experiment ; 4th, Establishment and application of the law.

It may be easier to explain this by taking a concrete example. Let us consider for a moment Pasteur's celebrated refutation of spontaneous generation of life. First of all he observed the various changes which take place in liquids and other things, known as fermentation and putrefaction, which he concluded were caused by living germs of various kinds. Then he began his experiments. He took highly-organized material and placed it in the open air under different conditions and he found that where the air was damp and impure, fermentation progressed more favorably than where it was dry and clean. This led him to believe that these supposed germs were present in the air. Then he sterilized his material and again gave it to the action of the air ; and again he found that fermentation still took place ; but less rapidly where the air was bright and pure. He now had further reason to believe in the truth of his hypothesis, that fermentation was due to minute living organisms ever present in the air. So again he sterilized his material and placing one vessel closed with cotton wool alongside another open one, found that the latter fermented rapidly while in the former there was scarcely any action. His last experiment was one in which he exercised the greatest care. Taking liquid that contained everything favorable to "*new generation*," he completely destroyed all possible living beings by heat, then placed it in carefully sterilized tubes which he sealed to avoid all possibility of contamination by the air. Some years later referring to this experiment, he said :

"And, therefore, gentlemen, I could point to that liquid and say to you, I have taken my drop of water from the immensity of creation and I have taken it full of the elements fitted for the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb—dumb ever since these experiments were begun several years ago ; it is dumb because I have kept it from the only thing which man cannot produce—from the germs which float in the air ; from Life ; for Life is a germ and a germ is Life."

These unanswerable arguments gave him the material from which to extract the universal law : "omne vivum e vivo."

All this presupposes the principles of *causality and uniformity* of nature. The principle of causality states that "Whatever happens has a cause," also expressed in the axiom : "*ex nihilo, nihil fit.*" Thus Pasteur's experiments demonstrated that living germs were the *cause* of fermentation and that these germs were in turn *caused* by other living germs.

But more proper to induction is the principle of *uniformity of nature* usually stated in the fomula : "The same causes, acting in similar circumstances, produce similar results." This is the *founaamentum* of all physical science ; and being so important it may be necessary to explain the origin of our belief in it and our reasons for assenting to it.

The principle of causality as stated is in itself *evidently* true ; it is a self-evident *a priori* judgment formed by analyzing the notion of the subject : "*what happens*, and the predicate : "*has a cause.*" But can we say the same of the principle of *uniformity?* Can we say that the same cause acting in the same circumstances produces the same effect? We can. It is a proposition *per se nota*, not perhaps, "*quoad omnes*" but "*quoad se ;*" that is to say, the predicate is contained in the notion of the subject, and if not perceived at once by *us*, still, when we come to understand the notion of "*cause*" (non-free) and "*effect,*" "the *same circumstances* placed," we immediately see the universal connexion between them. So far, then, as the proposition is concerned, we have here also a self-evident, analytic judgment. But how do we know that there exist non-free causes bound by nature to fined and determined action?

Philosophers, differing in their views about the ultimate nature of the universe, propose different solutions and it would require much more space than we have here at our disposal to expose the theories of the various schools. We shall, therefore, only give the view of the Scholastics, which we believe is the only convincing explanation. Their justification is based in the

fact that there exists an all-wise, all-powerful Supreme Being. By tracing back from effect to cause in an unbroken chain, we must come at last to a first cause itself not caused. This first cause we call God. God is infinite, omipotent, omniscient. By a single act of His all-powerful will. He created the vast system of the universe and by that same act preserves it in existence and concurs in every act of His creation. Over all He placed man with an intellect and free-will, lord of all physical nature, which He made for "man's use and benefit." To him alone, He gave understanding and freedom of action. To all other agencies, it is manifest, He gave definite order to fixed tendencies ; otherwise, they would not serve the purpose for which they were intended. On this we rest our firm belief in the Uniformity of Nature, the back bone of all scientific discovery.

But it does not follow that we cannot do any scientific work without a thorough knowledge of this principle We can assume that it is true and make a legitimate transit from particular phenomena to a universal concept of the relation existing between these particulars ; and every process of this kind is only a specific example of the great law of uniformity under which it is contained. The same is true with respect to the rational sciences. We can use the syllogism with the utmost confidence and deduce positively true conclusions without having known beforehand the foundamental principles : "*Dictum de omni ; et dictum de nullo.*" These are implicitly contained in every syllogism ; so also is the uniformity of nature contained in every ascent from the particular to the general.

We have seen that one of the earliest steps in the process of induction is the formation of a hypothesis. This must conform to several conditions. It must be based on reality and be capable of giving a possible explanation of the facts under observation ; that is, it must bar altogether all fanciful pre-conceived suppositions. Some hypothesis will not stand the test of experiment and must be immediately abandoned ; while others, though they cannot be verified, give an apparently correct explanation of phenomena and are retained as working

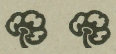
theories; for example, the former geocentric theory of the universe and the present electron explanation of electricity. The verification of a hypothesis demands, not only that it be true of all possible cases but that it be the only possible explanation, absolutely excluding all fear of an exception.

Real scientific hypotheses should aim at the discovery of the *causes* of phenomena. The application of the intellect to the determination of the causes of our sense experience is the most difficult part of the whole process; and it is the most important; for it is in this that the mind proceeds from the particular to the establishment of a universal law. The five methods arranged by Mill are accepted by most philosophers. We shall merely name them and illustrate each by an example: 1st, The method of *agreement*: when two events accompany one another, it is probable that they are causally connected. 2nd, The method of *difference*: when the addition or subtraction of an agent causes phenomena to appear or disappear, the agent is causally connected with the event. 3rd, The method of *concomitant variations*: when the effect varies as the supposed agent is varied, there is a causal connection between the effect and the agent. 4th, The method of *residues*: make allowance for all known causes and the remaining phenomena must be the effect of other causes. 5th, the *mixed* method which is only a union of two or more of the other methods for greater surety of determination. The first three are exemplified in Pasteur s experiments above quoted: different liquids were similarly acted upon by the same agent, the "*air*", *agreement*; the exclusion of "*air*' caused fermentation to cease, *difference*; the different conditions of "*air*" caused fermentation to take place more or less rapidly, *concomitant variations.* The discovery of the planet Neptune was a result of the appiication of the method of *residues*: all known influences failed to account for the deviations in the path computed for Uranus; a new cause was sought for and found in the gravitational effects of Neptune.

It can be seen what a long and tedious work this process usually is, requiring unstinted application and

patience. But without it we would have none of the great inventions of this "wonder-working" age; we would have no trains, steamers or aeroplanes, no telephone, phonagraph or motion picture, no anesthetics, anti-toxin or X-ray, and so on almost indefinitely. It is the all-absorbing study of the day, so absorbing, perhaps, that by some the study of higher things is neglected; and no doubt, the "unfolding of the contents of the Divine deposit of Revelation" of Scholastic days is being forgotten by too large a number. This, however, is not the fault of the science, for witness the words of the great Pasteur whose discoveries did so much for suffering humanity: "These are the living springs of great thoughts and great actions. Everything grows clear in the reflections from the Infinite. . . . . The more I know, the more nearly is my faith that of the Breton peasant. Could I but know all I would have the faith of a Breton peasant woman."

J. S. H.—'18.



Energy, invincible determination, with a right motive, are the levers that move on the world.—Porter

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Happiness is purfume you cannot pour on others without getting a few drops yourself.

The faithful performanee of the common-places of daily life is the best preparation for any great demand that may suddenly break in upon our lives.